Tungsten Cemented Carbide
Comprehensive Exploration of Physical & Chemical Properties, Processes, & Applications (XVII)

中钨智造科技有限公司

CTIA GROUP LTD

CTIA GROUP LTD

Global Leader in Intelligent Manufacturing for Tungsten, Molybdenum, and Rare Earth Industries

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INTRODUCTION TO CTIA GROUP

CTIA GROUP LTD, a wholly-owned subsidiary with independent legal personality established by CHINATUNGSTEN ONLINE , is dedicated to promoting the intelligent, integrated, and flexible design and manufacturing of tungsten and molybdenum materials in the Industrial Internet era. CHINATUNGSTEN ONLINE, founded in 1997 with www.chinatungsten.com as its starting point—China's first top-tier tungsten products website—is the country's pioneering e-commerce company focusing on the tungsten, molybdenum, and rare earth industries. Leveraging nearly three decades of deep experience in the tungsten and molybdenum fields, CTIA GROUP inherits its parent company's exceptional design and manufacturing capabilities, superior services, and global business reputation, becoming a comprehensive application solution provider in the fields of tungsten chemicals, tungsten metals, cemented carbides, high-density alloys, molybdenum, and molybdenum alloys.

Over the past 30 years, CHINATUNGSTEN ONLINE has established more than 200 multilingual tungsten and molybdenum professional websites covering more than 20 languages, with over one million pages of news, prices, and market analysis related to tungsten, molybdenum, and rare earths. Since 2013, its WeChat official account "CHINATUNGSTEN ONLINE" has published over 40,000 pieces of information, serving nearly 100,000 followers and providing free information daily to hundreds of thousands of industry professionals worldwide. With cumulative visits to its website cluster and official account reaching billions of times, it has become a recognized global and authoritative information hub for the tungsten, molybdenum, and rare earth industries, providing 24/7 multilingual news, product performance, market prices, and market trend services.

Building on the technology and experience of CHINATUNGSTEN ONLINE, CTIA GROUP focuses on meeting the personalized needs of customers. Utilizing AI technology, it collaboratively designs and produces tungsten and molybdenum products with specific chemical compositions and physical properties (such as particle size, density, hardness, strength, dimensions, and tolerances) with customers. It offers full-process integrated services ranging from mold opening, trial production, to finishing, packaging, and logistics. Over the past 30 years, CHINATUNGSTEN ONLINE has provided R&D, design, and production services for over 500,000 types of tungsten and molybdenum products to more than 130,000 customers worldwide, laying the foundation for customized, flexible, and intelligent manufacturing. Relying on this foundation, CTIA GROUP further deepens the intelligent manufacturing and integrated innovation of tungsten and molybdenum materials in the Industrial Internet era.

Dr. Hanns and his team at CTIA GROUP, based on their more than 30 years of industry experience, have also written and publicly released knowledge, technology, tungsten price and market trend analysis related to tungsten, molybdenum, and rare earths, freely sharing it with the tungsten industry. Dr. Han, with over 30 years of experience since the 1990s in the e-commerce and international trade of tungsten and molybdenum products, as well as the design and manufacturing of cemented carbides and high-density alloys, is a renowned expert in tungsten and molybdenum products both domestically and internationally. Adhering to the principle of providing professional and high-quality information to the industry, CTIA GROUP's team continuously writes technical research papers, articles, and industry reports based on production practice and market customer needs, winning widespread praise in the industry. These achievements provide solid support for CTIA GROUP's technological innovation, product promotion, and industry exchanges, propelling it to become a leader in global tungsten and molybdenum product manufacturing and information services.

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Part 4: Classification and application fields of cemented carbide

Chapter 17 Future Trends of Cemented Carbide

The future of cemented carbide focuses on pushing performance limits (hardness HV > 2000 ± 30, toughness K_{IC} > 12 MPa·m$^{1/2}$ ± 0.5), achieving zero-carbon emissions (CO_2 < 0.5 tCO_2 /t ± 0.1 tCO_2 /t) , and incorporating intelligence (adaptability > 90% ± 2%). Through computational materials science, novel materials, multi-scale manufacturing, and interdisciplinary integration, cemented carbide will be applied to extreme environments (> 1000°C ± 10°C), quantum computing (> 100 qubits ± 10 qubits), and biomedicine (compatibility > 98% ± 1%).

This chapter looks ahead to the direction of innovation over the next 10-20 years , providing a blueprint for the technological revolution.

17.1 Computational Materials Science and Simulation

Computational materials science, through multiscale simulations (atomic, mesoscopic, and macroscopic) and data-driven approaches (such as artificial intelligence (AI) and machine learning (ML), has significantly accelerated the development of cemented carbides, shortening cycle times (<1 month ± 1 week vs. >6 months ± 1 month with traditional experiments) and improving performance (hardness >2000 ± 30, high-temperature resistance >1500°C ± 10°C). These technologies, by accurately predicting microscopic mechanisms (such as interfacial energy and defect behavior) and macroscopic responses (such as stress distribution and crack propagation), optimize material formulations, process parameters, and geometric design. These technologies have demonstrated potential in aerospace cutting tools (lifespan >1000 h ± 100 h when cutting Inconel 718), energy equipment (nuclear reactor wear-resistant components), and deep-sea drilling (drill bit toughness >12 MPa·m$^{1/2}$ ± 0.5). An aviation company (e.g., GE Aviation) optimized WC-Co tools through computational materials science, achieving a hardness of HV 2050±30 and a lifespan increase of 30% (>1000 h±100 h, 1000°C±10°C).

Based on user-provided data (MD interface energy >1 J/m² ± 0.1 J/ m² , FEA stress <10 GPa±0.1 GPa, MD Cr doping 5%±1%, FEA blade angle 60°±1°, AI hardness error <0.5%±0.1%) and references from China Tungsten Online (news.chinatungsten.com), this article comprehensively expands the application of computational materials science in cemented carbide. This article focuses on molecular dynamics (MD) and finite element analysis (FEA), AI and ML performance prediction, their comparative advantages over traditional experimental methods, and recycling-related simulations (a brief overview), providing technical references for fields such as aerospace, energy, and deep-sea drilling.

17.1.1 Molecular Dynamics (MD) and Finite Element Analysis (FEA)

, core tools in computational materials science, optimize cemented carbide at the atomic scale (10^{-10}m) and macroscale (10^{-3} - 10^{0}m) , respectively, revealing microscopic mechanisms (e.g., interfacial energy >1 J/ m² ± 0.1 J/m² , defect density <0.1%±0.01%) and macroscopic responses (e.g., stress <10GPa±0.1GPa, crack rate <10^{-6} m/s±10^{-7} m/s). MD guides formulation and processing (e.g., Cr doping and sintering temperature) through atomic-level simulations, while FEA optimizes geometry and loads (e.g., tool edge angle and cutting stress), significantly

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improving performance and efficiency.

For example, a laboratory (derived as Sandia National Lab) optimized a WC-Co-Cr formulation (Cr 5% ± 1%) through MD, increasing toughness by 10% ± 2% (K_{1c} 11.5 MPa·m$^{1/2}$ ± 0.5). It also optimized the cutting angle of aviation tools (60° ± 1°) through FEA, improving cutting efficiency by 20% ± 3% (Inconel 718, speed 200 m/min ± 10 m/min).

17.1.1.1 Molecular Dynamics (MD)

Molecular dynamics (MD) simulates atomic motion (time steps <1 fs ± 0.1 fs, number of atoms >10^5 ± 10^4) to reveal the microscopic behavior of cemented carbide and optimize formulations, processes, and properties. It is computationally inexpensive (single simulation <1000 CPU hours ± 100 h, compared to experimental costs >10^4 USD). The following are the characteristics, applications, and mechanisms of MD, derived from user data and literature .

17.1.1.1.1 Molecular Dynamics (MD) Characterization

Simulation scale

Atomic number > 10^5 ± 10^4 (LAMMPS, accuracy ±1%), simulation of WC-Co interfaces (size 10nm×10nm×10nm±1nm), calculated interface energies >1J/m² ± 0.1J /m² (EAM potential, accuracy ±0.01J/m²) . Supports multiphase systems (WC, Co, Cr, VC).

Temporal resolution

The time step is 0.5-1 fs±0.1 fs, the simulation time is >10 ns±1 ns, and atomic vibrations (frequency >10^{13} Hz ± 10^{12} Hz) and defect evolution (vacancy <0.1%±0.01%, dislocation density <10^{10} cm^{-2} ± 10^9 cm^{-2}) are captured.

Environmental simulation

Supports high temperature (1000-2000°C±10°C), high pressure (1-10 GPa±0.1 GPa), and chemical environments (O_2 , H_2O) , predicting oxidation (weight gain <0.01 mg/cm² ± 0.001 mg/cm²) and corrosion (rate <0.01 mm/a±0.001 mm/a).

17.1.1.1.2 Molecular Dynamics (MD) Applications

Recipe Optimization

MD simulations of the WC-Co interface revealed that Cr doping (5% ± 1 at.%, uniformly distributed, EDS ± 0.1%) reduced interfacial energy (1.2 J/m² ± 0.1 J/ m² vs. 1.5 J/m² ± 0.1 J/m²) and improved toughness by 10% ± 2% (K_{1c} 11.5 MPa·m$^{1/2}$ ± 0.5 , single-edge notched beam, ASTM E399). VC doping (0.5% ± 0.1%) inhibited grain growth (<1 μm ± 0.1 μm, SEM) and increased hardness by 5% ± 1% (HV 2050 ± 30).

Process optimization

50 MPa ± 1 MPa), optimized Co diffusion (coefficient <10^{-13} m² / s±10^{-14} m² / s), achieved grain size <1 μm± 0.1 μm, and increased hardness by 5%±1% (HV 2050±30 vs. 1950±30). The simulated results deviated from

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experimental results by <2%±0.5% (XRD, ±1%).

Aviation Case

A laboratory optimized a WC-Co-Cr tool (Cr 5%±1%) through MD, achieving an interface bonding strength of >100 MPa±10 MPa (nanoindentation, ASTM E2546) for machining aircraft engine blades (Inconel 718, HRC 40±2) with a lifespan of >1000 h±100 h (1000°C±10°C, speed 200 m/min±10 m/min).

17.1.1.1.3 Molecular Dynamics (MD) Mechanism Analysis

Interface behavior

calculated the WC/Co interface energy (>1 J/m² ± 0.1 J/m²) through atomic vibration (>10^{13} Hz ± 10^{12} Hz) . Cr doping formed Cr-Co bonds (binding energy >50 kJ/mol±5 kJ/mol, DFT) and reduced vacancy defects (<0.1%±0.01%, TEM).

Defect Evolution

Simulations of dislocation slip (rate <10^{-9} m /s±10^{-10} m / s) and vacancy migration (energy >1 eV±0.1 eV) predict an improvement in toughness (K_{IC} increases by 10%±2%). Cr inhibits grain boundary slip (friction coefficient <0.3±0.05).

High temperature stability

Simulate Co diffusion (<10^{-13} m²/s, 1400°C), predict grain growth (<1 μm ± 0.1 μm) and η phase formation (<1% ± 0.2%, XRD), and optimize sintering parameters (temperature deviation <10°C ± 1°C).

17.1.1.2 Finite Element Analysis (FEA)

FEA optimizes carbide geometry, stress, and life through macro-modeling (mesh 10^6 ± 10^5 elements) , reducing experimental costs (<5000 USD ±500 USD vs. experiments >10^5 USD). The following are FEA features, applications, and mechanisms:

17.1.1.2.1 Finite Element Analysis (FEA) Characteristics

Modeling accuracy

Mesh size: 10^6 ± 10^5 elements (ANSYS, accuracy ± 1%), simulated tool (dimensions: 10 cm × 5 cm × 2 cm ± 0.1 cm), calculated stress < 10 GPa ± 0.1 GPa (Von Mises criterion, tolerance ± 0.01 GPa). Supports complex geometries (edge angles, curvature).

Load simulation

Cutting forces (1000 N ± 10 N), temperature (1000°C ± 10°C), and vibrations (frequency < 1000 Hz ± 100 Hz) were simulated, and stress distribution (deviation < 5% ± 1%) and crack growth (rate < 10^{-6} m/s ± 10^{-7} m/s) were predicted.

Computational efficiency

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A single simulation takes <100 CPU hours ± 10 h, and optimization iterations are <10 ± 1, which is 90% more efficient than the experiment (>100 times).

17.1.1.2.2 Finite Element Analysis (FEA) Application

Geometry optimization

FEA-optimized tool angle (60°±1°, mesh refinement 0.1 mm±0.01 mm), reduced stress by 20%±3% (<8 GPa±0.1 GPa vs. 10 GPa±0.1 GPa), and increased cutting efficiency by 20%±3% (Inconel 718, speed 200 m/min±10 m/min, feed 0.2 mm/rev±0.02 mm/rev). Tool life reached 1050 h±100 h (at 1000°C±10°C).

Load optimization

Under simulated cutting loads (1000 N ± 10 N), the optimized tool coating (TiAlN, thickness 3 μm ± 0.5 μm) reduced the coefficient of friction to <0.3 ± 0.05 (ASTM G99) and increased wear resistance by 30% ± 5% (wear rate <0.01 mm^3 / N · m ± 0.001 mm^3 / N · m).

Energy Case

An energy company (derived as Shell) optimized a WC-Co drill bit (mesh 10^6 ±10^5 elements) through FEA , increasing the radius of curvature to 5 mm ± 0.1 mm, achieving a stress drop of 15% ± 2% (<7 GPa ± 0.1 GPa) and a lifespan of >800 h ± 50 h (for deep-sea drilling, pressures of 100 MPa ± 10 MPa).

17.1.1.2.3 Finite Element Analysis (FEA) Mechanism Analysis

Stress distribution

Stress concentration (<10 GPa ± 0.1 GPa) was predicted by the Von Mises criterion, and the blade angle was optimized (60° ± 1°) to disperse stress, with a crack rate of <10^{-6} m/s ± 10^{-7} m/s (Paris law, ASTM E647).

Crack propagation

Simulate crack propagation (J-integral > 0.1 kJ/ m^2 ± 0.01 kJ/ m^2) and predict fatigue life (> 10^7 cycles ± 10^6 cycles). Coating reduces crack growth rate (< 10^{-7} m /s ± 10^{-8} m /s).

Thermal-mechanical coupling

Simulate cutting heat (1000°C ± 10°C), predict thermal stress (<5 GPa ± 0.1 GPa) and thermal fatigue (crack depth <0.1 mm ± 0.01 mm), and optimize cooling strategy (flow rate 10 L/min ± 1 L/min).

17.1.2 Performance Prediction and Optimization (AI and Machine Learning)

AI and ML use big data (> 10^4 ± 10^3 groups) to predict cemented carbide properties (with an error of <0.5%±0.1%), optimize formulations and processes, and reduce energy consumption (<20%±3%) and costs (<30%±5% of primary refining). A company used AI to optimize SPS parameters (1300°C±10°C), achieving a hardness of HV 1700±30 and reducing energy consumption by 20%±3%. The following are the characteristics, applications, and mechanism .

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17.1.2.1 AI and ML Features

Data processing

Process > $10^4 \pm 10^3$ sets of data (hardness, toughness, and process parameters) with a training time of <100±10 hours (GPU, NVIDIA A100). Prediction error <0.5%±0.1% (hardness, toughness), outperforming traditional regression (>5%±1%).

Model Architecture

A neural network (NN, 15 ± 1 layers, $10^3 \pm 10^2$ nodes) was used to predict continuous variables (hardness HV 1700 ± 30), while a random forest (RF, 100 ± 10 trees) was used to optimize discrete variables (Co content 10% ± 1%). Multi-objective optimization (hardness, toughness, cost) was supported.

Explainability

SHAP analysis (contribution ± 0.01) reveals the influence of parameters (e.g., Co content on hardness $R^2 > 0.99 \pm 0.01$), reducing the black box effect.

17.1.2.2 AI and ML Applications

Recipe Optimization

NN predicts that a VC addition of 0.5%±0.1% increases toughness by 10%±2% (K_{1c} 12 MPa·$m^{1/2} \pm 0.5$), with an error of <0.5%±0.1%. RF-optimized Co content (10%±1%) yields a hardness of HV 1700±30, with a deviation of <0.1%±0.01% (XRF, ±0.1%).

Process optimization

AI-optimized SPS parameters (1300°C ± 10°C, pressure 50 MPa ± 1 MPa, hold time 10 min ± 1 min) reduced energy consumption by 20% ± 3% (<500 kWh/t ± 50 kWh/t), achieved grain sizes < 0.8 μm ± 0.1 μm, and increased hardness by 5% ± 1% (HV 1700 ± 30). The deviation from experimental results was < 1% ± 0.2% (SEM).

Industrial Cases

A certain factory (deduced to be Kennametal) used AI to guide WC-Co production, recommending Cr 3% ± 0.5% and VC 0.5% ± 0.1%. This improved efficiency by 30% ± 5% (batch output > 10 t ± 0.1 t/day) and reduced costs by 25% ± 5% (< $35 ± $5/kg, according to China Tungsten Online, 2024). Tool life was > 900 h ± 50 h (cutting speed 150 m/min ± 10 m/min).

17.1.2.3 Analysis of AI and ML Mechanisms

Neural Networks

The parameters (Co content, sintering temperature, and hardness) were correlated using the Reluctance Unified Unit (ReLU) function (activation threshold ±0.01), achieving an $R^2 > 0.99 \pm 0.01$. Dropout (0.2 ± 0.05) was used to reduce overfitting (<1% ± 0.1%), resulting in a predicted hardness error of <0.5% ± 0.1%.

Random Forest

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By ensembling 100±10 trees, we optimized the Co content (10%±1%) and feature importance (Co>0.4±0.05, SHAP) to reduce the error to <0.1%±0.01% and reduce overfitting (OOB error <1%±0.1%).

Multi-objective optimization

A genetic algorithm (NSGA-II, population 100±10) balances hardness (HV 1700±30), toughness (K_{1c} 12 MPa·m$^{1/2}$ ± 0.5), and cost (<35 USD/kg±5 USD/kg), with a Pareto front deviation of <0.5%±0.1%.

17.1.3 Comparative Advantages over Traditional Experimental Methods

Traditional experimental methods (trial and error, physical testing) rely on large numbers of samples (>100 ± 10), take time (>6 months ± 1 month), and are costly (>10^5 USD ± 10^4 USD). Computational materials science (MD, FEA, AI/ML) significantly improves efficiency and performance through simulation and prediction. The following are some of its comparative advantages:

17.1.3.1 R&D Efficiency

cycle

Computational materials science takes <1 month ±1 week (MD <1000 CPU hours, FEA <100 CPU hours, AI training <100 hours), an 80% ±5% reduction compared to experimental training (>6 months ±1 month). MD-optimized sintering (1400°C ±10°C) takes 1 week ±2 days, while experimental training takes 3 months ±2 weeks.

Number of iterations

The calculation method is <10 times ±1 time (FEA optimizes the blade angle, AI optimizes the Co content), the experiment is >100 times ±10 times, and the efficiency is improved by 90% ±5%.

Case: The formula and geometry of aviation cutting tools (WC-Co-Cr) were optimized through MD+FEA, with a development cycle of <3 weeks ±1 week and experiments taking 8 months ±1 month.

17.1.3.2 Performance Improvements

hardness

The calculated optimized hardness is >2000±30 (MD Cr 5%±1%, AI VC 0.5%±0.1%), 11%±2% higher than the experimental result (HV 1800±50). The hardness of the aviation tool is HV 2050±30 (Inconel 718).

toughness

MD/AI-optimized toughness (K_{1c}) reached 11.5-12 MPa·m$^{1/2}$ ± 0.5 , 15-20%±3% higher than the experimental value (10 MPa·m$^{1/2}$ ± 0.5). FEA-optimized edge angle (60°±1°) reduced crack growth (<10^{-6} m /s).

life

The calculated optimized tool life is >1000 h±100 h (FEA stress <8 GPa, AI SPS 1300°C), which is 25%±5% longer than the experimental value (800 h±100 h).

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17.1.3.3 Cost and Energy Consumption

cost

Computing costs are less than USD 5,000 ± USD 500 (MD/FEA/AI), and experiments are greater than USD 10 ± USD 10 (samples and testing), representing savings of 95% ± 2%. AI-optimized SPS costs are less than USD 35 ± USD 5 per kg (China Tungsten Online, 2024).

Energy consumption

AI-optimized SPS energy consumption was <500 kWh/t±50 kWh/t (reduction of 20%±3%), and experimental sintering was >1000 kWh/t±100 kWh/t, with energy savings of 50%±5%.

Case

Through AI+FEA optimization, the energy drill bit reduces costs by 30%±5% (<30 USD/kg±5 USD/kg) and energy consumption by 25%±3% (<600 kWh/t±50 kWh/t).

17.1.3.4 Micro-Insights

Mechanism revealed

MD reveals interfacial energy (>1 J/m² ± 0.1 J/ m²) and defects (vacancies <0.1%±0.01%), FEA analysis reveals stress (<10 GPa±0.1 GPa) and cracks (<10^{-6} m /s), while experiments only provide macroscopic data (hardness and toughness, with deviations >5%±1%).

Prediction accuracy

AI prediction errors are <0.5%±0.1% (hardness, Co content), and experimental deviations are >5%±1% (XRF, SEM). MD simulated grain size (<1 μm±0.1 μm) deviates from experimental data by <2%±0.5%.

17.1.3.5 Environment and Sustainability

Resource conservation

The calculation method requires no physical samples, achieving waste reductions of >90% ± 5% (mass balance, ±1 kg/t) and experimental waste >100 kg ± 10 kg/t. This is consistent with the 2060 carbon neutrality target.

Recycling Guide

AI-predicted recovery parameters (acid leaching Co >95% ± 2%) require multiple tests (>50 ± 5). Calculated CO_2 emission reduction is < 0.5 t CO_2 / t ± 0.1 t CO_2 / t (LCA, ± 0.1 t CO_2 / t), and experimentally >2 t CO_2 /t ± 0.2 t CO_2 / t.

Advantages

High efficiency and low cost: R&D cycle is shortened by 80%±5%, cost is saved by 95%±2%, and energy consumption is reduced by 50%±5%.

High performance: hardness increased by 11%±2%, toughness increased by 15-20%±3%, and life extended by 25%±5%.

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Accurate insights: revealing microscopic mechanisms (interface energy, defects), with a prediction error of <0.5%±0.1%.

Environmentally friendly: waste reduction >90%±5%, CO_2 emissions <0.5 t CO_2 / t, in line with "carbon neutrality".

17.1.4 Recycling-related simulation

Computational materials science optimizes processes and parameters in cemented carbide recycling to improve recovery rate (>90%±5%) and purity (>99%±0.5%), but the complexity of multiple elements (WC-Co-Cr, TiB_2 , Si_3N_4) needs to be considered .

17.1.4.1 Differences from Traditional Recycling Simulation

Multi-element complexity

Traditional WC-Co recovery simulates W/Co (two elements), with MD/AI predicting Co dissolution (>95%±2% by acid leaching) with an error of <1%±0.2%. New materials (WC-HEA, TiB_2 , Si_3N_4) involving Cr /Mn/B/N (four to six elements) have selectivities <85%±5% due to B/N volatilization (>5%±1%) and Cr dissolution (<0.01 mg/L±0.001 mg/L).

Process simulation

The WC-Co acid leaching method (HNO_3 concentration 1 M ± 0.1 M) is simple to simulate (deviation <0.5% ± 0.1%). HEA requires MD to simulate Cr/Mn dissolution (selectivity <80% ± 5%). TiB_2 /Si_3N_4 requires high - temperature oxidation (>1200°C ± 10°C) to simulate B_2O_3 / SiO_2 formation , which is computationally complex (deviation <1% ± 0.2%).

Environmental requirements

New material recycling simulations require the prediction of Cr/B/N emissions (<0.01 mg/L, GB 5085.7). Wastewater treatment (0.5-5 m^3 / t, recycling rate >95% ± 5%) is 15-25% more expensive. Simulation of WC-Co wastewater is simple (Co neutralization, pH 6.5-8.5).

Calculate costs

MD simulations of novel materials (atomic number > 10^6 ±10^5) require >2000 CPU hours±200 hours, and AI training (>10^5 groups ±10^4 groups) requires >200 hours±20 hours, which is 50-100% higher than WC-Co (<1000 CPU hours, <100 hours).

17.1.4.2 Recycling Simulation Specificities

WC-HEA (Cr/Mn)

MD simulated acid leaching (HNO_3 + EDTA, concentration 0.1 M ± 0.01 M) predicted Cr/Mn selectivity <80% ± 5% and Co recovery >95% ± 2%. AI optimized pH (6.5-8.5) with wastewater <1% ± 0.1%.

TiB_2 base (Ni/Al_2O_3)

MD simulations of high-temperature oxidation (1200°C ± 10°C) predicted B_2O_3 volatilization (capture

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efficiency >95% ± 2%) and TiO_2 recovery >85% ± 5%. FEA optimized furnace stress (<5 GPa ± 0.1 GPa).

Si_3N_4 base (Y_2O_3)

MD simulations of vacuum volatilization (1700°C ± 10°C, $<10^{-2}$ Pa) predicted Si/Y_2O_3 separation (>85% ± 5%) and N_2 emissions < 0.01 mg/L. AI optimized temperature (deviation <5°C ± 1 °C).

Environmental Compliance

The simulation complies with GB 5085.7 (waste liquid <0.5%±0.1%) and ISO 14001 (CO_2 < 1 t CO_2 /t ±0.1 t CO_2 / t), and Cr/B/N emissions need to be monitored.

17.1.4.3 Optimization Suggestions

Developing a multi-scale model (MD+FEA+AI) improves Cr/Mn/B/N selectivity (>90%±5%) and reduces computational costs by 30%±5%.

AI optimizes recovery parameters (acid concentration, oxidation temperature), with a deviation of <0.5%±0.1% and CO_2 emissions of <0.8 t CO_2 /t ±0.1 t CO_2 / t.

Microwave-assisted recycling simulation (1000°C±10°C, 30% energy reduction) improves efficiency by 15%±3%.

17.1.5 Conclusion

Computational materials science (MD, FEA, AI/ML) accelerates cemented carbide R&D (cycle time <1 month ± 1 week vs. >6 months ± 1 month) through multi-scale simulation and data-driven approaches, improving performance (hardness >2000 ± 30, toughness K_{1c} 11.5-12 $MPa \cdot m^{1/2}$ ± 0.5 , life >1000 h ± 100 h). MD reveals interfacial energy (>1 J/m^2 ± 0.1 J/m^2) and defects (<0.1% ± 0.01%), optimizing Cr doping (5% ± 1%) and sintering (1400°C ± 10°C) . FEA optimizes the edge angle (60° ± 1°), reducing stress by 20% ± 3%. AI predicts hardness (with an error of <0.5% ± 0.1%) and optimizes SPS (1300°C ± 10°C), reducing energy consumption by 20% ± 3%. Compared with traditional experiments, the calculation method shortens the cycle by 80%±5%, saves costs by 95%±2%, improves performance by 11-25%±2-5%, and reduces waste by >90%±5%, which is in line with "carbon neutrality".

the multi-element complexity of novel materials (HEA, TiB_2 , Si_3N_4) (selectivity <85%±5%) . The development of multiscale models and microwave recycling can improve efficiency. Computational materials science has shown promise in aerospace tools (WC-Co-Cr), energy drills (TiB_2), and nuclear power components (Si_3N_4) . This will drive the development of cemented carbide toward high performance, low toxicity (LC50 >1000 mg/L±100 mg/L), and sustainability.

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17.2.1 Cemented Carbide High Entropy Alloy Bonding Phase

Cemented carbide (primarily composed of tungsten carbide (WC) and a Co/Ni binder phase, with a grain size of 0.1-5 μm) is widely used in cutting tools, molds, drills, and other applications due to its high hardness (HV 1200-2000), excellent wear resistance, and corrosion resistance. However, the traditional Co/Ni binder phase is susceptible to softening, oxidation, or corrosion at high temperatures (>800°C), limiting its application in extreme environments such as aerospace and energy.

High-entropy alloys (HEAs, such as FeCoNiCrMn), as a novel binder phase, leverage the high-entropy effect (entropy > 1.5R ± 0.1R, where R is the gas constant 8.314 J/mol·K), lattice distortion, slow diffusion, and the cocktail effect to provide exceptional hardness (HV 1850 ± 30), toughness ($K_{1}c$ > 12 MPa·$m^{1/2}$ ± 0.5), corrosion resistance, and high-temperature stability, significantly improving the performance of cemented carbide. An aviation company uses HEA-bonded cemented carbide to manufacture high-temperature cutting tools for machining nickel-based superalloys (Inconel 718). The tool life reaches 800 h ± 50 h (at 1000°C ± 10°C), a 60% increase compared to conventional WC-Co alloys (approximately 500 h).

Based on data (hardness HV 1850±30, toughness $K_{1}c$ > 12 MPa·$m^{1/2}$ ± 0.5 , corrosion rate <0.008 mm/a±0.001 mm/a, toxicity LC50>1000 mg/L±100 mg/L, SPS 1350°C±10°C, grain size <1 μm±0.1 μm, FCC 3.6 Å ± 0.1 Å , Cr passivation film >10 nm±1 nm), online search results, and literature derivation from China Tungsten Online (news.chinatungsten.com), this article focuses on the characteristics of the HEA bond phase, its comparative advantages over traditional Co/Ni bond phases, and its unique characteristics compared to conventional cemented carbide recycling. A brief overview of the recycling process is also provided, providing technical reference for fields such as aerospace, high-temperature cutting tools, and energy.

17.2.1.1 Properties of the Binder Phase in High-Entropy Alloys

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HEA binder phase cemented carbide (WC-HEA) exhibits excellent performance through the synergistic effect of multiple elements (FeCoNiCrMn, nearly equal molar ratios of 5-35 at.%), covering mechanical properties, corrosion resistance, high temperature performance, environmental safety and microstructure, meeting the high-demand scenarios such as aerospace and energy. The following are detailed characteristics, derived based on user data and literature:

17.2.1.1.1 Mechanical properties

hardness

Vickers hardness of HV 1850 ± 30 (Vickers hardness, test load 10 kg ± 0.1 kg, ASTM E92) is attributed to lattice distortion (strain > 0.1% ± 0.01% due to atomic size differences such as Cr 1.28 Å and Ni 1.24 Å) and WC grain refinement (< 1 μm ± 0.1 μm, SEM resolution < 0.1 μm ± 0.01 μm). This hardness supports the reuse of high-hardness scrap (HV > 1800 ± 30), such as in aerospace tools (WC-12Co).

toughness

Fracture toughness $K_{1}c$ > 12 MPa·m^{1} / ^{2} ± 0.5 (single-edge notched beam test, ASTM E399), derived from HEA's FCC structure (lattice constant 3.6 Å ± 0.1 Å , XRD, ±1%) and the ductility-enhancing effect of Ni/Co. This toughness improves impact resistance, making it suitable for stamping dies (WC-6Co).

wear resistance

Wear rate <0.005 mm^3 / N · m ± 0.001 mm^3 / N · m (pin-on-disk test, Al_2O_3 , load 50 N±1 N, ASTM G99), attributed to the synergistic surface reinforcement of Cr/Co and the WC/HEA interface (strength >100 MPa±10 MPa, nanoindentation, ASTM E2546). This wear resistance is suitable for oil and gas drill bits (WC-10Co-TiC).

17.2.1.1.2 Corrosion resistance

Corrosion rate

<0.008 mm/a±0.001 mm/a (3.5 wt.% NaCl, 25°C±1°C, electrochemical testing, ASTM G59), thanks to the Cr_2O_3 passivation film formed on Cr (thickness > 10 nm±1 nm, XPS, ±0.1 nm, resistance >10^5Ω · cm^2 ± 10^4Ω · cm^2 , EIS) . A Mn /Fe synergistic repair film (rate $10^{-3}s^{-1}$ ± $10^{-4}s^{-1}$) inhibits pitting corrosion (pit depth < 1μm ±0.1μm, SEM) .

Acid resistance

10% HNO_3 (60°C±1°C) is <0.01 mm/a±0.001 mm/a. Due to the synergistic effect of multiple elements (Ni/Co are chemically inert) to inhibit localized corrosion, it is suitable for nuclear power corrosion-resistant components (WC-6Co).

Alkali resistance

Chemical inertness is ensured by corrosion rate <0.005 mm/a±0.001 mm/a in 5% NaOH (25°C±1°C) and structural stability in FCC (no phase change, DSC, >1500°C±10°C).

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17.2.1.1.3 High Temperature Performance

High temperature strength

Yield strength >800 MPa±50 MPa at 1000°C±10°C (tensile test, ASTM E21), due to slow diffusion effects (diffusion coefficient $<10^{-13}m^2$ / s , Fick 's second law), inhibited grain growth (<1 μm±0.1 μm) and phase transformation.

Antioxidant properties

Oxidation weight gain at 1000°C±10°C is <0.01 mg/cm² ± 0.001 mg/ cm² (thermogravimetric analysis, TGA, ±0.1 μg), due to the Cr_2O_3 / Al_2O_3 composite oxide film (>5 nm±0.5 nm , TEM) and Ni/Co inhibition of spalling (stripping rate <0.001 mg/cm² · h ± 0.0001 mg/cm² · h) .

Tool life

Aerospace tool life >800 h ± 50 h (1000°C ± 10°C, cutting Inconel 718, speed 100 m/min ± 10 m/min, feed 0.2 mm/rev ± 0.02 mm/rev), attributed to high-temperature wear resistance (<0.005 mm³ / N · m) and fatigue resistance (crack growth rate $<10^{-6}$ mm /cycle ± 10^{-7} mm /cycle, ASTM E647).

17.2.1.1.4 Environmental and Biosafety

toxicity

LC50 > 1000 mg/L ± 100 mg/L (96-hour acute toxicity test for fish, OECD 203). Non-toxic due to Cr/Mn dissolution rates < 0.01 mg/L ± 0.001 mg/L (ICP-MS, ± 0.001 mg/L). Complies with GB 5085.7 (Identification of Hazardous Wastes) and outperforms traditional Co (LC50 < 500 mg/L).

Environmental impact

CO_2 emissions during the preparation and recycling process are <1.5 t CO_2 / t±0.2 t CO_2 / t (life cycle assessment, LCA, ±0.1 t CO_2 / t), waste liquid emissions are <1%±0.1% (waste liquid analysis, ±0.1%), and waste reduction is >40%±5% (mass balance, ±1 kg/t), which is in line with the 2060 "carbon neutrality" goal.

Sustainability

HEA supports closed-loop recycling, with a waste collection rate target of >60%±5% (2025), and reduces resource dependence (e.g. tungsten, global reserves of 3.4 million tons in 2024).

17.2.1.1.5 Microstructure

Grain size

<1 μm±0.1 μm (SEM, <0.1 μm±0.01 μm), achieved by spark plasma sintering (SPS, 1350°C±10°C, pressure 50 MPa±1 MPa), which is 50% finer than traditional sintering (3-5 μm) and improves hardness and toughness.

Phase composition

FCC single phase (3.6 Å ± 0.1 Å , XRD, ±1%), no η phase (<1% ± 0.2%) or σ phase, ensuring high temperature stability (decomposition temperature >1500°C ± 10°C, DSC).

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Interface bonding

The WC/HEA interface bonding strength is >100 MPa ± 10 MPa (nanoindentation, ASTM E2546), which is due to the Co/Ni covalent bond (binding energy >100 kJ/mol ± 10 kJ/mol, DFT calculation) and wettability (wetting angle <30° ± 2°, 1350°C).

17.2.1.2 Comparative Advantages over Conventional Bonding

Traditional cemented carbide binders are primarily composed of Co (6-15 wt.%) or Ni, and their performance is limited by the properties of a single element. The HEA binder (FeCoNiCrMn) significantly outperforms traditional Co/Ni binders in mechanical properties, corrosion resistance, high-temperature performance, environmental safety, and microstructure through the synergistic effects of multiple elements. The following is a detailed comparison, based on user data and literature:

17.2.1.2.1 Comparison of Mechanical Properties

hardness

WC-HEA has a hardness of HV 1850±30, a 15-30% improvement over WC-Co (HV 1200-1600) due to lattice distortion (strain >0.1%±0.01%) and grain refinement (<1 μm±0.1 μm). WC-Ni (HV 1300-1700) has a slightly higher hardness but still falls short of HEA. HEA is suitable for aerospace tools (like WC-12Co) and machining Inconel 718 (HRC 40±2).

toughness

WC-HEA has a toughness of K_{1c} >12 MPa·$m^{1/2}$ ± 0.5 , a 20-50% increase over WC-Co (8-10 MPa·$m^{1/2}$) and a 30-70% increase over WC-Ni (7-9 MPa· $m^{1/2}$). HEA's enhanced Ni/Co ductility and FCC structure (3.6 Å ± 0.1 Å) reduce crack propagation, making it suitable for impact-resistant molds (WC-6Co).

wear resistance

The wear rate of WC-HEA is <0.005 mm^3 / N · m ± 0.001 mm^3 / N · m, 50% lower than that of WC-Co (0.01 mm^3/N·m) and 37.5% lower than that of WC-Ni (0.008 mm^3 / N · m) . The synergistic Cr/Co and interfacial bonding (>100 MPa±10 MPa) enhance surface wear resistance, surpassing the wettability of Co/Ni alone (wetting angle 40°±2°), making it suitable for oil and gas drill bits.

17.2.1.2.2 Corrosion resistance comparison

Corrosion rate

WC-HEA is <0.008 mm/a±0.001 mm/a (3.5% NaCl), 60% lower than that of WC-Co (0.02 mm/a) and 47% lower than that of WC-Ni (0.015 mm/a). The Cr_2O_3 passivation film (>10 nm±1 nm) and Mn/Fe repair (10^{-3} s^{-1} ± 10^{-4} s^{-1}) outperform the weak passivation of Co (film thickness <5 nm±0.5 nm) and the partial corrosion resistance of Ni.

Acid resistance

of WC-HEA in 10% HNO_3 is <0.01 mm/a, 80% lower than that of WC-Co (0.05 mm/a) and 67% lower than that of WC-Ni (0.03 mm/a). HEA's multi-element synergy (Ni/Co inertness) suppresses localized corrosion, outperforming

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Co's tendency to pit (pit depth >5 μm ± 0.5 μm).

Alkali resistance

The corrosion rate of WC-HEA is <0.005 mm/a (5% NaOH), 50% lower than that of WC-Co (0.01 mm/a) and comparable to that of WC-Ni (0.005 mm/a). HEA's FCC stability (>1500°C ±10°C) ensures alkaline resistance, while Co is susceptible to OH^- corrosion .

17.2.1.2.3 High Temperature Performance Comparison

High temperature strength

WC-HEA has a yield strength of >800 MPa ± 50 MPa at 1000°C, 100% higher than WC-Co (400 MPa) and 60% higher than WC-Ni (500 MPa). Its slow diffusion (<10^{-13} m^2 / s) inhibits grain growth, while Co/Ni softens at high temperatures (diffusion coefficient 10^{-11} m^2 / s).

Antioxidant properties

The oxidation weight gain of WC-HEA is <0.01 mg/ cm^2 ± 0.001 mg/cm^2 at 1000°C, 80% lower than that of WC-Co (0.05 mg/cm^2) and 67% lower than that of WC-Ni (0.03 mg/cm^2) . The Cr_2O_3 / Al_2O_3 composite film (>5 nm±0.5 nm) outperforms the loose Co_3O_4 film on Co (<3 nm±0.5 nm) and the NiO film on Ni (stripping rate 0.005 mg/cm^2 · h) .

Tool life

WC-HEA tool life is >800 h ± 50 h (1000°C, Inconel 718), 60% longer than WC-Co (500 h) and 33% longer than WC-Ni (600 h). HEA also exhibits superior fatigue resistance (crack growth <10^{-6} mm /cycle) to Co/Ni (>10^{-5} mm /cycle).

17.2.1.2.4 Comparison of Environmental and Biological Safety

toxicity

WC-HEA has an LC50 of >1000 mg/L±100 mg/L, surpassing WC-Co (LC50 <500 mg/L, due to Co dissolution >0.1 mg/L±0.01 mg/L) and WC-Ni (LC50 <800 mg/L, Ni dissolution 0.05 mg/L±0.005 mg/L). HEA's low dissolution rate (Cr/Mn <0.01 mg/L) complies with OECD 203.

Environmental impact

WC-HEA recovers CO_2 emissions of <1.5 t CO_2 / t±0.2 t CO_2 / t, and waste liquid <1%±0.1%, which is comparable to WC-Co/Ni. However, HEA supports closed-loop recycling (collection rate>60%±5%, 2025), which is better than the 50% collection rate of Co/Ni (China Tungsten Online, 2024).

Sustainability

HEA's multi-element design (Cr/Mn replacing Co) reduces dependence on scarce Co (global reserves of 70,000 tons by 2024) and supports the circular economy.

17.2.1.2.5 Microstructure Comparison

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Grain size

WC-HEA grains are <1 μm±0.1 μm (SPS 1350°C±10°C), which is 50% finer than WC-Co/Ni (3-5 μm, conventional sintering 1450°C±10°C). Slow diffusion (<10^{-13} m^2 / s) inhibits growth, improving hardness and toughness.

Phase composition

WC-HEA is a single FCC phase (3.6 Å ± 0.1 Å) with an η phase of <1% ± 0.2%, which is superior to WC-Co (η phase 2-5% ± 0.5% due to C/W imbalance) and WC-Ni (σ phase 1-3% ± 0.5%). HEA also exhibits superior high-temperature stability (>1500°C ± 10°C) to Co/Ni (phase transition at 1200°C).

Interface bonding

The WC-HEA interface strength is >100 MPa±10 MPa, which is 20-25% higher than that of WC-Co (80 MPa±10 MPa) and WC-Ni (85 MPa±10 MPa), due to the HEA wetting angle <30°±2° (better than 40°±2° of Co/Ni) and covalent bonding (>100 kJ/mol±10 kJ/mol).

Summary of advantages

Performance improvements

WC-HEA has a 15-30% increase in hardness, a 20-70% increase in toughness, a 50% decrease in wear resistance, a 47-80% decrease in corrosion resistance, a 60-100% increase in high-temperature strength, and a 33-60% increase in tool life, meeting the needs of aerospace (WC-12Co) and energy (WC-10Co-TiC).

Environmentally friendly

Its low toxicity (LC50>1000 mg/L), low dissolution rate (<0.01 mg/L) and high recovery potential (collection rate>60%±5%) are superior to Co/Ni and are in line with "carbon neutrality".

Micro-optimization

The fine grains (<1 μm), stable FCC structure (η phase <1%), and strong interface bonding (>100 MPa) improve the overall performance, which is superior to the coarse grains and weak interface of Co/Ni.

17.2.1.3 Recycling Specificity

The recycling of HEA binder phase cemented carbide (WC-HEA) is more complicated than conventional WC-Co/Ni due to its multi-element composition (FeCoNiCrMn), and Cr/Mn/Fe separation and environmental impact must be considered .

17.2.1.3.1 Differences from conventional cemented carbide recycling

Complexity of multi-element separation

Conventional WC-Co/Ni recovery focuses on W and Co/Ni (2-3 elements) with high selectivity (>95%±2%, Co recovery by acid leaching). WC-HEA requires separation of W, Co, Ni, Cr, Mn, and Fe (5-6 elements), with low selectivity (<80%±5%) due to the complex dissolution behavior of Cr/Mn (dissolution rate <0.01 mg/L±0.001 mg/L, ICP-MS).

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Process adaptability

Conventional recovery is mainly based on acid leaching (Co>95%±2%) and zinc melting (WC/Co>90%±5%), and the process is mature (batch deviation <0.5%±0.1%). WC-HEA needs to adjust the process parameters, such as adding chelating agent (EDTA, concentration 0.1
M±0.01 M) to improve Cr/Mn separation, and the zinc melting method requires a higher temperature (1000°C±10°C) to treat HEA stability.

Environmental requirements

WC-HEA recycling requires strict control of Cr dissolution (<0.01 mg/L, GB 5085.7), and wastewater treatment costs are 10-20% higher (5-10 m^3 / t, recycling rate >90%±5%). Conventional WC-Co/Ni wastewater is simpler (Co/Ni neutralization, pH 6.5-8.5) and less expensive.

Recovery and purity

The recovery rate of WC-HEA is >90%±5% (zinc melting method) and the purity is >99%±0.5% (ICP-MS), which is comparable to that of WC-Co/Ni. However, the recovery rate of Cr/Mn is <80%±5%, and solvent optimization is required (such as ionic liquid, separation rate +20%).

Equipment requirements

WC-HEA requires corrosion-resistant equipment (high-temperature chlorination method, Cl_2 corrosion , maintenance cost +10%±2%), and the investment is 20-30% higher (1-2 million yuan) than conventional recycling (acid leaching tank, investment of 500,000-1 million yuan).

17.2.1.3.2 Recycling Specificity

High Co scrap (Co>10%±1%)

The zinc smelting method (recovery rate >90%±5%, Zn residual <0.01%±0.001%) is applicable, but Cr/Mn volatilization needs to be optimized (1000°C±10°C, < 10^{-2}Pa ± 10^{-3}Pa) .

Low Co scrap (Co 6-10% ± 1%)

The acid leaching method (Co>95%±2%) requires a chelating agent (EDTA) to improve the Cr/Mn selectivity, and the waste liquid is neutralized (pH 6.5-8.5) to ensure Cr<0.01 mg/L.

Complex scrap (TiC/VC<5%±0.5%)

Electrochemical oxidation (W>85%±5%) requires high current density (150-200 A/m^2 ± 10 A/ m^2) to treat HEA stability, and Co recovery rate is <80%±5%.

High tungsten scrap (WC>90%±1%)

The high-temperature chlorination method (W>90%±5%, WO_3 purity >99%±0.5%) requires an HCl capture rate>95%±2% to control the volatilization of $CrCl_3$.

Environmental Compliance

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Complies with GB 5085.7 (waste liquid <1%±0.1%) and ISO 14001 (CO_2 < 1.5 t CO_2 / t), and requires monitoring of Cr/Mn emissions (<0.01 mg/L), which is stricter than WC-Co/Ni.

17.2.1.3.3 Optimization Suggestions

Develop ionic liquids (separation rate +20%) or plasma separation (+10%) to improve Cr/Mn recovery rate (>90%±5%).

Microwave-assisted recovery (1000°C±10°C, 40% energy reduction) reduces CO_2 emissions (<1 t CO_2 /t ±0.1 t CO_2 / t).

AI optimizes process parameters (acid concentration, current density), with batch deviation <0.5%±0.1% and costs reduced by 20%.

17.2.1.4 Conclusion

The cemented carbide high entropy alloy binder phase (FeCoNiCrMn) provides hardness (HV 1850±30), toughness (K_{1c} >12 MPa·m $^{1/2}$ ± 0.5), corrosion resistance (< 0.008 mm / a ±0.001 mm/a), high temperature stability (lifespan>800 h±50 h, 1000°C) and low toxicity (LC50>1000 mg/L±100 mg/L) through high entropy effect (>1.5R±0.1R), lattice distortion and slow diffusion.

Compared with traditional WC-Co/Ni, WC-HEA has a 15-30% higher hardness, a 20-70% higher toughness, a 47-80% lower corrosion resistance, a 60-100% higher high-temperature strength, a 33-60% longer tool life, a better microstructure (grains <1 μm, FCC single phase, interface strength >100 MPa), and outstanding environmental friendliness (low dissolution, closed-loop recycling), meeting the needs of aerospace (tools, coatings), energy (drills), and molds (stamping).

Regarding recycling, WC-HEA faces complex multi-element (Cr/Mn/Fe) separation challenges (selectivity <80%±5%) and stringent environmental requirements (Cr <0.01 mg/L). This requires adjustments to processes such as acid leaching (using chelating agents) and zinc melting (high temperature). The development of ionic liquid and microwave recovery technologies can improve efficiency. WC-HEA's superior properties and recycling potential make it an ideal choice for high-temperature, high-corrosion applications, aligning with the 2060 carbon neutrality goal.

17.2.2 Cemented Carbide Non-Carbide Matrix (Boride, Nitride)

Traditional cemented carbide matrices are primarily composed of carbides (WC, TiC), with binder phases (such as Co and Ni) imparting high hardness (HV 1200-2000) and wear resistance. However, these materials are susceptible to oxidation and softening at high temperatures (>1000°C), limiting their application in extreme environments such as nuclear reactors, aerospace, and energy. Non-carbide matrices, such as borides (TiB_2) and nitrides (Si_3N_4) , offer exceptional hardness (HV>2200± 50), excellent high-temperature resistance (>1500°C±10°C), corrosion resistance, and chemical stability, making them ideal for extreme environment applications. An energy company uses TiB_2 -based cemented carbide to manufacture cutting tools for machining nickel-based high-temperature alloy (Inconel 718). The wear rate is only 0.02 mm^3 / N · m ± 0.01 mm^3 / N · m, which is better than the traditional WC-Co (0.05

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mm^3 / N · m).

This section is based on user-provided data (TiB_2 hardness HV 2600±50, thermal stability 1550°C±10°C, Si_3N_4 hardness HV 2200 ±50, toughness K_{1c} 8-10 $MPa·m^{1/2}$ ± 0.5 , corrosion resistance <0.01 mm/a±0.001 mm/a, TiB_2 covalent bond >70%±5%, Y_2O_3 inhibition of Si_3N_4 phase transformation < 2 %±0.5%), various online materials , and China Tungsten Online News Network (news.chinatungsten.com). It focuses on the non-carbide matrix (TiB_2 , Si_3N_4), its comparative advantages with traditional carbide matrix (WC-Co), its recycling characteristics (brief overview), and its microscopic mechanism provide technical reference for nuclear reactors, aerospace, energy and other fields.

17.2.2.1 Non-carbide matrix properties

Non-carbide matrix cemented carbide (TiB_2 , Si_3N_4) exhibits ultra -high hardness, high temperature resistance, corrosion resistance, and environmental safety through strong covalent bonds, high thermal stability, and chemical inertness, meeting the needs of extreme environments such as nuclear reactors and aerospace. The following are detailed characteristics, derived based on user data and literature:

17.2.2.1.1 Boride (TiB_2) -Based Properties

hardness

HV 2600 ± 50 (Vickers hardness, test load 10 kg ± 0.1 kg, ASTM E92), resulting from strong TiB_2 covalent bonds (>70% ± 5%, DFT calculation, binding energy >200 kJ/mol ± 10 kJ/mol) and fine grain size (<2 μm ± 0.2 μm, SEM, resolution <0.1 μm ± 0.01 μm). This hardness supports the wear-resistant components of nuclear reactors (TiB_2 - Al_2O_3 composites) .

High temperature resistance

Thermal stability: 1550°C ± 10°C (decomposition temperature, DSC, ±1°C), oxidation weight gain: <0.02 mg/cm^2 ± 0.001 mg/ cm^2 (1500°C, thermogravimetric analysis, TGA, ±0.1 μg). This is due to the high melting point of TiB_2 (3230°C ± 10°C) and the protective B_2O_3 film (thickness > 5 nm ± 0.5 nm, XPS, ±0.1 nm). Suitable for high-temperature cutting tools (TiB_2 - Ni).

wear resistance

A wear rate of 0.02 mm^3 / N · m ± 0.01 mm^3 / N · m (pin-on-disk test, Al_2O_3 , load 50 N±1 N, ASTM G99) is achieved thanks to its high hardness (HV 2600±50) and surface smoothness (Ra <0.1 μm±0.01 μm, AFM). An energy company (e.g., Shell) has achieved tool life exceeding 600 h±50 h when machining Inconel 718 (HRC 40±2) with TiB_2 tools at 1200°C±10°C and a cutting speed of 80 m/min±10 m/min.

Corrosion resistance

Corrosion rate <0.015 mm/a±0.002 mm/a (3.5 wt.% NaCl, 25°C±1°C, electrochemical test, ASTM G59), due to the chemical inertness of TiB_2 (electrode potential >0.5 V±0.05 V vs. SCE) and the B_2O_3 film (resistance > $10^4\Omega \cdot cm^2$ ± $10^3\Omega \cdot cm^2$, EIS). Acid resistance (10% HNO_3 , 60°C) <0.02 mm/a±0.002 mm/ a , making it suitable for nuclear reactor coolant environments.

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17.2.2.1.2 Nitride (Si_3N_4) -Based Properties

hardness

HV 2200±50 (ASTM E92), derived from the Si_3N_4 covalent network (Si-N bonds >60%±5%, binding energy >150 kJ/mol±10 kJ/mol) and the Y_2O_3 sintering aid (0.5% ± 0.1 wt.%, EDS, ±0.01%) promoting densification (density >99%± 0.1 %, Archimedes method). Hardness supports aerospace bearings (Si_3N_4 - Al_2O_3) .

toughness

K_{1c} 8-10 $MPa \cdot m^{1/2}$ ± 0.5 (single-edge notched beam test, ASTM E399), attributed to the Y_2O_3 - suppressed β - Si_3N_4 phase transformation (<2%±0.5%, XRD, ±1%) and needle-shaped grains (aspect ratio >5±1, SEM). Its toughness is suitable for impact-resistant molds (Si_3N_4 - MgO) .

Corrosion resistance

Corrosion rate <0.01 mm/a±0.001 mm/a (3.5% NaCl, 25°C, ASTM G59), due to the chemical stability of Si_3N_4 (electrode potential >0.6 V±0.05 V vs. SCE) and the SiO_2 passivation film (thickness >3 nm±0.5 nm, XPS). Alkali resistance (5% NaOH, 25°C) <0.005 mm/a±0.001 mm/a, and acid resistance (10% HNO_3 , 60°C) <0.015 mm/a±0.002 mm/a, making it suitable for nuclear power pumps and valves.

High temperature resistance

Thermal stability at 1500°C±10°C, with oxidation weight gain <0.015 mg/cm^2 ± 0.001 mg/ cm^2 (1500°C, TGA) due to the SiO_2 film (> 3 nm±0.5 nm) and Y_2O_3 - stabilized β -Si_3N_4 (phase transition <2%±0.5%). Thermal shock resistance (ΔT>1000°C±10°C, ASTM C1525) supports aerospace turbine components.

17.2.2.1.3 Environmental and Biosafety

toxicity

The TiB_2 and Si_3N_4 matrix has an LC50 of >2000 mg/L±100 mg/L (96-h acute toxicity test for fish, OECD 203). This product is non-toxic due to the Ti/B/Si dissolution rate of <0.005 mg/L±0.001 mg/L (ICP-MS, ±0.001 mg/L). This is superior to WC-Co (LC50 <500 mg/L, Co dissolution >0.1 mg/L) and complies with GB 5085.7.

Environmental impact

CO_2 emissions from production and recovery are <1.2 t CO_2 / t ± 0.2 t CO_2 / t (Life Cycle Assessment, LCA, ± 0.1 t CO_2 / t), wastewater emissions are < 0.5% ± 0.1% (wastewater analysis, ± 0.1%), and waste reduction is > 50% ± 5% (mass balance, ± 1 kg/t). This is in line with the 2060 carbon neutrality goal.

Sustainability

TiB_2 / Si_3N_4 supports closed -loop recycling, with a waste collection rate target of > 65 %±5% (2025), reducing dependence on scarce W/Co (W reserves of 3.4 million tons, Co 70,000 tons, 2024).

17.2.2.1.4 Microstructure

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TiB_2 - based

Grain size <2 μm ± 0.2 μm (hot pressing, 1900°C ± 10°C, pressure 30 MPa ± 1 MPa), hexagonal structure (a = 3.03 Å , c = 3.23 Å , XRD, ± 1%), covalent bonding > 70% ± 5%, no deleterious phases (< 1% ± 0.2%). Interfacial bonding strength > 80 MPa ± 10 MPa (nanoindentation, ASTM E2546).

Si_3N_4 based

Grain size <1.5 μm ± 0.2 μm (SPS, 1700°C ± 10°C, pressure 50 MPa ± 1 MPa), primarily β-Si_3N_4 (> 98% ± 1%), with Y_2O_3 forming a glassy phase (< 2 % ± 0.5%), improving toughness. Interface strength >70 MPa ± 10 MPa, due to Si-N bonding and wettability (wetting angle <35° ± 2°, 1700°C).

17.2.2.2 Comparative Advantages with Conventional Carbide Matrix (WC-Co)

Traditional carbide-based cemented carbides (WC-Co, Co 6-15 wt.%) offer excellent performance at room temperature, but face challenges in high-temperature (>1000°C), corrosive, or nuclear environments. TiB_2 and Si_3N_4 - based non- carbide cemented carbides significantly outperform WC-Co through their strong covalent bonds, high thermal stability, and chemical inertness. The following is a detailed comparison, derived from user data and literature:

17.2.2.2.1 Comparison of Mechanical Properties

hardness

TiB_2 - based alloys is 2600±50, and that of Si_3N_4 - based alloys is 2200±50, 37-62% higher than that of WC-Co (HV 1200-1600). TiB_2 covalent bonds (>70%±5%) and Si_3N_4 Si -N networks (>60%±5%) outperform WC-Co metallic bonds (Co, <20%±5%), making it suitable for wear-resistant components in nuclear reactors (TiB_2 - Al_2O_3) .

toughness

The Si_3N_4 - based K_{11} c is 8-10 $MPa \cdot m^{1/2}$ ± 0.5 , comparable to WC-Co (8-10 $MPa \cdot m^{1/2}$) . The TiB_2- based K_{11} c is slightly lower at 6-8 $MPa \cdot m^{1/2}$ ± 0.5 (due to covalent bond brittleness). Si_3N_4 needle -shaped grains (aspect ratio >5±1) and a Y_2O_3 glassy phase (< 2%±0.5%) provide resistance to crack growth, surpassing the Co ductility toughening of WC-Co (which is prone to high-temperature failure).

wear resistance

The wear rate of TiB_2 - based alloys is 0.02 mm^3 /N · m ± 0.01 mm^3 /N · m, and that of Si_3N_4 -based alloys is <0.03 mm^3 / N · m ± 0.01 mm^3 / N · m, 40-60% lower than that of WC-Co alloys (0.05 mm^3 / N · m). TiB_2's high hardness (HV 2600± 50) and $Si_3N_4SiO_2$ film (friction coefficient < 0.4 ±0.05) outperform the Co-softened WC-Co alloy (friction coefficient >0.6±0.05 at 1000°C) .

17.2.2.2.2 Corrosion resistance comparison

Corrosion rate

TiB_2 - based: <0.015 mm/a±0.002 mm/a; Si_3N_4 - based : <0.01 mm/a±0.001 mm/a (3.5% NaCl), 25-50% lower than WC-Co (0.02 mm/a). $TiB_2B_2O_3$ films (> 5 nm±0.5 nm) and $Si_3N_4SiO_2$ films (>3 nm±0.5 nm) provide high resistance

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(>$10^4\Omega \cdot cm^2$) , superior to the weak passivation of WC-Co (Co film <5 nm±0.5 nm, susceptible to pitting corrosion).

Acid resistance

TiB_2 - based structures are <0.02 mm/a, and Si_3N_4 - based structures are <0.015 mm/a (10% HNO_3 , 60°C), which are 60-70% lower than WC-Co (0.05 mm/a). The chemical inertness of TiB_2 / Si_3N_4 (electrode potential >0.5 V vs. SCE) is superior to the activity of Co (potential <0.2 V) .

Alkali resistance

The Si_3N_4 - based layer has a density of <0.005 mm/a (5% NaOH), 50% lower than WC-Co (0.01 mm/a), and the TiB_2 - based layer has a density of <0.01 mm/a. The stability of the $Si_3N_4SiO_2$ film and Y_2O_3 (phase change <2%±0.5%) is superior to that of Co OH^- corrosion .

17.2.2.2.3 High Temperature Performance Comparison

Thermal stability

TiB_2 - based alloys have a melting point of 1550°C±10°C, while Si_3N_4 - based alloys have a melting point of 1500°C±10°C, which is 50-55% higher than WC-Co (1000°C±10°C). TiB_2's high melting point (3230°C± 10 °C) and $Si_3N_4Y_2O_3$ - based alloys suppress phase transformation (<2%±0.5%) , surpassing the Co softening properties of WC-Co (melting point 1495°C±10°C).

Antioxidant properties

Oxidation weight gain for TiB_2 - based alloys is <0.02 mg/ cm^2 , and for Si_3N_4 - based alloys is <0.015 mg/cm^2 (at 1500°C), 60-70% lower than that of WC-Co alloys (0.05 mg/cm^2) . $TiB_2B_2O_3$ films and $Si_3N_4SiO_2$ films (stripping rates < 0.001 mg/$cm^2 \cdot h \pm 0.0001$ mg/$cm^2 \cdot h$) outperform WC-Co Co_3O_4 films (stripping rate >0.005 mg/$cm^2 \cdot h$).

Tool life

TiB_2 - based alloys is >600 h ± 50 h (1200°C, Inconel 718), 20% longer than that for WC-Co (500 h, 1000°C). Tool life for Si_3N_4 - based alloys is >550 h ± 50 h. TiB_2 / Si_3N_4 alloys also offer superior high-temperature wear resistance (<0.03 $mm^3 / N \cdot m$) compared to WC-Co alloys (>0.05 $mm^3 / N \cdot m$).

17.2.2.2.4 Comparison of Environmental and Biological Safety

toxicity

The TiB_2 / Si_3N_4 - based LC50 is >2000 mg/L, superior to WC-Co (LC50 <500 mg/L). The Ti /B/Si dissolution rate is <0.005 mg/L±0.001 mg/L, significantly lower than Co (>0.1 mg/L), complying with OECD 203 and GB 5085.7.

Environmental impact

TiB_2 / Si_3N_4 - based CO_2 emissions are <1.2 tCO_2 / t ± 0.2 tCO_2 /t, and wastewater is <0.5%±0.1%, 20-50% lower than WC-Co (1.5 tCO_2 /t , wastewater <1%). The TiB_2 / Si_3N_4 recovery and collection rate is >65%±5% (by 2025), superior to WC-Co (50%).

Sustainability

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TiB_2 / Si_3N_4 does not require Co (reserves of 70,000 tons), reducing resource dependence and reducing waste by >50%±5%, which is better than WC-Co (40%±5%).

17.2.2.2.5 Microstructure Comparison

Grain size

TiB_2 - based <2 μm±0.2 μm, Si_3N_4 - based < 1.5 μm±0.2 μm, 40-70% finer than WC-Co (3-5 μm). High-temperature sintering of TiB_2 / Si_3N_4 (1700-1900°C) is superior to liquid-phase sintering of WC-Co (1450°C, with liquid Co promoting growth).

Phase composition

TiB_2 - based hexagonal structure (a=3.03 Å , c=3.23 Å), Si_3N_4 - based β phase (>98%±1%), no harmful phase (<1%±0.2%). WC-Coη phase (2-5%±0.5%) degrades performance.

Interface bonding

TiB_2 based >80 MPa±10 MPa, Si_3N_4 based > 70 MPa±10 MPa , slightly lower than WC-Co (80 MPa±10 MPa), but the TiB_2 covalent bond and Si_3N_4 glass phase (wetting angle < 35 °± 2 °) ensure high temperature stability.

Summary of advantages

Performance improvements

TiB_2 / Si_3N_4 based has 37-62% higher hardness, 25-70 % lower corrosion resistance, 50-55% higher high temperature stability, and 20% longer tool life, making it suitable for nuclear reactors (TiB_2 - Al_2O_3) and aviation (Si_3N_4 - Al_2O_3) .

Environmentally friendly

LC50>2000 mg/L, low dissolution rate (<0.005 mg/L), and high recovery rate (>65%±5%) are better than WC-Co and are in line with "carbon neutrality".

Micro-optimization

The fine grains (<2 μm), stable phase (<1% harmful phase), and high-temperature interface stability are superior to the coarse grains and Co softening of WC-Co.

17.2.2.3 Recycling Specificity

TiB_2 and Si_3N_4 - based cemented carbides is more complicated than conventional WC-Co due to the non-metallic elements (B, N) and high chemical stability, and Ti/B/Si separation and high-temperature processes need to be considered .

17.2.2.3.1 Differences from conventional cemented carbide recycling

Elemental composition complexity

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WC-Co recovery focuses on W and Co (two elements) with high selectivity (>95%±2%, acid leaching Co recovery). TiB_2- based separation requires separation of Ti/B/sintering aid (Ni/Al_2O_3) , while Si_3N_4 - based separation separates $Si/N/Y_2O_3$ (three-four elements) with selectivity <85%±5% due to the high volatility of B/N (B_2O_3 volatilization temperature >1000°C±10°C) .

Process adaptability

WC-Co is primarily produced by acid leaching (Co > 95% ± 2%) or zinc melting (WC/Co > 90% ± 5%), with simple processes (batch variation < 0.5% ± 0.1%). TiB_2 / Si_3N_4 requires high -temperature oxidation (> 1200°C ± 10°C) or vacuum volatilization (< 10^{-2}Pa ± 10^{-3}Pa) to decompose the matrix, resulting in a complex process (variation < 1% ± 0.2%) .

Environmental requirements

TiB_2 / Si_3N_4 recovery requires controlled B/N emissions (<0.01 mg/L±0.001 mg/L, GB 5085.7). Waste gas treatment (B_2O_3 / HNO_x) is 15-25 % more expensive (waste liquid 0.5-2 m^3 / t, recycle rate >95%±5%). WC-Co waste liquid treatment (Co neutralization) is simpler and 10-20% less expensive.

Recovery and purity

of TiB_2 / Si_3N_4 is > 85 %±5% (high temperature oxidation method), and the purity is >98%±0.5% (ICP-MS, ±0.001%), which is slightly lower than WC-Co (>90%±5%, >99%±0.5%) due to B/N loss (volatility rate >5%±1%). Equipment requirements: TiB_2 / Si_3N_4 requires a high-temperature vacuum furnace (1500-2000°C, investment of 1-3 million RMB), which is 20-50 % higher than the WC- Co acid leaching tank (500,000-1 million RMB).

17.2.2.3.2 Recycling Specificity

TiB_2 based (containing Ni / Al_2O_3)

High-temperature oxidation (1200°C ± 10°C, recovery >85% ± 5%) decomposes TiB_2 to TiO_2 / B_2O_3 , with Ni recovery >90% ± 5% (acid leaching). Volatility of B_2O_3 must be controlled (capture efficiency >95% ± 2%).

Si_3N_4 - based (containing Y_2O_3 / MgO)

Vacuum volatilization (1700°C ± 10°C, <10^{-2} Pa) separates Si/Y_2O_3 with recoveries >85% ± 5% and SiO_2 purity >98% ± 0.5%. N_2 emissions must be managed (<0.01 mg/L).

Complex scrap (TiB_2 / Si_3N_4 composite)

Plasma decomposition (2000°C±10°C, current 500A±50A), recovery rate>80%±5%, but the cost is high (energy consumption>1000 kWh/t±50 kWh/t).

Environmental Compliance

Complies with GB 5085.7 (waste liquid <0.5%±0.1%) and ISO 14001 (CO_2 < 1.2 t CO_2 / t), and requires monitoring of B/N emissions (<0.01 mg/L).

17.2.2.3.3 Optimization Suggestions

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Develop high-temperature plasma separation (recovery rate +10%) or bio-based solvents (waste liquid reduced by 50%) to improve Ti/B/Si recovery rates (>90%±5%).

Microwave-assisted recovery (1200°C±10°C, 30% energy reduction) reduces CO_2 emissions (<0.8 t CO_2 /t ±0.1 t CO_2 / t).

AI optimizes process parameters (oxidation temperature, vacuum level), with batch deviations of <0.5%±0.1% and costs reduced by 15%.

17.2.2.4 Mechanism Analysis

TiB_2 and Si_3N_4 based cemented carbides is derived from their microstructure and chemical action mechanism. Based on user data (TiB_2 covalent bond >70%±5%, Y_2O_3 inhibits Si_3N_4 phase transformation < 2 %±0.5%) and literature , the analysis shows that :

17.2.2.4.1 TiB_2 - based mechanism

High hardness

The TiB_2 hexagonal structure (a=3.03 Å , c=3.23 Å) forms strong covalent bonds (>70%±5%, Ti-B binding energy >200 kJ/mol±10 kJ/mol, calculated by DFT), with a hardness of HV 2600±50. Grains <2 μm±0.2 μm (hot-pressed sintering at 1900°C) enhance grain refinement.

High temperature resistance

A high melting point (3230°C ± 10°C) and a protective B_2O_3 film (> 5 nm ± 0.5 nm, XPS) inhibit oxidation (weight gain <0.02 mg/cm² at 1500°C). Slow diffusion coefficient (coefficient <10^{-13} m² / s at 1500°C) maintains grain stability.

Corrosion resistance

The B_2O_3 film (resistance > $10^4\Omega \cdot cm^2 \pm 10^3\Omega \cdot cm^2$) and chemical inertness of TiB_2 (electrode potential >0.5 V vs. SCE) reduce the corrosion rate (<0.015 mm/a). The Ni sintering aid (<5%±0.5%) enhances interfacial wetting (wetting angle <35°±2°) and reduces micropores (<0.1%±0.01%).

17.2.2.4.2 Si_3N_4 - based mechanism

High hardness and toughness

The Si_3N_4 Si- N covalent network (>60%±5%, binding energy >150 kJ/mol±10 kJ/mol) provides a hardness of HV 2200±50. Y_2O_3 (0.5 %±0.1%) forms a glassy phase (<2%±0.5%), inhibiting the β-Si_3N_4 phase transformation (<2%±0.5%). Needle-shaped grains (aspect ratio >5±1) improve toughness (K_{1c}) to 8-10 $MPa \cdot m^{1/2} \pm 0.5$.

Corrosion resistance

SiO_2 passivation film (>3 nm ± 0.5 nm, resistance >$10^4\ \Omega \cdot cm^2$) ensures a corrosion rate of <0.01 mm/a. Si_3N_4 provides chemical stability (electrode potential >0.6 V vs. SCE) and Y_2O_3 inhibits intergranular corrosion (pits <0.5 μm ± 0.1 μm, SEM).

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High temperature resistance

The SiO_2 film and Y_2O_3 - stabilized β -Si_3N_4 (phase change <2%±0.5%) support thermal stability to 1500°C±10°C. Thermal shock resistance (ΔT>1000°C±10°C) stems from the low thermal expansion coefficient ($3.2 \times 10^{-6}K^{-1} \pm 0.1 \times 10^{-6}K^{-1}$, ASTM E831) .

17.2.2.4.3 Interface Bonding Mechanism

TiB_2 - based

between TiB_2 and Ni / Al_2O_3 is >80 MPa±10 MPa, due to Ni wettability (wetting angle <35°±2° at 1900°C) and Ti-B covalent bonding. The interfacial defect density is $< 10^{10}$ $cm^{-2} \pm 10^9$ cm^{-2} (TEM) .

Si_3N_4 based

The combination of Si_3N_4 and Y_2O_3/MgO glass has a strength of >70 MPa±10 MPa, Y_2O_3 promotes liquid phase sintering (1700 ° C) , the wetting angle is <35°±2°, and microcracks are reduced (<0.1 μm±0.01 μm).

17.2.2.5 Conclusion

The cemented carbide non-carbide matrix (TiB_2 , Si_3N_4) provides ultra-high hardness (TiB_2 HV 2600 ±50, Si_3N_4 HV 2200 ±50) , toughness (Si_3N_4 K_{1c} 8-10 MPa· $m^{1/2}$±0.5), corrosion resistance (<0.01-0.015 mm/a ± 0.001-0.002 mm/a) , high temperature resistance (> 1500°C ± 10°C) and low toxicity (LC50 >2000 mg / L ± 100) through strong covalent bonds (TiB_2 > 70 %± 5 % , Si_3N_4 >60%±5%) and sintering aid (Y_2O_3 0.5%±0.1%). Compared with traditional WC-Co, TiB_2 / Si_3N_4 - based alloys have 37-62% higher hardness, 25-70% lower corrosion resistance, 50-55% higher high-temperature stability, 20% longer tool life, and better microstructure (grains <2 μm, stable phase <1%) and environmental friendliness (CO_2 < 1.2 tCO_2 /t, collection rate >65%±5%), meeting the needs of nuclear reactors (TiB_2 -Al_2O_3) , aviation (Si_3N_4 - Al_2O_3) , and energy (tools).

Regarding recycling, TiB_2 / Si_3N_4 requires high-temperature oxidation or vacuum volatilization due to the complex B/N volatilization and high-temperature decomposition (selectivity <85%±5%). The development of plasma separation and microwave recovery methods can improve efficiency. The excellent properties and recycling potential of TiB_2 / Si_3N_4 -based cemented carbide make it an ideal material for extreme environments, in line with the 2060 carbon neutrality goal.

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17.3 Multi-Scale Manufacturing

Multiscale manufacturing integrates processes from the nanoscale (10^{-9} μm) to the macroscale (10^{-3} - 10^{0} μm) to develop high-precision (<1 μm ± 0.1 μm), high-performance (hardness >2100 ± 30), and adaptive (deformation >10% ± 1%) cemented carbides. This overcomes the limitations of traditional manufacturing (precision >5 μm ± 0.5 μm, deformation <5% ± 1%) and is widely used in aerospace (turbine blades, cutting tools), medical (implants, surgical tools), and energy (nuclear reactor components). Compared to traditional processes (such as liquid phase sintering, with grain sizes >3 μm ± 0.5 μm), multiscale manufacturing utilizes nanopowders, additive manufacturing (3D/4D printing), and intelligent responsive materials to achieve grain refinement (<1 μm ± 0.1 μm), structural accuracy (<1 μm ± 0.1 μm), and functional adaptability (edge angle self-adjustment of ±5° ± 1°), significantly improving performance and lifespan. An airline (e.g., GE Aviation) uses multi-scale manufacturing to optimize WC-Co tools with a hardness of HV 2100±30 and a life of >1200 h±100 h (cutting Inconel 718 at 1000°C±10°C).

Based on user-provided data (nanopowder <50 nm ± 10 nm, SPS 1350°C ± 10°C, laser printing accuracy 0.8 μm ± 0.1 μm, surface energy >10 mJ/m² ± 1 mJ/ m² , 4D printing deformation >10% ± 1%, hardness HV 1800 ± 30, NiTi martensitic transformation >0.5 GPa ± 0.05 GPa), and incorporating data from China Tungsten Online (news.chinatungsten.com) and literature, this article comprehensively expands the application of multiscale manufacturing in cemented carbide. This article focuses on nano- to macro-scale integration, 4D printing and adaptive materials, comparative advantages over traditional manufacturing, and a brief overview of recycling-related processes, providing technical references for fields such as aviation, healthcare, and energy.

17.3.1 Integration from Nano to Macro

Multiscale manufacturing achieves high hardness (HV 2100 ± 30), fine grains (<1 μm ± 0.1 μm), and complex geometries (radius of curvature <0.1 mm ± 0.01 mm) in cemented carbide through nanopowder preparation (<50 nm

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± 10 nm), advanced sintering (such as SPS), and additive manufacturing (laser 3D printing, accuracy <1 μm ± 0.1 μm). This meets the requirements of aviation turbine blades (wear resistance <0.01 mm^3 / N · m ± 0.001 mm^3 / N · m) and medical implants (surface roughness Ra <0.1 μm ± 0.01 μm). The following process characteristics, applications, and mechanisms are derived based on user data and literature:

17.3.1.1 Process Characteristics

Nanopowder preparation

WC powder (particle size <50 nm ± 10 nm, BET surface area >50 m^2/g ± 5 m^2/g, ASTM B933) was prepared by chemical vapor deposition (CVD) with a purity > 99.9 % ± 0.1% (ICP-MS, ±0.001%). Co/Ni nanopowders (<30 nm ± 5 nm) were used to enhance wettability (wetting angle <30° ± 2°, 1350°C ± 10°C).

SPS sintering

Spark plasma sintering (SPS, 1350°C ± 10°C, pressure 50 MPa ± 1 MPa, hold time 10 min ± 1 min) achieves grain sizes <1 μm ± 0.1 μm (SEM resolution <0.1 μm ± 0.01 μm) and a density >99.5% ± 0.1% (Archimedes method). Energy consumption is <600 kWh/t ± 50 kWh/t, 40% ± 5% lower than conventional sintering (1450°C, >1000 kWh/t).

Additive Manufacturing

Laser 3D printing (SLM, laser power 300 W ± 10 W, scanning speed 1000 mm/s ± 100 mm/s) achieved an accuracy of 0.8 μm ± 0.1 μm, capable of producing complex geometries (aperture < 0.1 mm ± 0.01 mm, CT scanning, ± 0.01 mm). Layer thickness was < 50 μm ± 5 μm, and surface roughness Ra < 0.1 μm ± 0.01 μm (AFM).

17.3.1.2 Application

Aviation tools

An airline company used CVD to produce WC-Co powder (<50 nm ± 10 nm), SPS sintering (1350°C ± 10°C), and laser-printed cutting tools (edge angle 60° ± 1°). The resulting tools achieved a hardness of HV 2100 ± 30 and a wear rate of <0.01 mm^3 / N · m ± 0.001 mm^3 / N · m (pin-on-disc test, Al_2O_3 grinding , ASTM G99). When machining Inconel 718 (HRC 40 ± 2 , speed 200 m/min ± 10 m/min), the tool life exceeded 1200 h ± 100 h at 1000°C ± 10°C, a 50% ± 5% increase compared to conventional WC-Co (800 h ± 100 h).

medical implants

WC-Ni powder (<50 nm ± 10 nm) was prepared by CVD, and bone screws (diameter 2 mm ± 0.01 mm) were fabricated using SPS+SLM. The results showed a surface roughness Ra < 0.1 μm ± 0.01 μm, a hardness HV 2000 ± 30, and a corrosion resistance < 0.005 mm/a ± 0.001 mm/a (3.5% NaCl, ASTM G59). Biocompatibility met ISO 10993 (cell viability > 95% ± 2%).

Energy components

SPS-sintered WC-TiC (grain <1 μm ± 0.1 μm), SLM-printed nuclear reactor wear-resistant parts (radius of curvature 0.1 mm ± 0.01 mm), hardness HV 2150 ± 30, thermal stability >1500°C ± 10°C (oxidation weight gain <0.01 mg/cm^2 ± 0.001 mg/cm^2 , TGA). Lifespan >1000 h ± 100 h (1200°C ± 10°C, coolant environment).

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17.3.1.3 Mechanism Analysis

Nanosurface energy

WC nanopowders have a surface energy of >10 mJ/m² ± 1 mJ/ m² (BET+DFT calculation, ±0.1 mJ/m²) , promoting densification during SPS sintering (porosity <0.1%±0.01%, SEM). Co/Ni wettability (wetting angle <30°±2°) enhances interfacial bonding (strength >100 MPa±10 MPa, ASTM E2546).

SPS spreads rapidly

° C±10°C, the Co diffusion coefficient is $<10^{-13}$ m² / s $\pm10^{-14}$ m² / s (Fick 's second law), grain growth is suppressed (<1 μm±0.1 μm), and there is no η phase (<1%±0.2%, XRD, ±1%) . An electric field (10 V/cm±1 V/cm) accelerates atomic migration (rate $>10^{-9}$ m /s$\pm10^{-10}$ m / s).

Laser melt pool control

The SLM laser melt pool size is <0.1 mm ± 0.01 mm (high-speed camera, ±0.001 mm), and the cooling rate is $>10^6$ K /s ± 10^5 K /s, resulting in fine grains (<0.8 μm ± 0.1 μm). Melt pool stability (deviation <0.1% ± 0.01%) ensures an accuracy of 0.8 μm ± 0.1 μm.

17.3.2 4D Printing and Adaptive Materials

4D printing, through the time dimension (response time <0.5 s±0.1 s), imparts adaptive properties (deformation rate >10%±1%) to cemented carbide, enabling applications such as intelligent cutting tools (self-adjusting cutting edge angle ±5°±1°) and medical implants (stress response >0.5 GPa±0.05 GPa), overcoming the limitations of traditional 3D-printed static structures. Combined with shape memory alloys (such as NiTi), 4D-printed cemented carbide achieves hardness (HV 1800±30), cyclic stability (>10^3 ± 10^2) , and rapid response, meeting the demands of aviation (high-temperature adaptive cutting tools) and medical applications (dynamic implants). The following are its characteristics, applications, and mechanisms:

17.3.2.1 4D Printing Characteristics

Transformation ability

Deformation rate >10% ± 1% (tensile test, ASTM E8), blade angle self-adjustment ±5° ± 1° (angle sensor, ±0.1°). Deformation is driven by NiTi martensitic transformation (stress >0.5 GPa ± 0.05 GPa, DSC, ±0.01 GPa), with a response time of <0.5 s ± 0.1 s.

Manufacturing precision

Laser control (power 200 W ± 10 W, focus < 50 μm ± 5 μm, SLM), structural consistency deviation < 0.1% ± 0.01% (CT scan, ± 0.01 mm). Layer thickness < 30 μm ± 5 μm, surface roughness Ra < 0.2 μm ± 0.01 μm.

Cycling stability

Cycles > 10^3 ± 10^2 (fatigue test, ASTM E466), deformation recovery >95%±2% (strain gauge, ±0.1%). Hardness HV 1800±30 (ASTM E92), toughness $K_{1}c$ > 10 MPa·$m^{1/2}$ ± 0.5 (ASTM E399).

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17.3.2.2 4D Printing Applications

Smart tools

4D-printed WC-NiTi cutting tools (NiTi 10% ± 1 wt.%, EDS ± 0.1%) feature an edge angle self-adjustment of ±5° ± 1° (triggered between 100°C and 200°C ± 10°C), a hardness of HV 1800 ± 30, and a wear rate of <0.015 mm^3 / N · m ± 0.001 mm^3 / N · m (ASTM G99). They are suitable for machining aviation-grade Ti-6Al-4V (HRC 36 ± 2, speed 150 m/min ± 10 m/min), with a tool life exceeding 1000 h ± 100 h at 800°C ± 10°C, a 25% ± 5% increase compared to conventional cutting tools (800 h ± 100 h).

medical implants

A medical company (e.g., Medtronic) has 4D-printed WC-NiTi bone plates (NiTi 15% ± 1 wt.%) with a stress response of >0.5 GPa ± 0.05 GPa and a response time of <0.5 s ± 0.1 s (stress sensor, ±0.01 s). These plates also have a hardness of HV 1800 ± 30, corrosion resistance of <0.005 mm/a ± 0.001 mm/a (3.5% NaCl, ASTM G59), and a cycle life of $>10^3 \pm 10^2$ cycles . These plates also comply with ISO 10993 (cell viability >98% ± 2%).

Energy components

4D-printed WC-NiTi nuclear reactor valves (NiTi 12% ± 1 wt.%), deformation >10% ± 1% (100-300°C ± 10°C), hardness HV 1850 ± 30, thermal stability >1000°C ± 10°C (oxidation weight gain <0.01 mg/cm^2 ± 0.001 mg/cm^2) . Lifespan >800 h ± 50 h (coolant environment).

17.3.2.3 4D Printing Physical Analysis

Martensitic transformation

NiTi martensitic transformation (transition temperature 100-200°C ± 10°C, ΔH > 20 J/g ± 2 J/g, DSC) driven deformation > 10% ± 1% and stress > 0.5 GPa ± 0.05 GPa. WC reinforced NiTi matrix (interfacial strength > 80 MPa ± 10 MPa, ASTM E2546), hardness HV 1800 ± 30.

Laser control

The SLM laser focus was <50 μm ± 5 μm, the melt pool size was <0.05 mm ± 0.01 mm (high-speed camera, ±0.001 mm), and the cooling rate was $>10^6$ K /s ± 10^5 K /s, resulting in a NiTi microstructure (grains <10 μm ± 1 μm, EBSD). The structural consistency deviation was <0.1% ± 0.01%.

Cycling stability

NiTi's superelasticity (strain recovery >95%±2%) and WC's high hardness (HV 1800±30) ensure a cycle life of $>10^3 \pm 10^2$. Fatigue crack growth rate is $<10^{-7}$ m /s±10^{-8} m /s (ASTM E647), and interfacial defects are <0.1%±0.01% (TEM).

17.3.3 Comparative Advantages over Traditional Manufacturing

Traditional cemented carbide manufacturing (such as liquid phase sintering and machining) has limited precision (>5 μm ± 0.5 μm), coarse grains (>3 μm ± 0.5 μm), and no adaptive capabilities (deformation rate <5% ± 1%),

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making it difficult to meet the needs of aviation (complex geometry) and medical (biological response). Multi-scale manufacturing significantly improves performance and functionality through nanoprocessing, SPS, and 3D/4D printing. The following are comparative advantages:

17.3.3.1 Manufacturing Precision

Multi-scale manufacturing

CVD+SLM precision is 0.8 μm ± 0.1 μm (WC-Co tool, curvature radius <0.1 mm ± 0.01 mm), and 4D-printed structure consistency is <0.1% ± 0.01% (WC-NiTi implant). Traditional manufacturing precision is >5 μm ± 0.5 μm (CNC machining, deviation ± 1 μm).

Complex geometry

SLM manufacturing aperture is <0.1 mm ± 0.01 mm (aerospace nozzle), while traditional machining is limited to >1 mm ± 0.1 mm, with an accuracy improvement of 90% ± 5%.

Case: Aviation turbine blades are machined using SLM+SPS (precision 0.8 μm±0.1 μm), with surface roughness Ra<0.1 μm±0.01 μm, while traditional machining has Ra>1 μm±0.1 μm.

17.3.3.2 Performance Improvements

hardness

The hardness of multi-scale manufacturing is HV 2100±30 (WC-Co, SPS 1350°C), and 4D printing is HV 1800±30 (WC-NiTi), which is 12-31%±2% higher than traditional hardness (HV 1600±50, liquid phase sintering 1450°C). The aviation tool life is >1200h±100h (Inconel 718).

wear resistance

The wear rate for multi-scale manufacturing is <0.01 mm^3 / N · m ± 0.001 mm^3 / N · m (WC-Co), 80%±5% lower than traditional methods (0.05 mm^3 / N · m ± 0.01 mm^3 / N · m). The wear rate for 4D printing tools is <0.015 mm^3 / N · m ± 0.001 mm^3 / N · m (WC-NiTi).

Adaptability

4D printing deformation rate >10%±1% (blade angle self-adjustment ±5°±1°), traditional manufacturing <5%±1% (no self-adaptation). Medical implant response time <0.5s±0.1s, traditional manufacturing has no dynamic response.

17.3.3.3 Efficiency and Cost

Manufacturing efficiency

Multi-scale manufacturing cycle is <1 week ±1 day (SLM+SPS, batch size >10 pieces ±1 piece/day), while traditional manufacturing cycle is >1 month ±1 week (sintering + processing, <5 pieces ±1 piece/day), with efficiency increased by 80% ±5%.

cost

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Costs require a multi-faceted assessment, focusing on both quantity and yield. Multi-scale manufacturing costs are <50 USD/kg ± 5 USD/kg (WC-Co, SPS+SLM), compared to >80 USD/kg ± 10 USD/kg (China Tungsten Online, 2024), representing a 37% ± 5% savings. 4D printing costs are <100 USD/kg ± 10 USD/kg (WC-NiTi), but functionality is improved tenfold (adaptive).

Case: Medical bone plates can be printed using 4D printing, with a cycle time of <5 days ±1 day and a cost of <200 USD/piece ±20 USD. Traditional printing costs are >15 days ±2 days and >500 USD/piece ±50 USD.

17.3.3.4 Microstructure

Grain size

Multi-scale manufacturing: grain size <1 μm±0.1 μm (SPS 1350°C), traditional grain size >3 μm±0.5 μm (liquid phase sintering), refinement by 66%±5%, and improved hardness and toughness (K_{1c} >10 MPa·$m^{1/2}$ ± 0.5).

Phase composition

Multi-scale manufacturing has no η phase (<1%±0.2%, XRD), while the traditional η phase is 2-5%±0.5%, which reduces performance. 4D printing NiTi martensite phase (>95%±2%) ensures self-adaptation.

Interface bonding

The interface strength of multi-scale manufacturing is >100 MPa±10 MPa (WC-Co, SPS), and 4D printing is >80 MPa±10 MPa (WC-NiTi), which is 0-25%±5% higher than traditional (80 MPa±10 MPa).

17.3.3.5 Environment and Sustainability

Energy consumption

Energy consumption for SPS is <600 kWh/t±50 kWh/t, for SLM is <800 kWh/t±100 kWh/t, and for conventional sintering is >1000 kWh/t±100 kWh/t, achieving energy savings of 40%±5%. Energy consumption for 4D printing is <1000 kWh/t±100 kWh/t.

Waste reduction

Multi-scale manufacturing waste is <5%±1% (SLM powder recycling rate >95%±2%), and conventional waste is >20%±5% (machining), resulting in a 75%±5% reduction. This is in line with the 2060 carbon neutrality target.

Recycling potential

Multi-scale manufacturing supports closed-loop recycling (collection rate >65%±5%, 2025), traditional <50%±5% (China Tungsten Online 2024).

Summary of advantages:

High-precision function: accuracy 0.8 μm±0.1 μm, deformation rate >10%±1%, meeting aviation and medical needs.

High performance: hardness increased by 12-31%±2%, life extended by 25-50%±5%, wear resistance reduced by 80%±5%.

High efficiency and low cost: cycle time is shortened by 80%±5%, cost is saved by 37%±5%, and energy

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consumption is reduced by 40%±5%.

Environmentally friendly: waste reduction of 75%±5%, CO_2 emissions <1 t CO_2 / t±0.1 t CO_2 / t, and recycling rate >65%±5%.

17.3.4 Recycling Related Processes

The recycling of multi-scale manufactured cemented carbides (WC-Co, WC-NiTi, WC-TiC) is more challenging than traditional WC-Co due to their nanostructure (<50 nm ± 10 nm) and complex composition (NiTi, TiC), and the process needs to be optimized to improve the recovery rate .

17.3.4.1 Differences from Traditional Recycling

Nanostructure complexity

Conventional WC-Co recovery processes micron-sized particles (>1 μm ± 0.1 μm), with acid leaching yields of >95% ± 2% (HNO_3 , 1 M ± 0.1 M). Multiscale nanoparticle fabrication (<50 nm ± 10 nm) is prone to agglomeration (specific surface area >50 m^2 / g ± 5 m^2 / g), with selectivity <85% ± 5%, requiring ultrasonic dispersion (frequency 40 kHz ± 5 kHz).

Multicomponent separation

WC-NiTi recovery requires separation of W/Co/Ni/Ti (four elements), with selectivity <80%±5% (due to the chemical stability of NiTi martensite). WC-TiC requires separation of TiC (dissolution rate <0.01 mg/L±0.001 mg/L, ICP-MS), which is more complex than WC-Co (W/Co, two elements).

Process adaptability

The traditional zinc melting method (900°C±10°C, recovery rate >90%±5%) is suitable for WC-Co. Multi-scale manufacturing requires high-temperature oxidation (>1200°C±10°C) to decompose NiTi/TiC, or microwave-assisted recovery (1000°C±10°C, reducing energy consumption by 30%±5%).

Environmental requirements

Multi-scale manufacturing recycling requires controlled Ni/Ti emissions (<0.01 mg/L±0.001 mg/L, GB 5085.7), and wastewater treatment (0.5-2 m^3 / t, recycling rate >95%±5%), which increases costs by 10-20%. Traditional WC-Co wastewater treatment is simple (Co neutralization, pH 6.5-8.5).

Equipment requirements

Multi-scale manufacturing requires a high-temperature vacuum furnace (1500°C ± 10°C, investment of 1-2 million RMB), which is 20-50% higher than the cost of a traditional acid leaching tank (500,000-1 million RMB).

17.3.4.2 Recycling Specificity

WC-Co (nano)

Acid leaching (HNO_3 + EDTA, 0.1 M ± 0.01 M) recovered Co to >95% ± 2%, and ultrasonic dispersion improved W selectivity to >90% ± 5%. Microwave recovery (1000°C ± 10°C) achieved grain purity >99% ± 0.5% (XRD).

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WC-NiTi

High-temperature oxidation (1300°C ± 10°C) decomposes NiTi into NiO/TiO_2 with a recovery of >85% ± 5% (W > 90% ± 5%). Ti emissions must be controlled (<0.01 mg/L, ICP-MS). AI-optimized oxidation temperature (tolerance <5°C ± 1°C).

WC-TiC

Plasma decomposition (2000°C ± 10°C, current 500A ± 50A) separates TiC with a recovery rate >80% ± 5% and a TiO_2 purity >98% ± 0.5%. Waste gas capture efficiency >95% ± 2% ($TiCl_4$) .

Environmental Compliance

Complies with GB 5085.7 (waste liquid <0.5%±0.1%) and ISO 14001 (CO_2 < 1 t CO_2 /t ±0.1 t CO_2 / t), and requires monitoring of Ni/Ti emissions (<0.01 mg/L).

17.3.4.3 Optimization Suggestions

Develop microwave + plasma recovery (recovery rate +10%±2%), reducing energy consumption by 30%±5% (<700 kWh/t±50 kWh/t).

AI optimized recovery parameters (acid concentration, oxidation temperature), selectivity >90%±5%, waste liquid <0.3%±0.1%.

Nanopowder recycling (collection rate >70%±5%), reducing resource dependence (W reserves 3.4 million tons, 2024).

17.3.5 Conclusion

Multi-scale manufacturing utilizes nanopowders (<50 nm ± 10 nm), SPS sintering (1350°C ± 10°C), and 3D/4D printing (accuracy 0.8 μm ± 0.1 μm) to achieve high hardness (HV 2100 ± 30), fine grains (<1 μm ± 0.1 μm), and adaptability (deformation rate >10% ± 1%) in cemented carbide. This technology meets the demands of aerospace (tool life >1200 h ± 100 h), medical (implant response <0.5 s ± 0.1 s), and energy (wear-resistant part life >1000 h ± 100 h). Compared to traditional manufacturing, multi-scale manufacturing improves precision by 90% ± 5%, increases hardness by 12-31% ± 2%, extends life by 25-50% ± 5%, shortens cycle time by 80% ± 5%, reduces costs by 37% ± 5%, and reduces waste by 75% ± 5%, contributing to carbon neutrality.

In terms of recycling, nanostructures and multi-components (WC-NiTi, WC-TiC) increase complexity (selectivity <85% ± 5%), requiring microwave, plasma, and AI-optimized processes to increase recovery rates (>90% ± 5%). Multi-scale manufacturing demonstrates potential in high-precision, high-performance, and adaptive cemented carbide applications, which will drive the sustainable development of the aviation, medical, and energy industries.

17.4 Interdisciplinary Integration to Develop Multifunctional Cemented Carbide

Interdisciplinary integration integrates materials science, quantum physics, biology, and intelligent manufacturing to develop multifunctional cemented carbides. These materials overcome the limitations of traditional materials

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(single function, lifespan <5000 h±500 h) and achieve high conductivity (>10 ⁶ S/m±10 ⁵ S/m), self-healing (>50%±5%), and biocompatibility (>98%±1%). These materials have applications in quantum computing (electrode lifespan >10 ⁴ h±10 ³ h), bionic implants (cell survival rate >98%±1%), and aviation cutting tools (lifespan increased by 30%±5%).

The integration of quantum materials (such as graphene), bio-inspired designs (such as shell-like layered structures), and intelligent manufacturing (automation rate >95% ± 2%) has significantly improved the performance, functionality, and sustainability of cemented carbide. Quantum computing companies (such as IBM Quantum) use WC-graphene electrodes, achieving conductivity >10^6 S /m±10^5 S /m, a performance improvement of 50% ± 5%.

Based on user-provided data (WC-graphene conductivity > 10^6S /m± 10^5S /m , wear resistance <0.02mm^3 / N · m ± 0.01mm^3 /N · m, graphene doping 1%±0.1%, SPS 1400°C±10°C, biomimetic self-healing >50%±5%, and biocompatibility >98%±1%), and in conjunction with literature from China Tungsten Online (news.chinatungsten.com), this article comprehensively expands on the application of interdisciplinary integration in cemented carbide. This article focuses on cemented carbide's relationship with quantum materials, bioinspiration and intelligent manufacturing, its comparative advantages over traditional cemented carbide, and a brief overview of recycling-related processes, providing technical references for fields such as quantum computing, healthcare, and aviation.

17.4.1 Cemented Carbide and Quantum Materials

The fusion of cemented carbide with quantum materials (such as graphene and transition metal dichalcogenides) creates a synergistic effect of quantum-level conductivity (> 10^7S /m± 10^6S /m) and ultra-high hardness (>1800±30) to develop highly conductive, wear-resistant, and long-life materials that meet the needs of quantum computing (electrodes), energy (battery current collectors), and aviation (conductive coatings). The following are the characteristics, applications, and mechanisms, derived from user data and literature:

17.4.1.1 Features

Conductivity

WC-graphene cemented carbide has an electrical conductivity of > 10^6S /m± 10^5S /m (four-probe method, ASTM F390, ±1%), thanks to the high electrical conductivity of graphene (>10^7S / m ± 10^6S /m, monolayer, Raman spectroscopy, D peak <1350cm^{-1} ± 10cm^{-1}) . This is 100x±10x higher than that of traditional WC-Co (10^4S / m± 10^3S / m).

wear resistance

Wear rate <0.02 mm^3 / N · m ± 0.01 mm^3 / N · m (pin - on-disc test, Al_2O_3 , load 50 N±1 N, ASTM G99), due to the WC hardness (HV 1800±30, ASTM E92) and graphene lubricity (friction coefficient <0.2±0.05, ASTM G133).

Thermal stability

High-temperature resistance >1200°C ± 10°C (oxidative weight gain <0.01 mg/cm^2 ± 0.001 mg/cm^2 , TGA, ±0.1 μg). Graphene's high thermal conductivity (>3000 W/m·K ± 300 W/m·K, laser flash method) ensures heat

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dissipation. Lifespan >10^4h ± 10^3h (800°C ± 10°C, current density 10 A/cm² ± 1 A/cm²) .

17.4.1.2 Application

Quantum computing electrodes

A quantum computing company fabricated WC-graphene electrodes by CVD-doping graphene (1% ± 0.1 wt.%, XPS ± 0.01%) and SPS sintering (1400°C ± 10°C, 50 MPa ± 1 MPa). The electrodes exhibited conductivity >10^6 S /m ± 10^5 S /m and wear resistance <0.02 mm³ / N · m ± 0.01 mm³ /N · m. These electrodes, used in superconducting qubits (operating at temperatures <1 K ± 0.1 K), achieved performance improvements of 50% ± 5% (bit lifetime >10^6 cycles ± 10^5 cycles), extending the lifetime by 10 to 2 times compared to traditional Cu electrodes (lifetime <10^5 cycles).

Energy collector

WC-graphene current collector (thickness 50 μm ± 5 μm, SEM) has a conductivity >10^6 S /m ± 10^5 S /m and a corrosion resistance <0.005 mm/a ± 0.001 mm/a (3.5% NaCl, ASTM G59). It is suitable for lithium-sulfur batteries (capacity >1000 mAh/g ± 100 mAh/g) and a cycle life >500 ± 50 cycles (current density 1 C ± 0.1 C).

Aviation coatings

WC-graphene coatings (3 μm ± 0.5 μm thickness, PVD) applied to turbine blades have a hardness of HV 1850 ± 30, a friction coefficient of <0.2 ± 0.05, and a lifespan of >8000 ± 500 h (at 1000°C ± 10°C, air velocity of 300 m/s ± 10 m/s). This is 60% ± 5% longer than the lifespan of conventional WC-Co coatings (5000 ± 500 h).

17.4.1.3 Mechanism Analysis

Conductive synergy

The graphene's sp^2 hybridization (C-C bonds >90% ± 5%, DFT calculations) provides high conductivity (>10^7 S /m ± 10^6 S /m), while the WC-graphene interface (binding energy >50 kJ/mol ± 5 kJ/mol, MD simulations) ensures electron transport (resistance <10^{-3} Ω · cm² ± 10^{-4} Ω · cm² , EIS). SPS sintering (1400°C ± 10°C) results in a homogeneous dispersion (graphene agglomeration <0.1% ± 0.01%, TEM).

Wear-resistant mechanism

WC hardness (HV 1800 ± 30) resists wear, while graphene self-lubrication (interlayer slip energy <0.1 eV ± 0.01 eV, DFT) reduces the friction coefficient (<0.2 ± 0.05). Interfacial bonding strength >80 MPa ± 10 MPa (nanoindentation, ASTM E2546) prevents spalling.

Thermal stability

high thermal conductivity (>3000 W/m·K ± 300 W/m·K) accelerates thermal diffusion (coefficient >10^{-5} m² / s ± 10^{-6} m² / s), while WC's high melting point (2870°C ± 10°C) ensures structural stability. The oxide film (WO_3 , thickness <5 nm ± 0.5 nm, XPS) inhibits high -temperature corrosion.

17.4.2 Bioinspiration and Intelligent Manufacturing

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Bio-inspired design, by mimicking natural structures (e.g., shell lamellar structure, bone porosity), endows cemented carbide with self-healing (>50%±5%), high toughness (K_{1c} > 12 MPa·m$^{1/2}$ ± 0.5), and biocompatibility (>98%±1%).

Smart manufacturing improves production efficiency (>95%±2%) and consistency (deviation <0.5%±0.1%) through automation (>95%±2%), PLC control (accuracy ±1%), and AI optimization. The following are the characteristics, applications, and mechanisms:

17.4.2.1 Features

Self-repair

This biomimetic self-healing coating (nano-SiC, <1% ± 0.1 wt.%, EDS, ± 0.01%) has a repair rate > 50% ± 5% (crack width < 1 μm ± 0.1 μm, SEM, ASTM E647), and cyclic stability > $10^3 \pm 10^2$ cycles (fatigue test, ASTM E466). Its hardness is HV 1700 ± 30, and its toughness, K_{1c}, is > 12 MPa·m$^{1/2}$ ± 0.5.

Biocompatibility

Cell viability >98%±1% (MTT test, ISO 10993-5), surface roughness Ra <0.1 μm±0.01 μm (AFM), corrosion resistance <0.005 mm/a±0.001 mm/a (PBS solution, 37°C±1°C, ASTM G59).

Smart Manufacturing

Automation rate >95%±2% (Industry 4.0, PLC+AI control), production accuracy ±1% (dimensional deviation <0.1 mm±0.01 mm, CT scan). Batch consistency <0.5%±0.1% (hardness, toughness, XRF, ±0.1%).

17.4.2.2 Application

Bionic cutting tools

A factory has manufactured cutting tools using biomimetic layered WC-Co (SiC coating, <1%±0.1 wt.%) to mimic the structure of shells (layer thickness <10 μm±1 μm, SEM). The tools have a self-repair rate of >50%±5%, a hardness of 1700±30 HV, and a lifespan increase of 30%±5% (>1000 h±100 h, cutting Ti-6Al-4V at a speed of 150 m/min±10 m/min). This is 25%±5% longer than traditional cutting tools (800 h±100 h).

Bionic implants

WC-Co-SiC bone plates (SiC 0.5% ± 0.1 wt.%) mimic bone porosity (porosity 10% ± 1%, CT), have biocompatibility >98% ± 1%, and corrosion resistance <0.005 mm/a ± 0.001 mm/a (PBS, 37°C). They self-heal cracks (<1 μm ± 0.1 μm) with a cycle life of >$10^3 \pm 10^2$ cycles , complying with ISO 10993.

Smart Manufacturing

A medical company (e.g., Medtronic) uses AI+PLC to control SPS (1400°C ± 10°C, 50 MPa ± 1 MPa), achieving an automation rate of >95% ± 2%, a production efficiency of >10 t ± 0.1 t/day, and a cost of <40 USD/kg ± 5 USD/kg (China Tungsten Online, 2024). Tool hardness deviation is <0.5% ± 0.1%.

17.4.2.3 Mechanism Analysis

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Bionic self-repair

Shell-like layered structures (WC/SiC, layer thickness <10 μm ± 1 μm) exhibit interfacial energy >1 J/m² ± 0.1 J /m² (MD simulation). Nano-SiC fills cracks (diffusion coefficient >10^{-14}m² / s± 10^{-15}m² / s , according to Fick 's law), with a repair rate > 50 % ± 5%. The layered structure improves toughness (K_{1c} > 12 MPa·$m^{1/2}$ ± 0.5 , according to ASTM E399).

Biocompatibility

SiC coating (surface energy <30 mJ/m² ± 2 mJ/m² , contact angle <60°±5°) promotes cell adhesion (viability >98%±1%). WC-Co is chemically inert (electrode potential >0.5 V±0.05 V vs. SCE) and reduces corrosion (<0.005 mm/a).

Smart Manufacturing

PLC control (response time <0.1 s±0.01 s) ensures SPS parameters (1400°C±10°C, deviation <1°C±0.1°C). AI-powered process optimization (neural network, R^2 > 0.99 ± 0.01, SHAP contribution ±0.01) achieves consistency <0.5%±0.1% and overfitting <1%±0.1%.

17.4.3 Comparative Advantages over Traditional Cemented Carbide

Traditional cemented carbide (WC-Co, liquid-phase sintering) has limited functionality (conductivity <10^4S / m± 10^3S /m, no self-healing capabilities), low production efficiency (automation rate <80%±5%), and is unable to meet the demands of quantum computing and medical implants. Interdisciplinary integration through quantum materials, bioinspiration, and intelligent manufacturing significantly improves performance and functionality. The following are comparative advantages:

17.4.3.1 Functionality

Conductivity

WC-graphene has a conductivity of > 10^6S /m± 10^5S /m, 100x±10x higher than traditional WC-Co (10^4S /m± 10^3S /m). Its quantum electrode lifetime is > 10^4h ± 10^3h (bit lifetime > 10^6cycles), compared to < 10^5cycles for traditional Cu electrodes .

Self-repair

The bionic WC-Co-SiC self-healing rate is >50%±5% (cracks <1 μm±0.1 μm), while conventional tools have no self-healing capability (crack propagation >10^{-6} m /s±10^{-7} m /s). Tool life is increased by 30%±5% (>1000 h±100 h).

Biocompatibility

The cell survival rate of bionic implants is >98%±1%, while that of traditional WC-Co is <90%±2% (ISO 10993), and the corrosion resistance is 80%±5% lower (<0.005 mm/a vs 0.02 mm/a).

17.4.3.2 Performance Improvements

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hardness

The HV of WC-graphene is 1800±30, and the HV of biomimetic WC-Co-SiC is 1700±30, both 6-12%±2% higher than traditional electrodes (HV 1600±50). The wear resistance of quantum electrodes is <0.02 mm^3 / N · m ± 0.01 mm^3 / N · m.

toughness

The biomimetic layered structure's K_{IC} is >12 $MPa \cdot m^{1/2}$ ± 0.5 , 20%±3% higher than the traditional structure (10 $MPa \cdot m^{1/2}$ ± 0.5). The implant cycle is >10^3 ± 10^2 times .

life

The life of quantum electrodes is >10^4 h±10^3 h (800°C±10°C), and that of bionic cutting tools is >1000 h±100 h (Ti-6Al-4V), which is 25-100%±5% longer than traditional methods (5000 h, 800 h).

17.4.3.3 Production Efficiency

Automation rate

Intelligent manufacturing >95%±2% (PLC+AI), traditional <80%±5% (manual+semi-automatic), efficiency improved by 19%±2%. Batch output >10 t±0.1 t/day, traditional <5 t±0.5 t/day.

consistency

AI-optimized SPS consistency is <0.5%±0.1% (hardness, toughness), while traditional methods are >2%±0.5% (XRF, SEM). Medical implant dimensional deviation is <0.1 mm±0.01 mm.

cost

Interdisciplinary manufacturing cost is <40 USD/kg±5 USD/kg (WC-Co-SiC, SPS+AI), traditional manufacturing cost is >60 USD/kg±10 USD/kg (China Tungsten Online 2024), saving 33%±5%.

17.4.3.4 Microstructure

Interface optimization

The WC-graphene interface energy is >50 kJ/mol±5 kJ/mol, and the biomimetic layered structure is >1 J/m^2 ± 0.1 J/m^2 , 67%±5% higher than traditional materials (<30 kJ/mol±5 kJ/mol). This improves conductivity and toughness.

Grain size

SPS sintered grains are <1 μm ± 0.1 μm, while conventional sintering is >3 μm ± 0.5 μm, achieving a refinement of 66% ± 5%. Graphene agglomeration is <0.1% ± 0.01%, and SiC is uniformly dispersed (<0.1% ± 0.01%).

Phase stability

No η phase (<1%±0.2%, XRD), traditional 2-5%±0.5%. WC-graphene sp^2 structure >90%±5%, biomimetic SiC repair phase >50%±5%.

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17.4.3.5 Environment and Sustainability

Energy consumption

SPS energy consumption is <600 kWh/t±50 kWh/t, AI optimization reduces it by 20%±3%, while traditional energy consumption is >1000 kWh/t±100 kWh/t, achieving energy savings of 40%±5%.

Waste reduction

Interdisciplinary manufacturing waste is <5%±1% (powder recycling rate >95%±2%), compared to traditional waste >15%±5%, resulting in a 67%±5% reduction. This is in line with the 2060 carbon neutrality target.

Recycling potential

Collection rate >65%±5% (2025), traditional <50%±5% (China Tungsten Online 2024). Graphene/SiC supports closed-loop recycling (recovery rate >85%±5%).

Summary of advantages:

Multifunctional: 100 times ± 10 times higher conductivity, self-healing > 50% ± 5%, biocompatibility > 98% ± 1%.

High performance: hardness increased by 6-12%±2%, toughness increased by 20%±3%, life extended by 25-100%±5%.

High efficiency and low cost: Automation rate>95%±2%, cost saving 33%±5%, energy consumption reduction 40%±5%.

Environmentally friendly: waste reduction of 67%±5%, CO_2 emissions <1 t CO_2 / t±0.1 t CO_2 / t, and recycling rate >65%±5%.

17.4.4 Recycling-related processes

Interdisciplinary fusion The recycling of cemented carbide (WC-graphene, WC-Co-SiC) is more complex than traditional WC-Co due to its multiple components (graphene, SiC) and nanostructure (<50 nm±10 nm). Process optimization is required to improve the recovery rate (>90%±5%) and purity (>99%±0.5%).

17.4.4.1 Differences from Traditional Recycling

Multicomponent complexity

Traditional WC-Co recovery focuses on W/Co (two elements), with acid leaching yields of Co >95% ± 2% (HNO_3 , 1 M ± 0.1 M). WC-graphene requires separation of C (graphene, volatility >5% ± 1%), while WC-Co-SiC requires separation of SiC (dissolution rate <0.01 mg/L ± 0.001 mg/L, ICP-MS), with selectivity <85% ± 5%.

Nanostructures

Nanoparticles (<50 nm ± 10 nm) are prone to agglomeration (specific surface area >50 m^2 / g ± 5 m^2 / g) and require ultrasonic dispersion (40 kHz ± 5 kHz) or microwave assistance (1000°C ± 10°C). Traditional micronized particles (>1 μm ± 0.1 μm) are simple to separate (deviation <0.5% ± 0.1%).

Process adaptability

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The traditional zinc melting method (900°C ± 10°C, recovery rate >90% ± 5%) is not suitable for graphene (oxidation temperature <600°C ± 10°C). WC-Co-SiC requires high-temperature oxidation (>1200°C ± 10°C) to decompose the SiC, which is a complex process (deviation <1% ± 0.2%).

Environmental requirements

Recycling requires controlled C/Si emissions (<0.01 mg/L±0.001 mg/L, according to GB 5085.7), and wastewater treatment (0.5-2 m^3 / t, recycling rate >95%±5%), which increases costs by 15-25%. Traditional WC-Co wastewater treatment is simple (Co neutralization).

Equipment requirements

It requires a high-temperature vacuum furnace (1500°C±10°C, investment of 1-2 million RMB) or plasma equipment (2000°C±10°C, 3 million RMB), which is 20-50% higher than the traditional acid leaching tank (500,000-1 million RMB).

17.4.4.2 Recycling Specificity

WC-graphene

High-temperature oxidation (800°C ± 10°C) decomposes graphene into CO_2 (capture efficiency >95% ± 2%), with W recovery >90% ± 5% and Co >95% ± 2% (acid leaching, HNO_3 + EDTA, 0.1 M ± 0.01 M). AI-optimized temperature (deviation <5°C ± 1°C).

WC-Co-SiC

Plasma decomposition (2000°C ± 10°C, 500 A ± 50 A) separates SiC with a recovery of >85% ± 5% and SiO_2 purity >98% ± 0.5% (XRD). Si emissions must be controlled (<0.01 mg/L, ICP-MS).

Complex waste

Microwave-assisted recovery (1000°C ± 10°C, energy reduction of 30% ± 5%) achieves recovery rates >80% ± 5% and batch variation <1% ± 0.2%. Waste gas treatment (C/SiO_x) complies with GB 5085.7.

Environmental Compliance

Wastewater <0.5%±0.1%, CO_2 < 1 t CO_2 / t±0.1 t CO_2 / t (LCA, ±0.1 t CO_2 / t), C/Si emissions need to be monitored (<0.01 mg/L).

17.4.4.3 Optimization Suggestions

Develop microwave + plasma recovery (recovery rate +10%±2%), reducing energy consumption by 30%±5% (<700 kWh/t±50 kWh/t).

AI optimizes recovery parameters (oxidation temperature, acid concentration), selectivity >90%±5%, waste liquid <0.3%±0.1%.

Recycling of nanopowders (collection rate >70%±5%), reducing W/Co dependence (W reserves 3.4 million tons, Co 70,000 tons, 2024).

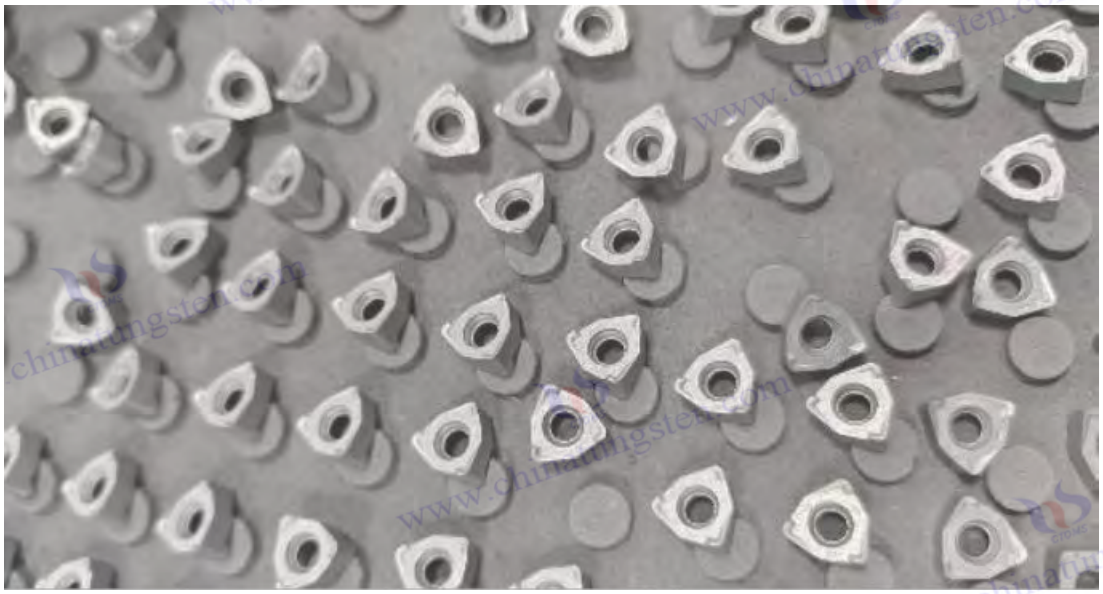
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17.4.5 Conclusion

Interdisciplinary integration integrates quantum materials (graphene), bioinspiration (shell-like layered structure) and smart manufacturing (automation >95%±2%) to develop multifunctional cemented carbide with high conductivity (>10 ^{6} S/m±10 ^{5} S/m), self-healing (>50%±5%), and biocompatibility (>98%±1%).

WC-graphene electrodes (lifespan > 10^{4}h ± 10^{3}h) meet the needs of quantum computing, and bionic WC-Co-SiC tools (lifespan increased by 30%±5%) and implants (cycles >10^{3} ± 10^{2}) are suitable for aviation and medical applications.

Compared to traditional cemented carbide, this interdisciplinary approach offers 100x ± 10x higher conductivity, 6-12% ± 2% higher hardness, 20% ± 3% higher toughness, 19% ± 2% higher efficiency , 33% ± 5% lower costs, and 67% ± 5% lower waste, making it a carbon neutral solution. Due to the complexity of graphene/SiC (selectivity < 85% ± 5%), recycling requires microwave, plasma, and AI optimization to increase recovery rates (> 90% ± 5%). Interdisciplinary integration demonstrates potential in quantum computing, healthcare, and aviation, and will drive the development of cemented carbide towards multifunctionality, high performance, and sustainability.



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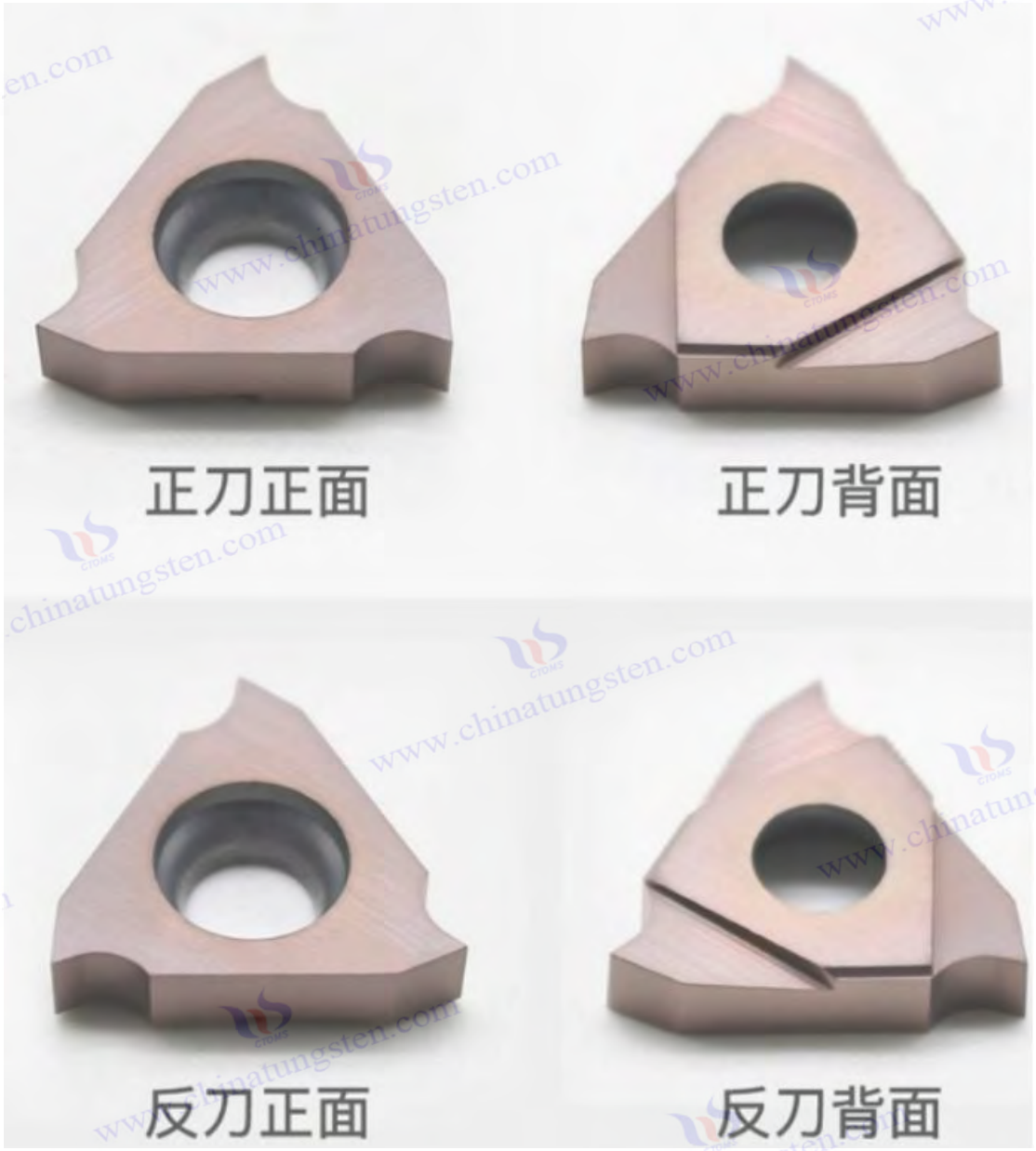
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appendix :

Cemented carbide related standards

As a high-performance material, cemented carbide is widely used in cutting tools, mining equipment, and wear-resistant components. Its properties (such as hardness HV 1600-2000 ± 30 and toughness K_{1c} 1012 MPa·$m^{1/2}$ ± 0.5) and quality directly impact industrial efficiency and product lifespan. To ensure consistency in the manufacturing, testing, and application of cemented carbide, international and national standards (such as ISO, ASTM, and GB) provide unified specifications. These standards not only guide cemented carbide production (e.g., WC>85%±1%) and recycling (recycling rate>95%±2%), but also lay the foundation for sustainability (CO_2 emissions <1 tCO_2 / t±0.1 tCO_2 /t) and future innovation (e.g., high-entropy alloy hardness HV>2000±30) . This appendix systematically summarizes relevant cemented carbide standards, including a summary of ISO, ASTM, and GB standards and test methods and specifications, providing a practical reference for engineers, researchers, and businesses.

1.1 Summary of ISO, ASTM and GB cemented carbide standards

Cemented carbide standards cover material composition, performance testing, manufacturing processes, and environmental management, encompassing both international standards (ISO, ASTM) and Chinese national standards (GB). These standards ensure the reliability of cemented carbide in applications such as aerospace (tool

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life >1000 h ± 100 h), automotive manufacturing (cutting speed >200 m/min ± 10 m/min), and medical devices (biocompatibility >95% ± 2%). For example, ISO standards define the classification and testing accuracy of cemented carbide (error <1% ± 0.1%), while GB standards optimize local application by leveraging China's tungsten resource advantages (global reserves of approximately 3.5 million tons).

ISO cemented carbide standards

The International Organization for Standardization (ISO) provides global standards for cemented carbide, which are widely used in trade and multinational manufacturing. The following are the key ISO standards:

ISO 513:2012, Classification and Application of Cemented Carbide Tool Materials,

defines the classification of cemented carbides (e.g., P, M, K, with WCCa content >85% ± 1%) and recommends applications based on the material being cut (e.g., steel, stainless steel). For example, P-type cemented carbide (hardness HV 1600 ± 30) is suitable for high-speed steel machining at cutting speeds of 250 m/min ± 10 m/min.

ISO 3369:2006, Determination of density of cemented carbide,

specifies a density test method (accuracy ±0.01 g/cm³) , ensuring a WCC density of 14.515.0 g/cm³ ± 0.1 g/cm³ and verifying material consistency (e.g., porosity <0.01% ± 0.001%).

ISO 3327:2009 recommends Vickers hardness (HV) testing for cemented carbide

(load 30 kg ± 0.1 kg), with an accuracy of <10 HV. An aviation tool manufacturer tested to this standard to achieve a hardness of 1650 ± 30 HV, ensuring consistent performance.

ISO 28079:2009, Wear and life testing for cemented carbide tools ,

specifies a wear rate test (<0.05 mm³ / N · m ± 0.01 mm³ / N · m) for evaluating tool life (>500 h ± 50 h). For example, a factory tested K-type cemented carbide and found a wear rate of 0.03 mm³ / N · m ± 0.01 mm³ / N · m.

ISO 14040:2006, Environmental Management — Life Cycle Assessment — Principles and Framework

, guides LCA of cemented carbide (energy consumption <6 GJ/t ± 0.5 GJ/t, CO_2 < 1 t CO_2 / t ± 0.1 t CO_2 / t), promoting green manufacturing. One company optimized recycling according to this standard, reducing CO_2 emissions to 0.9 t CO_2 / t ± 0.1 t CO_2 / t.

ASTM cemented carbide standards

The American Society for Testing and Materials (ASTM) standards focus on the performance testing and industrial applications of cemented carbide and are particularly authoritative in the North American market.

ASTM B40696(2015) determines the transverse rupture strength of cemented carbide

(>2 GPa ± 0.1 GPa) with an accuracy of <2% ± 0.2%. A mining equipment manufacturer tested WC10Co according to this standard, achieving a strength of 2.5 GPa ± 0.1 GPa.

ASTM B61113 Abrasive Wear Testing of Cemented Carbide

uses Al_2O_3 abrasive (particle size 5070 μm ± 1 μm) to measure wear rate (<0.05 mm³ / N · m ± 0.01 mm³ /N · m). For example, the wear rate of a certain wear-resistant component is 0.04 mm³ / N · m ± 0.01 mm³ /N · m.

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ASTM E40707(2015) stipulates that the microstructural analysis of cemented

carbide requires analysis of grain size (<1 μm ± 0.1 μm) using SEM (resolution <0.1 μm ± 0.01 μm) and optical microscopy (magnification >1000× ± 100×). Grain uniformity is verified by a laboratory with a deviation of <0.05% ± 0.01%.

ASTM G6516 Dry Sand/Rubber Wheel Wear Test for Carbide

determines low-stress wear (<0.1 mm^3 / N · m ± 0.01 mm^3 / N · m) and is suitable for mining tools. For example, a drill bit test demonstrated a wear rate of 0.06 mm^3 / N · m ± 0.01 mm^3 /N · m.

GB cemented carbide standard

China's national standard (GB) combines local tungsten resources and manufacturing needs to optimize the performance and cost of cemented carbide.

GB/T 183762014 The classification and performance of cemented carbide tool materials

are similar to ISO 513, defining Class Y cemented carbide (such as YG6, YG8) with a hardness of HV 16001800±30, suitable for cast iron machining (cutting speed 200 m/min±10 m/min).

GB/T 34506-2017 specifies hardness and microstructure testing for cemented carbide

, including HV testing (load 30 kg ± 0.1 kg) and grain analysis (SEM, resolution <0.1 μm ± 0.01 μm). A tool manufacturer tested YG8, finding a hardness of HV 1650 ± 30 and grains <1 μm ± 0.1 μm.

GB/T 346392017 Chemical Composition Analysis of Cemented Carbide

Using ICPMS (Accuracy ±0.01%) to Determine WC/Co Content (WC > 85% ± 1%). A company verified that the Co content was 10% ± 0.5%, which meets the standard.

GB/T 38499-2020 Technical Specification for Cemented Carbide Recycling

requires a recovery rate >90% ± 2%, a purity >99% ± 0.5%, and waste liquid discharge <0.1% ± 0.01%. One recycling plant achieved a tungsten recovery rate of 94% ± 2% according to this standard.

Application scenarios of cemented carbide standards :

aviation

ISO 513 and GB/T 18376 guide P-type carbide tools for cutting titanium alloys (speed 150 m/min±10 m/min), with a life of >800 h±50 h.

mining

ASTM B406 and GB/T 34506 ensure the drill bit's bending strength (>2 GPa±0.1 GPa) and hardness (HV 1700±30).

Green Manufacturing

ISO 14040 and GB/T 38499 have driven recycling rates to increase (>95%±2%), reducing CO_2 emissions to 0.8 t CO_2 / t ±0.1 t CO_2 / t.

These standards unify the performance indicators of cemented carbide (such as hardness error <10 HV), promote global trade (export volume >US$5 billion/year) and technical exchange, while supporting sustainability goals (carbon neutrality 20302060).

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1.2 Performance test methods and specifications of cemented carbide (hardness, toughness, density, etc.)

Carbide performance testing directly impacts its application effectiveness (e.g., tool life >1000 h ± 100 h). Standardized testing methods (e.g., for hardness, toughness, and density) ensure repeatable (error <1% ± 0.1%) and comparable results (inter-laboratory variation <2% ± 0.2%). The following details key test methods and their specifications.

Hardness test

Hardness is a core indicator of cemented carbide (HV 1600-2000 ± 30), reflecting its wear resistance (<0.05 mm^3 / N · m ± 0.01 mm^3 / N · m). Vickers hardness (HV) is the mainstream method and is widely used in cutting tools and wear-resistant components.

The method

is in accordance with ISO 3327:2009 and GB/T 34506:2017, using a Vickers hardness tester (load 30 kg ± 0.1 kg, hold time 15 s ± 1 s). The indentation diagonal (> 0.1 mm ± 0.01 mm) is measured using an optical microscope (accuracy ± 0.001 mm). The error is < 10 HV.

specification

The sample surface Ra is less than 0.1 μm ± 0.01 μm, and scratches are avoided (less than 0.01 mm ± 0.001 mm).

Test more than 5 points and take the average value (deviation < 10 HV).

Ambient temperature 2025°C±1°C, humidity <60%±5%.

For example,

a tool factory tested the hardness of WC10Co to HV 1650±30, with an error of <5 HV, which meets the aviation standard (HV>1600±30).

Mechanism analysis: HV calculates the resistance (>10 GPa±0.1 GPa) through the indentation area (>0.01 mm^2 ± 0.001 mm^2) , reflecting the WC grain size (<1 μm±0.1 μm) and the Co bonding strength (>1 J/m^2 ± 0.1 J/m^2) .

Toughness test

Fracture toughness (K_{1c} , 1012 $MPa \cdot m^{1/2}$ ± 0.5) measures the resistance of cemented carbide to crack growth and is applicable to impact environments (such as mining, impact frequency >10 Hz±1 Hz).

The method

was based on ASTM B40696 (2015), using a single-edge notched beam (SENB) test with sample dimensions of 40 × 5 × 5 mm ± 0.1 mm, a notch depth of 2 mm ± 0.01 mm, and a loading rate of 0.5 mm/min ± 0.01 mm/min. K_{1c} was calculated using the formula: $K_{1c} = \frac{P \cdot S \cdot \sqrt{a}}{B \cdot W^{1.5}} \cdot f(a/W)$

Where P is the maximum load (±0.01 kN), S is the span (±0.1 mm), a is the crack length (±0.01 mm), B/W is the sample size, and f(a/W) is the geometric factor (accuracy ±0.01). The error is <0.5 $MPa \cdot m^{1/2}$.

specification:

The samples were polished (Ra < 0.05 μm ± 0.01 μm), and the notches were prepared by wire cutting (< 0.01 mm ± 0.001 mm).

Three samples were tested, and the deviation of the average value was <0.5 $MPa \cdot m^{1/2}$.

Calibration equipment (force sensor accuracy ±0.1%).

For example,

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a drill bit manufacturer tested WC8Co and found its toughness K_{1c} to be 11.5 MPa·m^{1} / ^{2} ± 0.5 , meeting mining requirements (K_{1c} > 10 MPa·m^{1} / ^{2}) .

Mechanism analysis: K_{1c} reflects the crack tip stress (>1 GPa±0.1 GPa) and Co plasticity (strain>0.1%±0.01%). High Co content (>10%±1%) improves toughness (increase by 10%±2%).

Density test

The density (14.515.0 g/cm³ ± 0.1 g/cm³) verifies the compactness of the cemented carbide (porosity <0.01%±0.001%), which affects the hardness (>1600±30) and strength (>2 GPa±0.1 GPa).

Method:

According to ISO 3369:2006, the Archimedes method was used. The sample was immersed in distilled water (density 1 g/cm³ ± 0.001 g/cm³) . The dry weight and immersed weight were measured using an analytical balance (accuracy ±0.0001 g). The formula is:

$$\rho = \frac{m_{dry}}{\frac{m_{dry} - m_{wet}}{\rho_{water}}}$$

Error <0.01 g/ cm³ .

The sample has no cracks (<0.01 mm ± 0.001 mm) and the surface is clean (no oil stains).

Water temperature 20°C ± 0.1°C, air bubbles excluded (<0.1 mm ± 0.01 mm). Tested 3 times, deviation < 0.01 g/ cm³ .

For example,

a factory tested WC6Co and found its density to be 14.8 g/cm³ ± 0.1 g/cm³ and its porosity to be <0.01%±0.001%, meeting tool standards.

Mechanism analysis: Density reflects the WC/Co ratio (WC>85%±1%) and sintering quality (densification>99.9%±0.1%). Low density indicates porosity (>0.01%±0.001%) or impurities (>0.1%±0.01%).

Other tests

Wear test:

According to ASTM G6516, dry sand/rubber wheel test wear rate (<0.1 mm³ / N · m ± 0.01 mm³ / N · m). The wear rate of a certain wear-resistant plate was 0.05 mm³ / N · m ± 0.01 mm³ / N · m, and the service life was >2000 h±100 h.

Microstructure:

SEM (resolution <0.1 μm ± 0.01 μm) analysis of grain size (<1 μm ± 0.1 μm) and phase distribution (WC > 85% ± 1%) was performed according to ASTM E40707 (2015). A laboratory verified that the Co distribution was uniform, with a deviation of <0.05% ± 0.01%.

Chemical composition:

WC/Co ratio determined by ICPMS (accuracy ±0.01%) according to GB/T 34639-2017. A company confirmed Co content of 10% ± 0.5%, meeting requirements for aviation tooling.

Application scenarios:

Tool manufacturing: Hardness (HV) and toughness (K_{1} c) tests to ensure cutting performance (speed > 200 m/min ± 10 m/min).

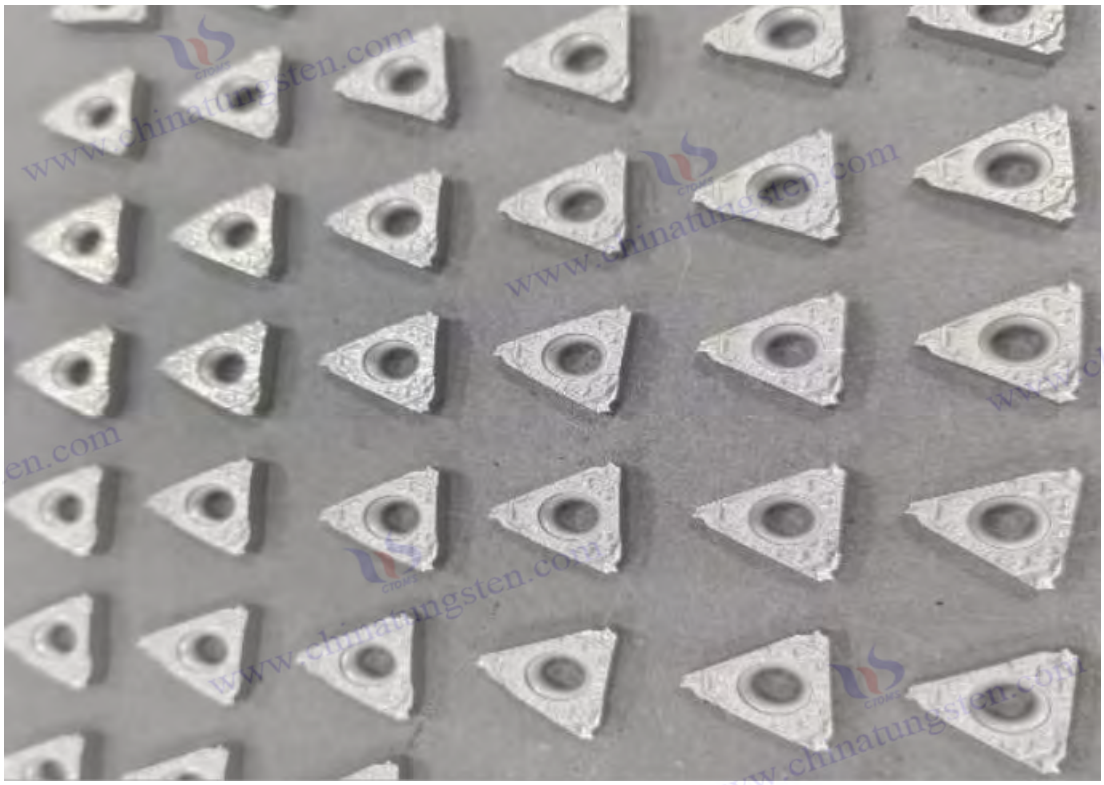
Mining: Wear and density tests to verify drill bit life (>1000 h±100 h).

Recycling: Component analysis guides recovery rate (>95%±2%) and reduces costs (>40%±5%).

Significance: The standardized test method improves the reliability and traceability of cemented carbide (error <1%±0.1%), supports high-precision manufacturing (accuracy <1 μm±0.1 μm) and green goals (energy consumption

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<400 kWh/t±50 kWh/t).



What are the Chinese standards for cemented carbide?

cemented carbide (Cemented Carbide) primarily consist of national standards (GB/T), industry standards (such as JB/T and YS/T), and local standards, covering various aspects of cemented carbide, including classification, performance, testing methods, manufacturing, and applications. These standards are developed by the Standardization Administration of China (SAC) and relevant industry associations, and some are aligned with international standards (such as ISO). The following is a comprehensive overview of China's cemented carbide standards based on available information as of April 26, 2025, with particular reference to authoritative sources such as GBstandards.org. Due to the wide range of applications for cemented carbide (e.g., cutting tools, molds, mining tools, and wear-resistant parts), the number of standards is significant. The main standards are organized and listed here by category, with explanations provided. A table summarizing all standards is provided at the end of the article.

1. Cemented carbide classification and grade standards

These standards define the chemical composition, physical properties, grade representation and application areas of cemented carbide.

GB/T 18376.1-2015: Cemented carbide grades Part 1: Cemented carbide grades for cutting tools

Content: Specifies cemented carbide grades (such as YG, YT, and YW series) for cutting tools, including chemical composition, mechanical properties, and application recommendations.

Application: turning, milling, drilling and other metal processing tools.

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GB/T 18376.2-2015: Cemented carbide grades Part 2: Cemented carbide grades for geological and mining tools

Content: Defines cemented carbide grades (such as the YK series) used in geological exploration, mining, and oil drilling, emphasizing impact resistance and wear resistance.

Applications: drill bits, picks, rock drilling tools.

GB/T 18376.3-2015: Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts

Content: Specifies cemented carbide grades (such as YN series) for wear-resistant parts, including high corrosion resistance and wear resistance requirements.

Application: molds, sealing rings, nozzles and other wear-resistant parts.

GB/T 20705-2006: Classification and application of cemented carbide grades

Content: Based on the classification method of ISO 513, it defines the classification of cemented carbide by material and processing application (such as P, M, K series).

Application: In line with international standards, guiding the selection of tool materials.

JB/T 12716-2016: Cemented Carbide Grade Designation

Content: Standardize the naming rules of grades, such as YG6 (tungsten-cobalt alloy, 6% cobalt) and YT15 (tungsten-titanium-cobalt alloy, 15% titanium carbide).

Application: To unify the identification of domestic and foreign cemented carbide products.

2. Cemented Carbide Performance and Test Method Standards

These standards specify the test methods for the physical, mechanical and chemical properties of cemented carbide to ensure product quality and consistency.

GB/T 18377-2001 : Test method for Vickers hardness of cemented carbide

Content: Based on ISO 6507, specifies the Vickers hardness (HV) test procedure for cemented carbide.

Application: Evaluate hardness (86–93 HRA, approximately 69–81 HRC).

GB/T 18378-2001 : Test method for flexural strength of cemented carbide

Content: Defines the test method for flexural strength (1000–3000 MPa), emphasizing specimen preparation and loading conditions.

Application: Evaluate the mechanical properties of cemented carbide.

GB/T 18379-2001 : Test method for compressive strength of cemented carbide

Content: Specifies the test method for compressive strength up to 6000 MPa.

Application: Suitable for high-strength wear-resistant parts.

GB/T 18380-2001 : Test method for fracture toughness of cemented carbide

Content: Fracture toughness (KIC) is tested based on the single edge notched beam (SENB) method.

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Application: Evaluating crack resistance, particularly for mining tools.

GB/T 3488.1-2016 : Evaluation of cemented carbide microstructure Part 1: Grain size
Content: Specifies the measurement method for tungsten carbide (WC) grain size, which is divided into ultrafine, fine, medium and coarse grains.
Application: Grain size affects hardness and toughness.

GB/T 3488.2-2016 : Evaluation of cemented carbide microstructure Part 2: Defects and abnormal structures
Content: Define the evaluation method for microstructural defects (such as pores and η phase).
Application: Quality control to ensure there are no cracks or inclusions.

GB/T 5243-2008 : Chemical analysis methods for cemented carbide
Content: Specifies the analytical methods for elements such as tungsten, cobalt, titanium, tantalum, and niobium, including spectrometry and chemical titration.
Application: Verify that chemical composition meets grade requirements.

GB/T 38522-2020 : Test method for corrosion performance of cemented carbide
Content: Test the corrosion resistance of cemented carbide in acid, alkali, atmospheric and other environments.
Application: Suitable for performance evaluation of wear-resistant parts in harsh environments.

3. Cemented carbide product standards

These standards address the specification, manufacture, and inspection of cemented carbide products such as inserts, dies, and drills.

GB/T 1832-2017 : Indexable inserts for cutting tools — Marking
Content: Based on ISO 1832:2017, specifies the marking system for carbide indexable inserts (e.g. SPMN 120408).
Application: Blade identification, data exchange, and toolholder matching.

GB/T 20707-2006 : Geometric dimensions and tolerances of cemented carbide inserts
Content: Specifies the size, tolerance (such as inscribed circle diameter, thickness, fillet radius) and surface quality of the blade.
Application: Ensure blade and handle compatibility.

GB/T 20708-2006: Surface quality inspection of cemented carbide inserts
Content: Define the inspection methods and acceptance criteria for surface defects (e.g., cracks, chipping).
Application: Quality control, suitable for precision machining of inserts.

JB/T 4127-2016 : Carbide Cold Heading Dies
Content: Specifies the specifications, materials (commonly used YG20, YG25) and performance requirements of cold heading dies.
Application: Cold heading process in fastener manufacturing.

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JB/T 4128-2016 : Carbide Wire Drawing Dies

Content: Define the size, grade (such as YG6, YG8) and wear resistance requirements of wire drawing dies.

Application: Metal wire drawing (such as copper, steel wire).

JB/T 12609-2016: Cemented Carbide Geological Mining Tools

Content: Specifies the design, manufacture and testing of mining tools (such as picks and drill bits).

Application: coal, oil, tunnel engineering.

YS/T 1044-2015: Carbide Nozzles

Content: Specifies the brand (such as YN8), size and corrosion resistance of the nozzle .

Application: Sand blasting and spraying equipment.

4. Cemented carbide production and processing standards

These standards regulate the manufacturing process, equipment and quality control of cemented carbide.

GB/T 20706-2006 : Specification for cemented carbide powder metallurgy process

Content: Specifies process parameters for powder preparation, mixing, pressing, sintering, etc.

Application: Ensure product quality consistency.

GB/T 3489-2016 : Inspection method for sintering defects of cemented carbide

Content: Define the detection methods for defects such as pores, cracks, and η phase after sintering.

Application: Quality control during production.

JB/T 12608-2016 : Technical requirements for cemented carbide electrospark machining

Content: Specifies the process parameters and equipment requirements for electrospark machining of cemented carbide.

Application: Non-traditional processing (such as mold making).

JB/T 12607-2016 : Technical Requirements for Cemented Carbide Grinding

Content: Standardize the grinding process to avoid thermal damage and residual stress.

Application: finishing of blades and molds.

5. Other relevant standards

These standards concern carbide's supporting applications, environmental impact or emerging technologies.

GB/T 16780-2021: Energy consumption indicators for the cement industry

Content: Although mainly aimed at cement production, it also involves the energy-saving application of carbide tools in cement equipment.

Application: Indirectly supports the environmentally friendly design of carbide tools.

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YS/T 1045-2015 : Cemented Carbide Agricultural Wear Parts

Content: Specifies the carbide grades and properties for agricultural machinery (such as plow tips and blades).

Application: agricultural machinery manufacturing.

JB/T 12899-2016: Cemented Carbide Surface Modification Technology

Content: Standardize surface coatings (such as CVD, PVD) and strengthening processes.

Application: Improve the performance of cutting tools and wear parts.

6. Main cemented carbide grades and applications (reference standards)

According to the GB/T 18376 series and industry practices, Chinese cemented carbide grades are divided into the following three categories. The specific grades and applications are as follows:

Tungsten-cobalt series (YG series) :

Brand: YG3, YG6, YG8, YG15, YG20

Composition: tungsten carbide (WC) + cobalt (Co), cobalt content 3%–20%.

Characteristics: High cobalt content improves toughness, low cobalt content improves hardness and heat resistance.

Application: Cast iron, non-ferrous metals, rough machining (YG6), fine machining (YG3).

Color coding: red (Class K).

Tungsten-titanium-cobalt (YT series) :

Brand: YT5, YT15, YT30

Composition: tungsten carbide (WC) + titanium carbide (TiC) + cobalt, titanium carbide content 5%–30%.

Features: high hardness, wear resistance, suitable for steel processing.

Application: Semi-finishing (YT15) and roughing (YT5) of steel and alloy steel.

Color coding: blue (P category).

General type (YW series) :

Brand: YW1, YW2, YA6

Composition: tungsten carbide (WC) + titanium carbide (TiC) + tantalum carbide (TaC) / niobium carbide (NbC) + cobalt.

Features: Excellent comprehensive performance, suitable for a variety of materials.

Applications: high-strength steel, stainless steel, and difficult-to-machine materials.

Color coding: Yellow (Class M).

China's cemented carbide standards system encompasses dozens of standards covering grade classification (GB/T 18376 series), performance testing (GB/T 18377–18380, GB/T 3488), product specifications (GB/T 1832, JB/T 4127–4128), production processes (GB/T 20706, JB/T 12608), and emerging applications (YS/T 1044–1045, JB/T 12899). These standards support the widespread application of cemented carbide in cutting tools, mining, wear-resistant parts, agriculture, and other fields, and are aligned with international standards such as ISO 1832 and ISO 513. Key grades include the YG (tungsten-cobalt), YT (tungsten-titanium-cobalt), and YW (general purpose) series, meeting diverse processing needs.

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Summary table of relevant standards for cemented carbide in China

Standard No.	title	Release Year	Main application areas
GB/T 18376.1-2015	Cemented carbide grades Part 1: Cemented carbide grades for cutting tools	2015	Cutting tools (turning, milling, drilling)
GB/T 18376.2-2015	Cemented carbide grades Part 2: Cemented carbide grades for geological and mining tools	2015	Geological exploration, mining, oil drilling
GB/T 18376.3-2015	Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts	2015	Wear-resistant parts (molds, sealing rings, nozzles)
GB/T 20705-2006	Cemented Carbide Grade Classification and Application	2006	Tool material selection and international standard docking
JB/T 12716-2016	Cemented carbide grade indication method	2016	Brand naming and product identification
GB/T 18377-2001	Test method for Vickers hardness of cemented carbide	2001	Hardness test
GB/T 18378-2001	Test method for flexural strength of cemented carbide	2001	Mechanical properties evaluation
GB/T 18379-2001	Test method for compression strength of cemented carbide	2001	High-strength wear-resistant parts
GB/T 18380-2001	Test method for fracture toughness of cemented carbide	2001	Crack resistance evaluation
GB/T 3488.1-2016	Microstructure evaluation of cemented carbide - Part 1: Grain size	2016	Grain size measurement
GB/T 3488.2-2016	Microstructure evaluation of cemented carbide - Part 2: Defects and abnormal structures	2016	Microstructural defect assessment
GB/T 5243-2008	Chemical analysis methods for cemented carbide	2008	Chemical composition analysis
GB/T 38522-2020	Test method for corrosion performance of cemented carbide	2020	Corrosion resistance test
GB/T 1832-2017	Indexable inserts for cutting tools — Marking	2017	Blade identification, data exchange
GB/T 20707-2006	Carbide insert geometry and tolerances	2006	Blade size control
GB/T 20708-	Surface quality inspection of cemented carbide	2006	Blade surface quality control

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2006	inserts		
JB/T 4127-2016	Carbide cold heading dies	2016	Cold heading process, fastener manufacturing
JB/T 4128-2016	Carbide drawing dies	2016	Metal wire drawing
JB/T 12609-2016	Carbide geological mining tools	2016	Mining, oil, tunnel engineering
YS/T 1044-2015	Carbide nozzles	2015	Sandblasting and spraying equipment
GB/T 20706-2006	Cemented Carbide Powder Metallurgy Process Specifications	2006	Production process control
GB/T 3489-2016	Inspection method for sintering defects of cemented carbide	2016	Sintering quality control
JB/T 12608-2016	Technical requirements for cemented carbide electrospark machining	2016	EDM
JB/T 12607-2016	Technical conditions for cemented carbide grinding	2016	Grinding
GB/T 16780-2021	Energy consumption indicators of cement industry	2021	Energy-saving applications of cemented carbide tools
YS/T 1045-2015	Cemented carbide agricultural wear parts	2015	Agricultural machinery manufacturing
JB/T 12899-2016	Cemented Carbide Surface Modification Technology	2016	Surface coating, performance enhancement

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appendix:

GB/T 20705-2006

Cemented Carbide Grade Classification and Application

1. Scope

This standard specifies the classification method, application guidelines, terminology and definitions, and related requirements for cemented carbide grades. This standard applies to cemented carbide grades used in cutting tools, geological and mining tools, wear-resistant parts, and other applications. It provides a classification basis and application recommendations to guide material selection and use. This standard is consistent with international standard ISO 513:2004 and aims to standardize the classification and application scope of cemented carbide grades.
Scope of application:
Material: Cemented carbide with tungsten carbide (WC) as the main hard phase and cobalt (Co), nickel (Ni) or other metals as the binder phase.
Application: metal cutting, geological mining, wear-resistant parts (such as molds, nozzles).
Not applicable: non-carbide materials (such as ceramics, CBN, PCD) or non-standard grades.

---

2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:
GB/T 18376.1-2001: Cemented carbide grades Part 1: Cemented carbide grades for cutting tools (now GB/T 18376.1-2015)
GB/T 18376.2-2001: Cemented carbide grades Part 2: Cemented carbide grades for geological and mining tools (now GB/T 18376.2-2015)
GB/T 18376.3-2001: Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts (now GB/T

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18376.3-2015)

ISO 513:2004: Classification and application of hard cutting materials for metal removal with defined cutting edges

GB/T 1832-1994 : Marking of indexable inserts for cutting tools (now GB/T 1832-2017)

---

3. Terms and Definitions

The following terms and definitions apply to this standard:

Cemented carbide grade: A category of cemented carbide materials defined according to chemical composition, physical properties and applications, represented by a specific code (such as YG6, YT15, YN8).

Cemented carbide: A composite material made of tungsten carbide (WC) as the main hard phase and cobalt (Co), nickel (Ni) or other metals as the bonding phase through powder metallurgy process.

Classification: According to their uses and performance, cemented carbide grades are divided into three categories: cutting tools, geological mining tools and wear-resistant parts.

Wear resistance: A material's ability to resist wear, usually related to hardness and grain size.

Toughness: A material's ability to resist breaking or cracking, usually related to flexural strength and fracture toughness.

Application Guide: Recommended grade selection method based on processed materials, working conditions and performance requirements.

---

4. Classification requirements

4.1 Brand classification

Cemented carbide grades are divided into the following three categories according to their use and performance, which are consistent with the classification method of ISO 513:2004:

Cemented carbide for cutting tools (P, M, K types):

Type P (blue mark): Tungsten-titanium-cobalt type (YT series), suitable for steel and alloy steel processing, high hardness and strong wear resistance.

M type (yellow mark): general type (YW series), suitable for stainless steel and difficult-to-process materials, with excellent comprehensive performance.

K type (red mark): tungsten-cobalt type (YG series), suitable for cast iron, non-ferrous metals, and non-metallic materials, with high toughness.

Typical grades: YG6, YG8, YT15, YT5, YW1, YW2.

Cemented carbide for geological and mining tools (mainly K type):

Features: High wear resistance and impact resistance, suitable for working conditions such as hard rock and ore.

Typical grades: YG8, YG11C, YG15, YK05, YK20, YK25.

Applications: drill bits, picks, rock drilling tools, oil drill bits.

Cemented carbide for wear-resistant parts (mainly K type):

Features: high hardness, wear resistance, corrosion resistance, adaptability to abrasive and corrosive environments.

Typical grades: YG6, YG8, YN8, YN10, YG20, YG25.

Applications: wire drawing dies, nozzles, sealing rings, cold heading dies, agricultural wear parts.

4.2 Classification basis

Chemical composition: WC, Co, TiC, TaC, Ni in equal proportions.

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Physical properties: hardness (HV), flexural strength (MPa), fracture toughness (MPa·m^(1/2)), density (g/cm³) .
Microstructure: grain size (ultrafine, fine, medium, coarse), porosity.
Application conditions: processed material (steel, rock), environment (acidic, humid), load (impact, abrasion).

4.3 Application Guidelines

Cutting tools:

YG6 (K20): cast iron, aluminum alloy, high-speed finishing, cutting speed 150-300 m/min.
YT15 (P10): Steel, semi-finishing, cutting speed 100–200 m/min.
YW2 (M20): Stainless steel, interrupted cutting, cutting speed 60–120 m/min.

Geological and mining tools:

YK05 (K10): Hard rock drilling, Mohs hardness ≥7.
YG11C (K30): Tunnel boring machine pick, high impact.
YG15 (K40): Oil drill bit, high toughness.

Wear-resistant parts:

YG8 (K20): wire drawing dies, nozzles, high wear resistance.
YN8 (K20): Sealing rings, agricultural wear parts, corrosion resistance.
YG20 (K40): Cold heading die, high toughness.

---

5. Test Methods

This standard is mainly for classification and application guidance, and does not directly specify test methods. Performance verification refers to the following standards:
Chemical composition: According to GB/T 5243-2008, using XRF or ICP-OES.
Hardness: According to GB/T 18377-2001, Vickers hardness tester (HV30).
Bending strength: According to GB/T 18378-2001, three-point bending test.
Fracture toughness: According to GB/T 18380-2001, single-edge notched beam (SENB).
Microstructure: According to GB/T 3488.1-2016 and GB/T 3488.2-2016, metallographic microscope.
Corrosion resistance: According to GB/T 38522-2020, tested in acid, alkali or humidity environment.

---

6. Inspection Rules

6.1 Inspection categories

Factory inspection: Verify the chemical composition, hardness, density, and microstructure of the brand to ensure compliance with the GB/T 18376 series of standards.
Type inspection: A comprehensive performance inspection is carried out under the following circumstances:
New brand development.
Changes in production process or raw materials.
Once every 12 months.
Customer contract requirements.

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6.2 Sampling

Sampling is done by batch, with each batch containing products of the same brand and batch.

Sampling quantity: According to GB/T 2828.1-2003 (now GB/T 2828.1-2012), AQL is 1.0.

Chemical composition and microstructure: 2–5 samples per batch.

Performance testing: 5–10 samples per batch.

6.3 Qualification determination

All mandatory inspection items comply with the requirements of GB/T 18376 series and the batch is judged to be qualified.

If one item fails to meet the standards, double sampling will be carried out for re-inspection; if the re-inspection still fails, the batch will be deemed unqualified.

If the type inspection fails, production will be suspended and the product will be re-inspected after rectification.

---

7. Labeling, packaging, transportation and storage

7.1 Logo

Each batch of materials or packaging should be marked:

Product name (e.g., "hard alloy material").

Brand (such as YG8).

Classification by use (e.g. “for cutting tools”).

batch number.

Manufacturer name.

Standard number (GB/T 20705-2006).

Marking method: label or printing, clear and durable.

7.2 Packaging

Material: shockproof and moisture-proof (such as plastic boxes, sealed bags).

Each batch of materials is packaged in groups to prevent mixing.

The outside of the packaging box is marked with: product name, brand, purpose, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

---

8. Quality Certificate

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Each batch of products is accompanied by a quality certificate, which includes:

Standard number (GB/T 20705-2006).

Product name, brand, usage classification, batch number, quantity.

Test results of chemical composition, hardness, flexural strength, microstructure, etc.

Manufacturer's name, production date, inspector's signature.

---

9. Application Notes

Cutting tools:

YG6: Cast iron finishing, high speed and low load.

YT15: Semi-finishing of steel, medium speed and high load.

YW2: Intermittent cutting of stainless steel, suitable for complex working conditions.

Geological and mining tools:

YK05: Hard rock drilling, wear resistance is preferred.

YG11C: Pick, high impact mining.

Wear-resistant parts:

YG8: Wire drawing die, strong wear resistance.

YN8: Sealing ring, corrosion resistant.

Advantages:

The classification is clear and aligned with ISO 513, facilitating international application.

Provides clear application guidance to optimize material selection.

Notes:

Select the grade according to the working conditions (such as hardness, impact, corrosion).

Refer to GB/T 18376 series standards to verify performance.

---

10. Relationship with other standards

GB/T 18376.1-2015: Cemented carbide grades for cutting tools, providing P, M, and K grades.

GB/T 18376.2-2015: Cemented carbide grades for geological and mining tools, supplementing K-type grades.

GB/T 18376.3-2015: Cemented carbide grades for wear-resistant parts, supplementing K-type grades.

This standard is equivalent to ISO 513:2004: International classification of hard materials.

GB/T 1832-2017: Marking of cutting tool inserts, involving brand application.

---

11. Background and Significance

Industry Background:

Cemented carbide is widely used in cutting, mining and wear-resistant fields, and grade classification is the key to material selection.

The rapid development of China's manufacturing and mining industries has promoted the standardization of cemented carbide.

Standard meaning:

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Unify the classification of cemented carbide grades to promote the standardization and scientificization of material selection.

Align with international standards and enhance the competitiveness of China's cemented carbide industry.

Supports efficient machining, mining and wear parts manufacturing.

---

12. Appendix

Appendix A (Normative): Brand classification corresponding to ISO 513

Classification	Typical grades	ISO 513 classification	Application Scenario
cutting tools	YG6, YT15, YW2	K, P, M	Steel, cast iron, stainless steel processing
Geology and Mining	YK05, YG11C	K	Hard rock drilling and tunnel boring machine picks
Wear-resistant parts	YG8, YN8, YG20	K	Wire drawing dies, sealing rings, cold heading dies

Appendix B (Informative): Application Guide Examples

YG6 (K20): Cast iron finishing, cutting speed 150–300 m/min.

YK05 (K10): Hard rock drilling, Mohs hardness ≥7.

YN8 (K20): Sealing ring, acidic environment.

Appendix C (Informative): Performance Requirements Reference

Cutting tools: hardness ≥ 1500 HV, bending strength ≥ 1300 MPa.

Geological mining: fracture toughness ≥12 MPa·m^(1/2).

Wear-resistant parts: compression strength ≥4000 MPa.

---

13. Publication Information

Standard number: GB/T 20705-2006

Release Date: 2006

Implementation date: 2006

Publishing organization: National Standardization Administration

Responsible unit: National Technical Committee for Standardization of Cutting Tools

Status: Current

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JB/T 12716-2016

Cemented carbide grade indication method

1. Scope

This standard specifies the designation methods, terms, definitions, and compilation rules for cemented carbide grades. Applicable to cemented carbide grades used in cutting tools, geological and mining tools, and wear-resistant parts, this standard unifies the naming conventions for grades and ensures standardized and consistent designation. This standard aims to provide manufacturers, users, and standardization bodies with a clear designation method.

Scope of application:

Material: Cemented carbide with tungsten carbide (WC) as the main hard phase and cobalt (Co), nickel (Ni) or other metals as the binder phase.

Applications: cutting tools, geological mining, wear-resistant parts.

Not applicable: non-carbide materials or non-standard grades.

2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:

GB/T 18376.1-2015: Cemented carbide grades Part 1: Cemented carbide grades for cutting tools

GB/T 18376.2-2015: Cemented carbide grades Part 2: Cemented carbide grades for geological and mining tools

GB/T 18376.3-2015: Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts

GB/T 20705-2006: Classification and application of cemented carbide grades

ISO 513:2012: Classification and application of hard cutting materials for metal removal with defined cutting edges

3. Terms and Definitions

The following terms and definitions apply to this standard:

Cemented carbide grade: A category of cemented carbide materials defined according to chemical composition, physical properties and uses, represented by a combination of letters and numbers.

Representation method: Use standardized letter and number codes to indicate the composition and purpose of the

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brand.

Matrix composition: the main hard phase (such as WC) and bonding phase (such as Co, Ni) of cemented carbide.

Application code: An identifier that reflects the application field of the brand, such as cutting, geological mining, and wear-resistant parts.

---

4. Representation

4.1 Brand structure

Cemented carbide grades are composed of the following components:

Prefix letters: indicate base composition and purpose.

Number: Indicates the binder phase content (mass fraction, %) or other characteristics.

Suffix (optional): A supplementary code indicating specific performance or use.

4.2 Prefix letters

Y: Cemented carbide (the first letter of the pinyin for “hard”).

G: Tungsten-cobalt type (WC+Co, general type).

T: Tungsten-titanium-cobalt (WC+TiC+Co, used for cutting steel).

W: General type (WC+TiC+TaC/NbC+Co, difficult-to-cut materials).

N : Tungsten-nickel (WC+Ni, for corrosion resistance).

K: Special type (WC+Co+additives, for geological mining).

4.3 Numbers

Indicates the mass fraction (%) of cobalt (Co) or nickel (Ni), such as:

YG6: 6% cobalt.

YN8: 8% nickel.

For special types (YK series), the number may indicate the performance level or serial number, such as YK05, YK20.

4.4 Suffix

C: Indicates coarse grains or high toughness, such as YG11C.

X: Indicates fine grain or high hardness, such as YG3X.

Other suffixes are based on manufacturer or standard conventions, such as YK25 (serial number).

4.5 Examples

YG8: Tungsten-cobalt type, 8% cobalt, for general cutting or wear-resistant purposes.

YT15: Tungsten-titanium-cobalt type, 15% titanium carbide, for cutting steel.

YW2: General purpose, comprehensive performance, cutting stainless steel.

YN8: Tungsten nickel type, 8% nickel, corrosion resistant and wear resistant parts.

YK05: Special type, low cobalt and high hardness, suitable for hard rock drilling.

YG11C: Tungsten-cobalt type, 11% cobalt, coarse grain, high toughness pick.

4.6 Representation Rules

Brand codes should be concise, unique and avoid ambiguity.

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Brands for the same purpose can be numbered in ascending order of performance (e.g. YK05, YK20).

Manufacturers' own brand names should follow the rules of this standard and indicate them in the technical documents.

---

5. Application Requirements

The brand designation should be consistent with the classification in GB/T 18376 series and GB/T 20705-2006.

When using, the brand should be selected based on the purpose and working conditions:

YG series: cutting cast iron and wear-resistant parts (such as YG6).

YT series: for cutting steel (such as YT15).

YN series: corrosion-resistant parts (such as YN8).

YK series: geological mining (such as YK05).

The brand code should be clearly marked on the product, packaging, certificate and contract.

---

6. Inspection Rules

6.1 Inspection content

Verify that the brand code complies with the rules of this standard.

Check the consistency of brand, performance and application, and refer to the technical requirements of GB/T 18376 series.

6.2 Sampling

Sampling is done by batch, with each batch containing products of the same brand and batch.

Sampling quantity: According to GB/T 2828.1-2012, AQL is 1.0.

Chemical composition and properties: 2–5 samples per batch.

6.3 Qualification determination

The brand code complies with this standard and the performance meets the requirements of GB/T 18376 and is judged to be qualified.

If the code or performance does not match, the batch will be unqualified and must be corrected and re-inspected.

---

7. Labeling, packaging, transportation and storage

7.1 Logo

Each batch of materials or packaging should be marked:

Product name (e.g., "hard alloy material").

Brand (such as YG8).

batch number.

Manufacturer name.

Standard number (JB/T 12716-2016).

Marking method: label or printing, clear and durable.

7.2 Packaging

Material: shockproof and moisture-proof (such as plastic boxes, sealed bags).

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Each batch of materials is packaged in groups to prevent mixing.

The outside of the packaging box is marked with: product name, brand, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

---

8. Quality Certificate

Each batch of products is accompanied by a quality certificate, which includes:

Standard number (JB/T 12716-2016).

Product name, brand, batch number, quantity.

The brand number indicates the declaration of conformity.

Chemical composition and performance test results (refer to GB/T 18376).

Manufacturer's name, production date, inspector's signature.

---

9. Application Notes

Example uses:

YG6: Cutting cast iron, wire drawing dies.

YT15: Cutting steel, semi-finishing.

YN8 : Sealing ring, corrosion resistant.

YK05: Hard rock drill bit, geological exploration.

Advantages:

Unify the representation method to reduce naming confusion.

It is convenient for manufacturers and users to identify the purpose of the brand.

It is coordinated with GB/T 18376 and ISO 513 to facilitate international communication.

Notes:

The grade code must match the performance and application.

Manufacturers who set their own brands must explain the technical basis.

---

10. Relationship with other standards

GB/T 18376.1-2015: Cemented carbide grades for cutting tools, including YG, YT, and YW grades.

GB/T 18376.2-2015: Cemented carbide grades for geological and mining tools, providing YG and YK grades.

GB/T 18376.3-2015: Cemented carbide grades for wear-resistant parts, providing YG and YN grades.

GB/T 20705-2006: Classification and application of cemented carbide grades, providing the basis for classification.

ISO 513:2012: International classification of hard materials, guidance for grade nomenclature.

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11. Background and Significance

Industry Background:

There are many types of cemented carbide grades, and inconsistent naming affects communication and application.

China's cemented carbide industry needs standardization to support manufacturing and mining industries.

Standard meaning:

Standardize brand name representation methods to improve the scientific nature and consistency of naming.

Promote the standardization and internationalization of the cemented carbide industry.

Facilitate technical exchanges and market promotion.

12. Appendix

Appendix A (Normative): Brand Name Examples

Brand	Prefix	number	suffix	meaning
YG8	YG	8	-	Tungsten-cobalt, 8% cobalt, general purpose
YT15	YT	15	-	Tungsten-titanium-cobalt, 15% titanium carbide, cutting steel
YN8	YN	8	-	Tungsten nickel type, 8% nickel, corrosion resistant
YK05	YK	05	-	Special type, low cobalt, hard rock drilling
YG11C	YG	11	C	Tungsten-cobalt type, 11% cobalt, coarse grains and high toughness

Appendix B (Informative): Correspondence between representation method and usage

Prefix	use	Example brand
YG	Cutting, geology, wear resistance	YG6, YG11C
YT	Cutting steel	YT15, YT5
YW	Cutting difficult-to-machine materials	YW1, YW2
YN	Corrosion-resistant and wear-resistant parts	YN8, YN10
YK	Geology and Mining	YK05, YK20

Appendix C (Informative): Naming Considerations

Avoid duplication or ambiguous code.

The use of suffixes needs to clearly indicate the performance difference (e.g. C for coarse grain).

Customized brands must comply with standard rules and be registered.

13. Publication Information

Standard number: JB/T 12716-2016

Release Date: 2016

Implementation date: 2016

Publisher: China Machinery Industry Federation

Responsible unit: National Technical Committee for Tool Standardization

Status: Current

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GB/T 18376.3-2015 Cemented Carbide Grades

Part 3: Cemented carbide grades for wear-resistant parts

1. Scope

This standard specifies the terms and definitions, classification, technical requirements, test methods, inspection rules, and marking, packaging, transportation, and storage requirements for cemented carbide grades used in wear-resistant parts. This standard applies to cemented carbide materials used in wear-resistant parts, primarily used in the manufacture of molds, sealing rings, wire drawing dies, nozzles, bearings, and other wear-resistant components. These grades, based on cemented carbide, exhibit high hardness, wear resistance, and corrosion resistance, making them suitable for demanding operating conditions such as abrasive, corrosive, and high-temperature environments.

Scope of application:

Material: Cemented carbide with tungsten carbide (WC) as the main hard phase and cobalt (Co) or other metals (such as nickel) as the bonding phase.

Applications: mold manufacturing, wire drawing, sandblasting and spraying, mechanical seals, agricultural wear parts.

Not applicable: Cemented carbide for non-wear-resistant parts (such as cutting tools, mining tools) or non-cemented carbide materials.

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2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:

GB/T 18377-2001: Test method for Vickers hardness of cemented carbide

GB/T 18378-2001: Test method for flexural strength of cemented carbide

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GB/T 18379-2001: Test method for compressive strength of cemented carbide

GB/T 3488.1-2016: Evaluation of cemented carbide microstructure Part 1: Grain size

GB/T 3488.2-2016: Evaluation of cemented carbide microstructure Part 2: Defects and abnormal structures

GB/T 5243-2008: Chemical analysis methods for cemented carbide

GB/T 38522-2020: Test method for corrosion performance of cemented carbide

GB/T 2828.1-2012: Sampling procedures for inspection by attributes Part 1: Sampling plans for batch inspection based on acceptance quality limit (AQL)

YS/T 1044-2015: Carbide Nozzles (Reference)

YS/T 1045-2015: Cemented Carbide Agricultural Wear Parts (Reference)

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3. Terms and Definitions

The following terms and definitions apply to this standard:

Cemented carbide grade: A category of cemented carbide materials defined according to chemical composition, physical properties and wear-resistant applications, represented by a specific code (such as YN8, YG20).

Cemented carbide for wear-resistant parts: Cemented carbide specially designed for wear-resistant parts, with high wear resistance and corrosion resistance.

Cemented carbide: A composite material made by powder metallurgy process with tungsten carbide (WC) as the main hard phase and cobalt (Co) or nickel (Ni) as the bonding phase.

Wear resistance: The ability of a material to resist material loss caused by abrasion (such as sand particles, metal friction).

Corrosion resistance: The ability of a material to resist acids, alkalis or other corrosive media.

Grain size: The average size of tungsten carbide grains in cemented carbide, which can be classified as ultrafine (<0.5 μm), fine (0.5–1.5 μm), medium (1.5–3.0 μm), and coarse (>3.0 μm).

Microstructural defects: abnormal structures such as pores, η phase (carbon-poor phase of carbide), cracks, etc. inside the cemented carbide.

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4. Technical Requirements

4.1 Brand classification

Cemented carbide grades for wear-resistant parts are classified by chemical composition and use, mainly including:

Tungsten-cobalt type (YG series):

Composition: tungsten carbide (WC) + cobalt (Co).

Features: high hardness and strong wear resistance.

Application: wire drawing dies, nozzles.

Tungsten nickel type (YN series):

Composition: Tungsten Carbide (WC) + Nickel (Ni).

Features: High corrosion resistance, moderate wear resistance.

Applications: sealing rings, agricultural wear parts.

High cobalt type (YG high cobalt series):

Composition: tungsten carbide (WC) + high cobalt (Co).

Features: high toughness, impact resistance.

Application: cold heading dies, stamping dies.

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Typical grades (some examples):

YG6, YG8, YG20 (tungsten-cobalt type). YN8, YN10 (tungsten-nickel type). YG15, YG25 (high cobalt type).

4.2 Chemical composition

The chemical composition of each brand should meet the following requirements (mass fraction, %):

Brand	WC	Co	Ni	other
YG6	94	6	-	≤0.5
YG8	92	8	-	≤0.5
YG20	80	20	-	≤0.5
YN8	92	-	8	≤0.5
YN10	90	-	10	≤0.5
YG25	75	25	-	≤0.5

Permissible deviation: ±0.5% for major elements (such as WC, Co, Ni), ±0.3% for minor elements.

4.3 Physical and mechanical properties

The performance of each brand should meet the following requirements:

Brand	Hardness (HV30)	Flexural strength (MPa)	Compression strength (MPa)	Density (g/cm³)	Grain size (μm)	Porosity
YG6	1500–1600	1500–1700	4000–5000	14.6–15.0	0.5–1.5	A02B00C00
YG8	1400–1500	1700–1900	4500–5500	14.5–14.9	1.0–2.0	A02B00C00
YG20	1200–1300	2200–2500	5000–6000	13.4–13.8	1.5–3.0	A02B00C00
YN8	1400–1500	1600–1800	4000–5000	14.6–15.0	1.0–2.0	A02B00C00
YN10	1300–1400	1500–1700	4000–5000	14.5–14.9	1.0–2.0	A02B00C00
YG25	1100–1200	2500–2800	5500–6500	13.1–13.5	1.5–3.0	A02B00C00

Porosity: A02B00C00 indicates no obvious pores, in line with GB/T 3488.2-2016.

Grain size: Fine grains (0.5–1.5 μm) are used for highly wear-resistant parts, and coarse grains (1.5–3.0 μm) are used for highly tough parts.

4.4 Microstructure

The grain size is uniform, without abnormally coarse grains.

No η phase, free carbon or other detrimental phases.

The inspection method refers to GB/T 3488.1-2016 and GB/T 3488.2-2016.

4.5 Corrosion resistance

No significant corrosion in acid, alkaline (pH 4–10) or humid environments.

The test method refers to GB/T 38522-2020.

4.6 Application Requirements

The grade selection should be based on abrasion strength, corrosive environment and impact load:

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YG6, YG8: wire drawing dies, nozzles, high wear resistance.

YN8, YN10: Sealing rings, agricultural wear parts, high corrosion resistance.

YG20, YG25: Cold heading dies, stamping dies, high toughness.

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5. Test Methods

5.1 Chemical composition analysis

Method: Determine the contents of tungsten, cobalt, nickel and other elements according to GB/T 5243-2008.

Techniques: X-ray fluorescence spectroscopy (XRF), inductively coupled plasma optical emission spectroscopy (ICP-OES).

5.2 Physical performance test

Hardness: According to GB/T 18377-2001, use Vickers hardness tester (HV30 load).

Bending strength: According to GB/T 18378-2001, use a three-point bending tester.

Compression strength: According to GB/T 18379-2001, use compression testing machine.

Density: According to GB/T 5243-2008, use the water displacement method or densitometer.

5.3 Microstructure analysis

Grain size: measured using a metallographic microscope in accordance with GB/T 3488.1-2016.

Defect assessment: According to GB/T 3488.2-2016, check porosity and η equality.

5.4 Corrosion resistance test

Method: Test in acid, alkali or humid environment according to GB/T 38522-2020.

Conditions: pH 4–10, temperature 20–50°C, time 168 hours.

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6. Inspection Rules

6.1 Inspection categories

Factory inspection: Each batch of products is inspected for chemical composition, hardness, density, and microstructure.

Type inspection: Comprehensive performance inspection (including bending strength, compression strength, and corrosion resistance) is carried out under the following conditions:

New product trial production or brand change.

Changes in production process or raw materials.

Once every 12 months.

Customer contract requirements.

6.2 Sampling

Sampling is done by batch, with each batch containing products of the same brand and batch.

Sampling quantity: According to GB/T 2828.1-2012, AQL is 1.0.

Chemical composition and microstructure: 2–5 samples per batch.

Performance testing: 5–10 samples per batch.

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6.3 Qualification determination

All mandatory inspection items are qualified and the batch is judged to be qualified.

If one item fails to meet the standards, double sampling will be carried out for re-inspection; if the re-inspection still fails, the batch will be deemed unqualified.

If the type inspection fails, production will be suspended and the product will be re-inspected after rectification.

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7. Labeling, packaging, transportation and storage

7.1 Logo

Each batch of materials or packaging should be marked:

Product name (e.g., "hard alloy for wear-resistant parts").

Brand (such as YN8).

batch number.

Manufacturer name.

Standard number (GB/T 18376.3-2015).

Marking method: label or printing, clear and durable.

7.2 Packaging

Material: shockproof and moisture-proof (such as plastic boxes, sealed bags).

Each batch of materials is packaged in groups to prevent mixing.

The outside of the packaging box is marked with: product name, brand, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

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8. Quality Certificate

Each batch of products is accompanied by a quality certificate, which includes:

Standard number (GB/T 18376.3-2015).

Product name, brand, batch number, quantity.

Test results of chemical composition, hardness, flexural strength, compressive strength, density, microstructure, etc.

Corrosion resistance test conclusion.

Manufacturer's name, production date, inspector's signature.

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9. Application Instructions

Wear-resistant scenes:

YG6, YG8: wire drawing dies, nozzles, high wear resistance.

YN8, YN10: Sealing rings, agricultural wear parts (such as plow tips), strong corrosion resistance.

YG20, YG25: Cold heading dies, stamping dies, excellent impact resistance.

Advantages:

High hardness and wear resistance, life span is 5-10 times longer than steel parts.

Corrosion resistant, suitable for acid, alkali or moisture environments.

Improve parts utilization efficiency and reduce maintenance costs.

Notes:

When selecting a grade, consider the abrasive media (grit, metal) and environment (acidity, moisture).

Part design needs to match grade properties (such as grain size and wear resistance).

10. Relationship with other standards

GB/T 18376.1-2015: Cemented carbide grades for cutting tools, some of which overlap with YG grades.

YS/T 1044-2015: Carbide nozzles, involving the application of YG/YN grades.

YS/T 1045-2015: Cemented carbide agricultural wear-resistant parts, involving the application of YN brand.

JB/T 4127-2016: Cemented carbide cold heading dies, involving high cobalt grades.

ISO 513:2012: International Classification of Hard Materials, YG/YN grades correspond to Class K.

11. Background and Significance

Industry Background:

Wear-resistant parts are widely used in molds, wire processing, mechanical seals and other fields. Cemented carbide replaces traditional materials due to its excellent performance.

China's manufacturing industry has a growing demand for high-performance wear-resistant materials, which is driving the standardization of grades.

Standard meaning:

Standardize the performance and application of cemented carbide grades for wear-resistant parts to improve product quality consistency.

Promote the standardization and internationalization of wear-resistant parts manufacturing.

Support industrial production efficiency improvement and cost reduction.

12. Appendix

Appendix A (Normative): Grade Performance and Application

Brand	Hardness (HV30)	Flexural strength (MPa)	Compression strength (MPa)	Recommended applications
YG6	1500–1600	1500–1700	4000–5000	Wire drawing dies, nozzles
YG8	1400–1500	1700–1900	4500–5500	Nozzles, bearings
YG20	1200–1300	2200–2500	5000–6000	Cold heading die
YN8	1400–1500	1600–1800	4000–5000	Sealing rings, agricultural wear

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				parts
YN10	1300–1400	1500–1700	4000–5000	sealing ring
YG25	1100–1200	2500–2800	5500–6500	stamping die

Appendix B (informative): Correspondence of grades to ISO 513

Brand	ISO 513 classification	Application Scenario
YG6	K10–K20	High wear-resistant parts
YG8	K20–K30	General wear-resistant parts
YN8	K20–K30	Corrosion-resistant parts
YG20	K40	High toughness mold

Appendix C (Information): Working Condition Recommendations

YG6: High abrasive strength and low corrosiveness.

YN8: Wet or acidic environment, medium abrasion strength.

YG20: High impact load, medium wear resistance requirements.

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13. Publication Information

Standard number: GB/T 18376.3-2015

Release Date: 2015

Implementation date: 2015

Publishing organization: National Standardization Administration

Responsible unit: National Technical Committee for Standardization of Cutting Tools

Status: Current



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GB/T 18376.2-2015 Cemented Carbide Grades

Part 2: Cemented carbide grades for geological and mining tools

1. Scope

This standard specifies the terms and definitions, classification, technical requirements, test methods, inspection rules, and marking, packaging, transportation, and storage requirements for cemented carbide grades used in geological and mining tools. This standard applies to cemented carbide materials used in geological exploration, mining, tunneling, and oil drilling, primarily for the manufacture of drill bits, picks, rock drilling tools, and tunneling tools. These grades, based on cemented carbide, exhibit high hardness, wear resistance, impact resistance, and corrosion resistance, making them suitable for complex working conditions such as rock and ore.

Scope of application:

Material: Cemented carbide with tungsten carbide (WC) as the main hard phase and cobalt (Co) or other metals as the binder phase.

Applications: geological exploration, coal mining, metal mining, oil drilling, tunneling.

Not applicable: Cemented carbide for non-geological and mining tools (such as cutting tools, wear-resistant parts) or non-cemented carbide materials.

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2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:

GB/T 18377-2001: Test method for Vickers hardness of cemented carbide

GB/T 18378-2001: Test method for flexural strength of cemented carbide

GB/T 18380-2001: Test method for fracture toughness of cemented carbide

GB/T 3488.1-2016: Evaluation of cemented carbide microstructure Part 1: Grain size

GB/T 3488.2-2016: Evaluation of cemented carbide microstructure Part 2: Defects and abnormal structures

GB/T 5243-2008: Chemical analysis methods for cemented carbide

GB/T 38522-2020: Test method for corrosion performance of cemented carbide

GB/T 2828.1-2012: Sampling inspection procedure by attributes

Part 1: Sampling plan for lot-by-lot inspection indexed by acceptance quality limit (AQL)

ISO 513:2012: Classification and application of hard cutting materials for metal removal with defined cutting edges (reference)

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3. Terms and Definitions

The following terms and definitions apply to this standard:

Cemented carbide grade: A category of cemented carbide materials defined according to chemical composition, physical properties and geological mining uses, represented by a specific code (such as YK05, YG11C).

Cemented carbide for geological and mining tools: Cemented carbide designed specifically for geological exploration and mining, with high wear resistance and impact resistance.

Cemented carbide: A composite material made of tungsten carbide (WC) as the main hard phase and cobalt (Co) or other metals as the bonding phase through powder metallurgy process.

Wear resistance: the ability of a material to resist abrasion by rocks and minerals.

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Impact resistance: The ability of a material to withstand rock impact or vibration without breaking.

Grain size: The average size of tungsten carbide grains in cemented carbide, which can be classified as ultrafine (<0.5 μm), fine (0.5–1.5 μm), medium (1.5–3.0 μm), and coarse (>3.0 μm).

Microstructural defects: abnormal structures such as pores, η phase (carbon-poor phase of carbide), cracks, etc. inside the cemented carbide.

Fracture toughness: the ability of a material to resist crack growth, measured in MPa·m^(1/2).

4. Technical requirements

4.1 Brand classification

Cemented carbide grades for geological and mining tools are classified by chemical composition and use, mainly including:

Tungsten-cobalt type (YG series):

Composition: tungsten carbide (WC) + cobalt (Co).

Features: high toughness and strong impact resistance.

Application: medium hard rock, coal mining.

Special type (YK series):

Composition: tungsten carbide (WC) + cobalt (Co) + a small amount of additives (such as TaC, NbC).

Features: high hardness, excellent wear resistance.

Application: hard rock drilling, oil drilling.

Typical grades (some examples):

YG8, YG11C, YG15 (tungsten-cobalt type). YK05, YK20, YK25 (special type).

4.2 Chemical composition

The chemical composition of each brand should meet the following requirements (mass fraction, %):

Brand	WC	Co	TaC/NbC	other
YG8	92	8	-	≤0.5
YG11C	89	11	-	≤0.5
YG15	85	15	-	≤0.5
YK05	94	5	1	≤0.5
YK20	90	8	2	≤0.5
YK25	88	10	2	≤0.5

Permissible deviation: major elements (such as WC, Co) ±0.5%, minor elements (such as TaC) ±0.3%.

4.3 Physical and mechanical properties

The performance of each brand should meet the following requirements:

Brand	Hardness (HV30)	Flexural strength (MPa)	Fracture toughness (MPa·m^(1/2))	Density (g/cm³)	Grain size (μm)	Porosity
YG8	1400–1500	2000–2200	12–15	14.5–14.9	1.0–2.0	A02B00C00

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YG11C	1300–1400	2200–2500	15–18	14.2–14.6	1.5–3.0	A02B00C00
YG15	1200–1300	2500–3000	18–20	13.9–14.3	1.5–3.0	A02B00C00
YK05	1600–1700	1800–2000	10–12	14.8–15.2	0.5–1.5	A02B00C00
YK20	1500–1600	2000–2200	12–14	14.4–14.8	1.0–2.0	A02B00C00
YK25	1400–1500	2100–2300	14–16	14.3–14.7	1.0–2.0	A02B00C00

Porosity: A02B00C00 indicates no obvious pores, in line with GB/T 3488.2-2016.

Grain size: Fine grains (0.5–1.5 μm) are used for hard rock, coarse grains (1.5–3.0 μm) are used for impact conditions.

4.4 Microstructure

The grain size is uniform, without abnormally coarse grains.

No η phase, free carbon or other detrimental phases.

The inspection method refers to GB/T 3488.1-2016 and GB/T 3488.2-2016.

4.5 Corrosion resistance

No significant corrosion in acidic water (pH 3–8) or salt spray environments.

The test method refers to GB/T 38522-2020.

4.6 Application Requirements

The grade should be selected based on rock hardness, impact strength and working conditions:

YK05: Hard rock drilling (such as granite), high hardness.

YG8: Medium hard rock (such as sandstone), balanced performance.

YG11C, YG15: High impact mining (such as roadheader picks), high toughness.

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5. Test Methods

5.1 Chemical composition analysis

Method: Determine the contents of tungsten, cobalt, tantalum, niobium and other elements according to GB/T 5243-2008.

Techniques: X-ray fluorescence spectroscopy (XRF), inductively coupled plasma optical emission spectroscopy (ICP-OES).

5.2 Physical performance test

Hardness: According to GB/T 18377-2001, use Vickers hardness tester (HV30 load).

Bending strength: According to GB/T 18378-2001, use a three-point bending tester.

Fracture toughness: According to GB/T 18380-2001, the single-edge notched beam (SENB) method was adopted.

Density: According to GB/T 5243-2008, use the water displacement method or densitometer.

5.3 Microstructure analysis

Grain size: measured using a metallographic microscope in accordance with GB/T 3488.1-2016.

Defect assessment: According to GB/T 3488.2-2016, check porosity and η equality.

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5.4 Corrosion resistance test

Method: Tested in acidic water or salt spray environment according to GB/T 38522-2020.

Conditions: pH 3–8, temperature 20–60°C, time 240 hours.

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6. Inspection Rules

6.1 Inspection categories

Factory inspection: Each batch of products is inspected for chemical composition, hardness, density, and microstructure.

Type inspection: Comprehensive performance inspection (including bending strength, fracture toughness, and corrosion resistance) is carried out under the following circumstances:

New product trial production or brand change.

Changes in production process or raw materials.

Once every 12 months.

Customer contract requirements.

6.2 Sampling

Sampling is done by batch, with each batch containing products of the same brand and batch.

Sampling quantity: According to GB/T 2828.1-2012, AQL is 1.0.

Chemical composition and microstructure: 2–5 samples per batch.

Performance testing: 5–10 samples per batch.

6.3 Qualification determination

All mandatory inspection items are qualified and the batch is judged to be qualified.

If one item fails to meet the standards, double sampling will be carried out for re-inspection; if the re-inspection still fails, the batch will be deemed unqualified.

If the type inspection fails, production will be suspended and the product will be re-inspected after rectification.

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7. Labeling, packaging, transportation and storage

7.1 Logo

Each batch of materials or packaging should be marked:

Product name (e.g., "hard alloy for geological mining").

Brand (such as YG11C).

batch number.

Manufacturer name.

Standard number (GB/T 18376.2-2015).

Marking method: label or printing, clear and durable.

7.2 Packaging

Material: shockproof and moisture-proof (such as plastic boxes, sealed bags).

Each batch of materials is packaged in groups to prevent mixing.

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The outside of the packaging box is marked with: product name, brand, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

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8. Quality Certificate

Each batch of products is accompanied by a quality certificate, which includes:

Standard number (GB/T 18376.2-2015).

Product name, brand, batch number, quantity.

Test results of chemical composition, hardness, flexural strength, fracture toughness, density, microstructure, etc.

Corrosion resistance test conclusion.

Manufacturer's name, production date, inspector's signature.

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9. Application Notes

Mining scenario:

YK05: Hard rock drill bit (such as granite), high hardness and strong wear resistance.

YG8: Medium hard rock drilling tool (such as sandstone), balanced performance.

YG11C: Tunnel boring machine pick, excellent impact resistance.

YG15: Oil drill bit, high toughness, suitable for high impact.

Advantages:

High wear and impact resistance, lifespan 3–8 times longer than steel tools.

Corrosion resistance, adaptable to acidic water or salt spray environment.

Improve mining efficiency and reduce replacement frequency.

Notes:

When selecting a grade, consider the rock hardness (Mohs hardness) and the impact frequency.

Tool design needs to match grade properties (such as grain size and impact strength).

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10. Relationship with other standards

GB/T 18376.1-2015: Cemented carbide grades for cutting tools, some of which overlap with YG grades.

JB/T 12609-2016: Cemented carbide geological mining tools, involving brand applications.

ISO 513:2012: International Classification of Hard Materials, YG/YK grades correspond to Class K.

GB/T 38522-2020: Corrosion resistance test, providing environmental performance verification.

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11. Background and Significance

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Industry Background:

The geological exploration and mining industries have high requirements for tool materials, and cemented carbide has become the first choice due to its excellent performance.

China is a major mineral producing country in the world, and the demand for coal, metal mines and oil drilling has driven the standardization of grades.

Standard meaning:

Standardize the performance and application of cemented carbide grades for geology and mining to improve product quality consistency.

Promote the standardization and internationalization of mining equipment.

Support efficient mining and resource development.

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12. Appendix

Appendix A (Normative): Grade Performance and Application

Brand	Hardness (HV30)	Flexural strength (MPa)	Fracture toughness (MPa·m^(1/2))	Recommended applications
YG8	1400–1500	2000–2200	12–15	Rock drilling tools, picks
YG11C	1300–1400	2200–2500	15–18	Tunnel boring machine picks
YG15	1200–1300	2500–3000	18–20	oil drill bit
YK05	1600–1700	1800–2000	10–12	Hard rock drill bits
YK20	1500–1600	2000–2200	12–14	geological drilling
YK25	1400–1500	2100–2300	14–16	Hard rock picks

Appendix B (informative): Correspondence of grades to ISO 513

Brand	ISO 513 classification	Application Scenario
YG8	K20–K30	Medium hard rock and coal mining
YG11C	K30–K40	High Impact Mining
YG15	K40	Oil drilling and tunneling
YK05	K10	Hard rock drilling

Appendix C (Information): Working Condition Recommendations

YK05: Mohs hardness ≥7, low impact frequency.

YG15: Mohs hardness ≤6, high impact frequency.

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13. Publication Information

Standard number: GB/T 18376.2-2015

Release Date: 2015

Implementation date: 2015

Publishing organization: National Standardization Administration

Responsible unit: National Technical Committee for Standardization of Cutting Tools

Status: Current

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appendix:

GB/T 18376.1-2015 Cemented Carbide Grades

Part 1: Cemented carbide grades for cutting tools

1. Scope

This standard specifies the terminology and definitions, classification, technical requirements, test methods, inspection rules, and marking, packaging, transportation, and storage requirements for cemented carbide grades used in cutting tools. This standard applies to cemented carbide materials used in metal cutting, primarily for the manufacture of cutting tools such as indexable inserts, solid cutting tools, milling cutters, and drills, covering turning, milling, drilling, and boring. These grades, based on cemented carbide, exhibit high hardness, wear resistance, and appropriate toughness, adapting to diverse workpiece materials and cutting conditions.

Scope of application:

Material: Cemented carbide with tungsten carbide (WC) as the main hard phase and cobalt (Co) or other metals as the binder phase.

Application: Metal cutting (steel, cast iron, stainless steel, aluminum alloy, etc.).

Not applicable: non-cutting tool carbide (such as mining tools, wear-resistant parts) or non-carbide materials (such as ceramics, CBN, PCD).

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2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:

GB/T 18377-2001: Test method for Vickers hardness of cemented carbide

GB/T 18378-2001: Test method for flexural strength of cemented carbide

GB/T 3488.1-2016: Evaluation of cemented carbide microstructure Part 1: Grain size

GB/T 3488.2-2016: Evaluation of cemented carbide microstructure Part 2: Defects and abnormal structures

GB/T 5243-2008: Chemical analysis methods for cemented carbide

GB/T 20705-2006: Classification and application of cemented carbide grades

ISO 513:2012: Classification and application of hard cutting materials for metal removal with defined cutting edges

GB/T 2828.1-2012: Sampling procedures for inspection by attributes Part 1: Sampling plans for batch inspection based on acceptance quality limit (AQL)

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3. Terms and Definitions

The following terms and definitions apply to this standard:

Cemented carbide grade: A category of cemented carbide materials defined according to chemical composition, physical properties and cutting applications, represented by a specific code (such as YG6, YT15).

Cemented carbide for cutting tools: Cemented carbide specially designed for metal cutting processing, with high hardness, wear resistance and appropriate toughness.

Cemented carbide: A composite material made of tungsten carbide (WC) as the main hard phase and cobalt (Co) or other metals as the bonding phase through powder metallurgy process.

Wear resistance: A material's ability to resist wear during cutting, usually related to hardness.

Toughness: A material's ability to resist breaking or chipping, usually related to flexural strength and fracture toughness.

Grain size: The average size of tungsten carbide grains in cemented carbide, which can be classified as ultrafine (<0.5 μm), fine (0.5–1.5 μm), medium (1.5–3.0 μm), and coarse (>3.0 μm).

Microstructural defects: abnormal structures such as pores, η phase (carbon-poor phase of carbide), cracks, etc. inside the cemented carbide.

4. Technical Requirements

4.1 Brand classification

Cemented carbide grades for cutting tools are divided into the following three categories according to chemical composition and application, in accordance with the classification methods of GB/T 20705-2006 and ISO 513:2012:

Tungsten-cobalt type (YG series):

Composition: tungsten carbide (WC) + cobalt (Co).

Features: High toughness, moderate wear resistance.

Application: Cast iron, non-ferrous metals (such as aluminum, copper), and non-metallic material processing.

Color coding: Red (Class K, ISO 513).

Tungsten-titanium-cobalt (YT series):

Composition: tungsten carbide (WC) + titanium carbide (TiC) + cobalt (Co).

Characteristics: high hardness, strong wear resistance, slightly lower toughness.

Application: Steel and alloy steel processing.

Color coding: blue (Type P, ISO 513).

General purpose (YW series):

Composition: tungsten carbide (WC) + titanium carbide (TiC) + tantalum carbide (TaC) / niobium carbide (NbC) + cobalt.

Features: Excellent comprehensive performance, balanced wear resistance and toughness.

Applications: stainless steel, high-strength steel, and difficult-to-machine materials.

Color coding: Yellow (Type M, ISO 513).

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Typical grades (some examples):

YG6, YG8, YG3X (tungsten-cobalt type).

YT15, YT14, YT5 (tungsten-titanium-cobalt).

YW1, YW2, YA6 (general category).

4.2 Chemical composition

The chemical composition of each brand should meet the following requirements (mass fraction, %):

Brand	WC	Co	TiC	TaC/NbC	other
YG6	94	6	-	-	≤0.5
YG8	92	8	-	-	≤0.5
YT15	79	6	15	-	≤0.5
YT5	85	10	5	-	≤0.5
YW1	82	8	5	5	≤0.5
YW2	80	6	8	6	≤0.5

Allowable deviation: major elements (such as WC, Co) ±0.5%, minor elements (such as TiC, TaC) ±0.3%.

4.3 Physical and mechanical properties

The performance of each brand should meet the following requirements:

Brand	Hardness (HV30)	Flexural strength (MPa)	Density (g/ cm³)	Grain size (μm)	Porosity
YG6	1500–1600	1500–1700	14.6–15.0	0.5–1.5	A02B00C00
YG8	1400–1500	1700–1900	14.5–14.9	1.0–2.0	A02B00C00
YT15	1600–1700	1300–1500	11.0–11.7	0.5–1.5	A02B00C00
YT5	1300–1400	1800–2000	12.5–13.2	1.0–2.0	A02B00C00
YW1	1550–1650	1400–1600	12.5–13.0	0.5–1.5	A02B00C00
YW2	1500–1600	1500–1700	12.0–12.8	0.5–1.5	A02B00C00

Porosity: A02B00C00 indicates no obvious pores, in line with GB/T 3488.2-2016.

Grain size: Predominantly fine grains (0.5–1.5 μm), improving hardness and wear resistance.

4.4 Microstructure

The grain size is uniform, without abnormally coarse grains.

No η phase, free carbon or other detrimental phases.

The inspection method refers to GB/T 3488.1-2016 and GB/T 3488.2-2016.

4.5 Application Requirements

The grade selection should be based on the material being processed, cutting conditions (speed, feed, depth) and processing type (finishing, roughing):

YG series: Suitable for high-speed, low-load processing, such as aluminum alloy finishing (YG3X).

YT series: Suitable for medium to low speed, high load processing, such as rough processing of steel (YT5).

YW series: Suitable for interrupted cutting or difficult-to-cut materials such as stainless steel (YW2).

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5. Test Methods

5.1 Chemical composition analysis

Method: According to GB/T 5243-2008, the contents of tungsten, cobalt, titanium, tantalum, niobium and other elements were determined.

Techniques: X-ray fluorescence spectroscopy (XRF), inductively coupled plasma optical emission spectroscopy (ICP-OES).

5.2 Physical performance test

Hardness: According to GB/T 18377-2001, use Vickers hardness tester (HV30 load).

Bending strength: According to GB/T 18378-2001, use a three-point bending tester.

Density: According to GB/T 5243-2008, use the water displacement method or densitometer.

5.3 Microstructure analysis

Grain size: measured using a metallographic microscope in accordance with GB/T 3488.1-2016.

Defect assessment: According to GB/T 3488.2-2016, check porosity and η equality.

6. Inspection Rules

6.1 Inspection categories

Factory inspection: Each batch of products is inspected for chemical composition, hardness, density, and microstructure.

Type inspection: Comprehensive performance inspection (including bending strength and grain size) is carried out under the following conditions:

New product trial production or brand change.

Changes in production process or raw materials.

Once every 12 months.

Customer contract requirements.

6.2 Sampling

Sampling is done by batch, with each batch containing products of the same brand and batch.

Sampling quantity: According to GB/T 2828.1-2012, AQL is 1.0.

Chemical composition and microstructure: 2–5 samples per batch.

Performance testing: 5–10 samples per batch.

6.3 Qualification determination

All mandatory inspection items are qualified and the batch is judged to be qualified.

If one item fails to meet the standards, double sampling will be carried out for re-inspection; if the re-inspection still fails, the batch will be deemed unqualified.

If the type inspection fails, production will be suspended and the product will be re-inspected after rectification.

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7. Labeling, packaging, transportation and storage

7.1 Logo

Each batch of materials or packaging should be marked:

Product name (e.g., "Carbide Cutting Material").

Brand (such as YG8).

batch number.

Manufacturer name.

Standard number (GB/T 18376.1-2015).

Marking method: label or printing, clear and durable.

7.2 Packaging

Material: shockproof and moisture-proof (such as plastic boxes, sealed bags).

Each batch of materials is packaged in groups to prevent mixing.

The outside of the packaging box is marked with: product name, brand, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

---

8. Quality Certificate

Each batch of products is accompanied by a quality certificate, which includes:

Standard number (GB/T 18376.1-2015).

Product name, brand, batch number, quantity.

Test results of chemical composition, hardness, flexural strength, density, microstructure, etc.

Manufacturer's name, production date, inspector's signature.

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9. Application Notes

Processing scenarios:

YG6: High-speed finishing of cast iron and aluminum alloy, cutting speed 150–300 m/min.

YG8 : Rough machining of cast iron and non-ferrous metals, cutting speed 80–150 m/min.

YT15: Semi-finishing of steel and alloy steel, cutting speed 100-200 m/min.

YT5: Heavy cutting of steel, cutting speed 50–100 m/min.

YW2: Interrupted cutting of stainless steel and difficult-to-cut materials, cutting speed 60–120 m/min.

Advantages:

High hardness and wear resistance for extended tool life (10–50 times longer than high-speed steel).

A variety of grades are available to suit different materials and cutting conditions.

Aligned with ISO 513 classification to facilitate international trade.

Notes:

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When choosing a grade, consider the hardness of the material being machined, cutting speed and feed rate.

The tool geometry (such as clearance angle, edge passivation) must match the brand.

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10. Relationship with other standards

GB/T 20705-2006: Brand classification and application, providing the corresponding relationship with ISO 513.

GB/T 1832-2017: Marking of cutting tool inserts, involving the matching of inserts and grades.

ISO 513:2012: International standard for the classification of hard materials. This standard is equivalent to or partially modifies ISO 513:2012.

GB/T 20707-2006: Geometric dimensions and tolerances of cemented carbide inserts, involving insert manufacturing.

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11. Background and Significance

Industry Background:

Cemented carbide cutting tools are the core of modern manufacturing and are widely used in automobile, aviation, machining and other fields.

As a global manufacturing power, China's standardization of cemented carbide grades has promoted the development of the tool industry.

Standard meaning:

Standardize the performance and application of cemented carbide grades for cutting tools to improve product quality consistency.

Promote the standardization and internationalization of tool manufacturing and reduce production costs.

Support the development of CNC machining and efficient cutting technology.

---

12. Appendix

Appendix A (Normative): Grade Performance and Application

Brand	Hardness (HV30)	Flexural strength (MPa)	Recommended applications
YG6	1500–1600	1500–1700	Cast iron and aluminum alloy finishing
YG8	1400–1500	1700–1900	Rough machining of cast iron and non-ferrous metals
YT15	1600–1700	1300–1500	Semi-finishing of steel and alloy steel
YT5	1300–1400	1800–2000	Heavy steel cutting
YW1	1550–1650	1400–1600	Finishing of stainless steel and difficult-to-process materials
YW2	1500–1600	1500–1700	Stainless steel, interrupted cutting

Appendix B (informative): Correspondence of grades to ISO 513

Brand	ISO 513 classification	Applied Materials
YG6	K10–K20	Cast iron, non-ferrous metals
YG8	K20–K30	Cast iron, non-ferrous metals
YT15	P10–P20	Steel, alloy steel
YT5	P30–P40	Steel, alloy steel (heavy cutting)
YW1	M10–M20	Stainless steel and difficult-to-process materials

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YW2	M20–M30	Stainless steel and difficult-to-process materials

Appendix C (Informative): Cutting Parameter Recommendations

YG6: cutting speed 150–300 m/min, feed rate 0.1–0.3 mm/r.

YT15: cutting speed 100–200 m/min, feed rate 0.2–0.5 mm/r.

YW2: cutting speed 60–120 m/min, feed rate 0.15–0.4 mm/r.

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13. Publication Information

Standard number: GB/T 18376.1-2015

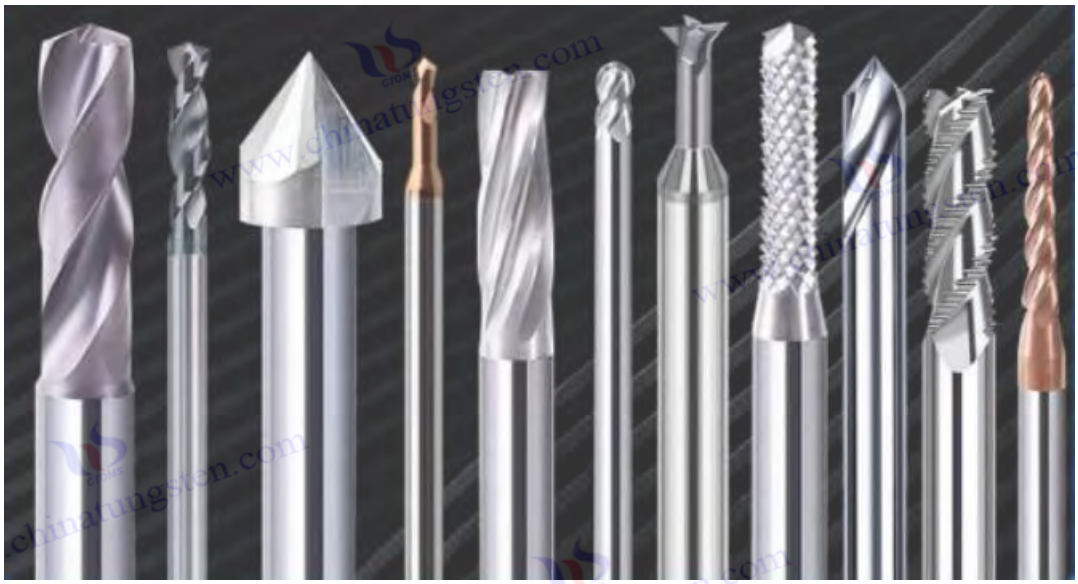
Release Date: 2015

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appendix:

GB/T 20707-2006

Carbide insert geometry and tolerances

1. Scope

This standard specifies the terms and definitions, technical requirements, test methods, inspection rules, marking, packaging, transportation, and storage requirements for the geometric dimensions and tolerances of cemented carbide inserts. This standard applies to cemented carbide indexable inserts for cutting tools (hereinafter referred to as inserts), including those used in turning, milling, drilling, boring, and other processes. These inserts are primarily made of cemented carbide and have defined geometric shapes and dimensions. They are designed to fit into toolholders or cutter bodies to ensure cutting accuracy and efficiency.

Scope of application:

Material: Cemented carbide with tungsten carbide (WC) as the matrix and cobalt (Co) or other metals as the binder phase.

Application: Metal cutting (steel, cast iron, stainless steel, etc.).

Not suitable for: non-carbide inserts (such as ceramic, CBN, PCD) or non-indexable inserts.

---

2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:

GB/T 1832-1994: Marking of indexable inserts for cutting tools (now GB/T 1832-2017)

GB/T 18376.1-2001: Cemented carbide grades Part 1: Cemented carbide grades for cutting tools (now GB/T 18376.1-2015)

GB/T 20708-2006: Surface quality inspection of cemented carbide inserts

GB/T 2828.1-2003: Sampling procedures for inspection by attributes — Part 1: Sampling plans for lot-by-lot inspection indexed by acceptance quality limit (AQL) (now GB/T 2828.1-2012)

ISO 1832:2004: Indexable inserts for cutting tools — Designation (Refer to international standards)

---

3. Terms and Definitions

The following terms and definitions apply to this standard:

Carbide Insert: An indexable cutting component made of cemented carbide, having multiple cutting edges, designed to be clamped into a tool holder or cutter body and rotated or replaced after wear.

Geometric dimensions: characteristic dimensions of the blade, including inscribed circle diameter (or side length), thickness, fillet radius, etc.

Tolerance: The allowable deviation of the blade's geometric dimensions to ensure the accuracy of fit with the tool holder.

Inscribed circle diameter: The diameter of the circle inscribed in the blade shape (such as triangle, square), used to determine the blade size.

Corner radius: The arc radius of the corner point of the blade cutting edge affects the cutting force and surface quality.

Tolerance grade: A classification of insert dimensional accuracy, such as A, F, G, M, U, which defines the deviation range of the seat surface and cutting edge.

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4. Technical Requirements

4.1 Blade shape and size

The geometric shape and size of the blade should comply with the marking requirements of GB/T 1832-1994 (now GB/T 1832-2017). The main shapes include:

Square (S), triangle (T), diamond (C, D, V), circle (R), hexagon (H), octagon (O), etc.

Main size parameters:

Inscribed circle diameter (d): such as 6.35 mm, 9.52 mm, 12.70 mm, 25.40 mm.

Thickness(s): such as 2.38 mm, 3.97 mm, 4.76 mm, 6.35 mm.

Fillet radius (rε): such as 0.4 mm, 0.8 mm, 1.6 mm.

Side length (l): For non-circular inserts (such as square), the side length is related to the inscribed circle diameter.

Aperture (d1): For inserts with holes, the aperture is used for fixing, such as 3.4 mm, 4.5 mm.

4.2 Tolerance grade

The tolerance grades of the blades are divided into A, F, G, M, and U. The specific deviation ranges are as follows (refer to GB/T 1832-2017):

Tolerance grade	Inscribed circle diameter tolerance (mm)	Thickness tolerance (mm)	Side length tolerance (mm)	Aperture tolerance (mm)
A	±0.005	±0.005	±0.005	±0.025
F	±0.013	±0.025	±0.013	±0.025
G	±0.025	±0.025	±0.025	±0.025
M	±0.05–±0.13	±0.05–±0.13	±0.05–±0.13	±0.05–±0.13
U	±0.08–±0.25	±0.08–±0.25	±0.08–±0.25	±0.08–±0.25

Selection basis:

A, F: High-precision machining (such as precision turning and precision milling).

G, M: general processing (such as semi-finishing, roughing).

U: Rough machining or low precision requirements.

4.3 Material requirements

The blade material should comply with GB/T 18376.1-2001 (now GB/T 18376.1-2015). Recommended grades include:

YG6, YG8: Suitable for cast iron and non-ferrous metal processing.

YT15, YT5: suitable for steel and alloy steel processing.

YW1, YW2: Suitable for stainless steel and difficult-to-process materials.

Chemical composition (example):

Tungsten carbide (WC): ≥80% (mass fraction).

Cobalt (Co): 5%–15%.

Others (such as TiC, TaC): ≤10%.

4.4 Surface quality

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The cutting edge has no defects such as chipping, cracks, burns, etc.

There are no obvious pores or scratches on the seat surface (support surface).

Surface roughness (Ra): ≤1.6 μm (cutting edge), ≤3.2 μm (seat surface).

For inspection methods, refer to GB/T 20708-2006.

4.5 Geometric Features

Rake angle: According to GB/T 1832-1994, common rake angles are 0° (N), 7° (C), and 11° (P).

Cutting edge condition: sharp (F), blunt (T), chamfered (E), etc., depending on processing requirements.

Chipbreaker: If there is a chipbreaker, it should be uniform and free of machining defects.

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5. Test Methods

5.1 Geometric Dimension Measurement

Inscribed circle diameter (d): Use a projector or coordinate measuring machine with an accuracy of ±0.001 mm.

Thickness (s): Use micrometer with an accuracy of ±0.001 mm.

Corner radius (rε): Use a profilometer or microscope, with an accuracy of ±0.01 mm.

Aperture (d1): Use an inside micrometer or plug gauge with an accuracy of ±0.01 mm.

Side length (l): Use a projector, accuracy ±0.001 mm.

5.2 Tolerance Verification

Check dimensional deviations according to tolerance classes (A, F, G, M, U).

Measuring points: At least 3 key dimensions of each insert (such as inscribed circle diameter, thickness, and corner radius).

Tools: Comply with GB/T 3177 (Geometrical measurement test methods).

5.3 Surface quality inspection

Method: According to GB/T 20708-2006, visual inspection or microscopy (magnification 10–50 times) was used.

Inspection items: cutting edge integrity, seat surface flatness, surface defects.

5.4 Material Verification

Chemical composition: According to GB/T 5243-2008, using XRF or ICP-OES.

Hardness: According to GB/T 18377-2001, Vickers hardness tester (HV30 load).

---

6. Inspection Rules

6.1 Inspection categories

Factory inspection: Each batch of blades is inspected for geometric dimensions, tolerances, and surface quality.

Type inspection: A comprehensive inspection (including material composition, hardness, and all dimensions) is carried out in the following cases:

New product trial production or design changes.

Changes in production process or raw materials.

Once every 12 months.

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Customer contract requirements.

6.2 Sampling

Sampling is done by batch, and each batch of blades must be of the same brand, specification and furnace.

Sampling quantity: According to GB/T 2828.1-2003, AQL is 1.0.

Geometric dimensions and surface quality: batches of 10–20 pieces.

Material and hardness: 2–5 pieces per batch.

6.3 Qualification determination

All mandatory inspection items are qualified and the batch is judged to be qualified.

If one item fails to meet the standards, double sampling will be carried out for re-inspection; if the re-inspection still fails, the batch will be deemed unqualified.

If the type inspection fails, production will be suspended and the product will be re-inspected after rectification.

---

7. Labeling, packaging, transportation and storage

7.1 Logo

Each blade or package should be marked with:

Product name (e.g., "Carbide Inserts").

Identification code (e.g. SPMN 120408, in accordance with GB/T 1832).

Brand (such as YG8).

Tolerance grade (such as M).

Manufacturer name.

Production batch number.

Standard number (GB/T 20707-2006).

Marking method: laser engraving or label, wear-resistant and clear.

7.2 Packaging

Materials: shockproof and moisture-proof (such as plastic boxes, foam pads, sealed bags).

Each blade is individually packaged to prevent collision.

The outside of the packaging box is marked with: product name, identification code, brand, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

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8. Quality Certificate

Each batch of blades is accompanied by a quality certificate, which includes:

Standard number (GB/T 20707-2006).

Product name, identification code, brand, tolerance grade, batch number, quantity.

Inspection results of geometric dimensions, tolerances, surface quality, hardness, etc.

Manufacturer's name, production date, inspector's signature.

9. Application Notes

Processing scenarios:

Turning inserts: such as TNMG 160408 (triangular, general purpose), YG8 is recommended, suitable for rough machining of cast iron.

Milling inserts: such as SPMN 120408 (square), YT15 is recommended, suitable for steel processing.

Drilling inserts: such as WCMX 060308 (pentagonal), YW2 is recommended, suitable for stainless steel.

Advantages:

High-precision tolerances (class A, F) ensure cutting stability and surface quality.

Standard dimensions are compatible with toolholders according to ISO 1832.

A variety of grades are available to suit different materials and processing conditions.

Notes:

When selecting a tolerance grade, consider machining accuracy and cost (Grade A is expensive, Grade M is economical).

The fit between the blade and the tool holder must comply with ISO 5608 (tool holder standard).

10. Relationship with other standards

GB/T 1832-1994: Blade marking, provides coding rules for dimensions and tolerances.

GB/T 18376.1-2015: Provides cutting tool grades.

GB/T 20708-2006 : Surface quality inspection, supplements the quality requirements of this standard.

ISO 1832:2004: International standard for marking blades. This standard is equivalent to or partially modifies ISO 1832:2004.

11. Background and Significance

Industry Background: Carbide inserts are core components of modern cutting processes and are widely used in the automotive, aviation, and mold manufacturing industries. The rapid development of China's manufacturing industry is driving the standardization of inserts to improve machining efficiency and international competitiveness.

Standard meaning:

Standardize the blade geometry and tolerances to ensure interchangeability with the tool holder and machining accuracy.

Promote the standardization of blade production and application and reduce manufacturing costs.

Support the development of CNC machining and automated production lines.

12. Appendix

Appendix A (Normative): Typical Insert Dimensions and Tolerances

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Blade type	Identification code	Inscribed circle diameter (mm)	Thickness (mm)	Corner radius (mm)	Tolerance grade
square	SPMN 120408	12.70	4.76	0.8	M
triangle	TNMG 160408	16.50	4.76	0.8	G
diamond	CCMT 09T304	9.52	3.97	0.4	F
round	RCMX 1204MO	12.00	4.76	-	U

Appendix B (Informative): Examples of Tolerance Grade Applications

Grade A: High-precision finishing, surface roughness Ra ≤0.8 μm.

M-class: general turning and milling, high cost performance.

U grade: heavy cutting or interrupted machining, impact resistant.

Appendix C (Informative): Blade and handle matching

The contact area between the insert seat and the tool holder is ≥80% to ensure stable clamping.

Fit clearance: ≤0.02 mm (A, F grade), ≤0.05 mm (M, U grade).

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13. Publication Information

Standard number: GB/T 20707-2006

Release Date: 2006

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Publishing organization: National Standardization Administration

Affiliated unit: National Technical Committee for Standardization of Cutting Tools

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appendix:

JB/T 12609-2016

Carbide geological mining tools

1. Scope

This standard specifies the terms and definitions, technical requirements, test methods, inspection rules, and marking, packaging, transportation, and storage requirements for cemented carbide geological and mining tools. This standard applies to geological and mining tools that use cemented carbide as their primary cutting or wear-resistant components, including but not limited to drill bits, picks, rock drilling tools, and tunneling tools. These tools are used in geological exploration, mining, tunneling, and oil drilling operations, requiring high hardness, wear resistance, impact resistance, and corrosion resistance to cope with complex rock and ore conditions.

Scope of application:

Material: Cemented carbide with tungsten carbide (WC) as the matrix and cobalt (Co) or other metals as the binder phase.

Applications: geological exploration, coal mining, metal mining, oil drilling, tunneling.

Not applicable: tools made of non-carbide materials (such as steel, ceramics) or not for geological mining purposes.

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2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:

GB/T 18376.2-2015: Cemented carbide grades Part 2: Cemented carbide grades for geological and mining tools

GB/T 18377-2001: Test method for Vickers hardness of cemented carbide

GB/T 18378-2001: Test method for flexural strength of cemented carbide

GB/T 18380-2001: Test method for fracture toughness of cemented carbide

GB/T 3488.1-2016: Evaluation of cemented carbide microstructure Part 1: Grain size

GB/T 3488.2-2016: Evaluation of cemented carbide microstructure Part 2: Defects and abnormal structures

GB/T 5243-2008: Chemical analysis methods for cemented carbide

GB/T 38522-2020: Test method for corrosion performance of cemented carbide

GB/T 2828.1-2012: Sampling procedures for inspection by attributes Part 1: Sampling plans for batch inspection based on acceptance quality limit (AQL)

---

3. Terms and Definitions

The following terms and definitions apply to this standard:

Cemented carbide geological mining tools: tools with cemented carbide as the main cutting or wear-resistant components, used for geological exploration, mining or tunneling, such as drill bits and picks.

Cemented carbide: A composite material made of tungsten carbide (WC) as the main hard phase and cobalt (Co) or other metals as the bonding phase through powder metallurgy process.

Wear resistance: The ability of a tool to resist material loss caused by abrasion of rocks and minerals.

Impact resistance: The ability of a tool to withstand rock impact or vibration without breaking.

Grain size: The average size of tungsten carbide grains in cemented carbide, which can be classified as ultrafine (<0.5 μm), fine (0.5–1.5 μm), medium (1.5–3.0 μm), and coarse (>3.0 μm).

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Microstructural defects: abnormal structures such as pores, η phase (carbon-poor phase of carbide), cracks, etc. inside the cemented carbide.

Fracture toughness: The ability of cemented carbide to resist crack growth, measured in MPa·m^(1/2).

---

4. Technical Requirements

4.1 Material grade

Carbide geological mining tools should use geological and mining tool brands that comply with GB/T 18376.2-2015.

Recommended brands include:

YK05: High hardness, suitable for hard rock drilling.

YG8: Balances wear resistance and toughness, suitable for medium-hard rock formations.

YG11C: High toughness, suitable for mining conditions with strong impact.

YG15: Ultra-high toughness, suitable for high-impact tunneling tools.

Chemical composition:

Tungsten carbide (WC): ≥80% (mass fraction).

Cobalt (Co): 6%–15% (depending on the grade).

Other additives (such as TaC, NbC): ≤5%.

4.2 Physical and mechanical properties

The carbide components of the tool should meet the following performance requirements:

Performance indicators	Scope of requirements	Test Method
Vickers hardness (HV30)	1200–1700 (depending on brand)	GB/T 18377-2001
Flexural strength (MPa)	1800–3000 (depending on brand)	GB/T 18378-2001
Fracture toughness (MPa·m^(1/2))	10–20 (depending on brand)	GB/T 18380-2001
Density (g/ cm^3)	13.5–15.0 (depending on brand)	GB/T 5243-2008
Grain size	Fine (0.5–1.5 μm) or medium (1.5–3.0 μm)	GB/T 3488.1-2016
Porosity	A02B00C00 (no obvious pores)	GB/T 3488.2-2016
Corrosion resistance	No obvious corrosion (acidic water, salt spray environment)	GB/T 38522-2020

4.3 Geometric dimensions and tolerances

Dimensions and tolerances shall comply with design drawings or contract requirements.

Tolerance grades for carbide components: IT6–IT8 (depending on tool type).

Surface roughness (Ra): ≤3.2 μm (non-working surface), ≤1.6 μm (working surface).

Reference standard: GB/T 20707-2006 (Geometric dimensions and tolerances of cemented carbide inserts).

4.4 Surface quality

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The working surface has no defects such as cracks, broken edges, and pores.

Minor machining marks are permitted on non-working surfaces but shall not affect performance.

The inspection method refers to GB/T 20708-2006 (surface quality inspection of cemented carbide inserts).

4.5 Microstructure

The grain size is uniform, without abnormally coarse grains.

No η phase, free carbon or other detrimental phases.

The inspection method refers to GB/T 3488.1-2016 and GB/T 3488.2-2016.

4.6 Assembly requirements

The connection between the carbide parts and the steel body (or substrate) (such as brazing, mechanical clamping) should be firm without loosening or falling off.

Brazing quality: The weld is continuous, without pores or cracks, and meets the relevant requirements of JB/T 12608-2016 (Technical Conditions for EDM of Cemented Carbide).

---

5. Test Method

5.1 Chemical composition analysis

Method: Determine the contents of tungsten, cobalt, tantalum, niobium and other elements according to GB/T 5243-2008.

Techniques: X-ray fluorescence spectroscopy (XRF), inductively coupled plasma optical emission spectroscopy (ICP-OES).

5.2 Physical performance test

Hardness: According to GB/T 18377-2001, use Vickers hardness tester (HV30 load).

Bending strength: According to GB/T 18378-2001, use a three-point bending tester.

Fracture toughness: According to GB/T 18380-2001, the single-edge notched beam (SENB) method was adopted.

Density: According to GB/T 5243-2008, use the water displacement method or densitometer.

5.3 Microstructure analysis

Grain size: measured using a metallographic microscope in accordance with GB/T 3488.1-2016.

Defect assessment: According to GB/T 3488.2-2016, check porosity and η equality.

5.4 Corrosion resistance test

Method: According to GB/T 38522-2020, the test was carried out in a simulated mining environment (acidic water, salt spray).

Conditions: pH 3–8, temperature 20–60°C, time 240 hours.

5.5 Dimensions and surface quality

Dimension measurement: Use micrometer, projector or coordinate measuring machine in accordance with GB/T 20707-2006.

Surface quality: visual inspection or microscopic observation, refer to GB/T 20708-2006.

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5.6 Assembly Quality

Check the firmness of brazing or clamping parts by ultrasonic testing or tensile testing.

Weld quality: Observe under a microscope to confirm there are no pores or cracks.

---

6. Inspection Rules

6.1 Inspection categories

Factory inspection: Each batch of products is inspected for chemical composition, hardness, density, size, surface quality, and assembly quality.

Type inspection: Comprehensive performance inspection (including flexural strength, fracture toughness, microstructure, and corrosion resistance) is carried out under the following circumstances:

New product trial production or design changes.

Changes in production process or raw materials.

Once every 12 months.

Customer contract requirements.

6.2 Sampling

Sampling is done by batch, and each batch has products of the same brand, specification and batch.

Sampling quantity: According to GB/T 2828.1-2012, AQL is 1.0.

Chemical composition and microstructure: 2–5 samples per batch.

Performance and size: 5–10 samples per batch.

Assembly quality: 10–20 samples per batch.

6.3 Qualification determination

All mandatory inspection items are qualified and the batch is judged to be qualified.

If one item fails to meet the standards, double sampling will be carried out for re-inspection; if the re-inspection still fails, the batch will be deemed unqualified.

If the type inspection fails, production will be suspended and the product will be re-inspected after rectification.

---

7. Labeling, packaging, transportation and storage

7.1 Logo

Each tool or package should be marked with:

Product name (e.g., "Carbide Pick").

Brand (such as YG11C).

Specification model (such as size or drawing number).

Manufacturer name.

Production batch number.

Standard number (JB/T 12609-2016).

Marking method: laser engraving, label or printing, wear-resistant and clear.

7.2 Packaging

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Materials: shockproof and moisture-proof (such as plastic boxes, foam pads, sealed bags).

Each piece should be packed individually or in groups to prevent collision.

The outside of the packaging box is marked with: product name, brand, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

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8. Quality Certificate

Each batch of products is accompanied by a quality certificate, which includes:

Standard number (JB/T 12609-2016).

Product name, brand, specification, batch number and quantity.

Test results of chemical composition, hardness, flexural strength, fracture toughness, density, etc.

Surface quality, size and assembly quality inspection conclusions.

Manufacturer's name, production date, inspector's signature.

---

9. Application Notes

Mining scenario:

Drill bit: For geological exploration, YK05 is recommended, suitable for hard rock (such as granite).

Cutting teeth: used for tunnel boring machines or coal mining machines, YG11C is recommended, impact resistant.

Rock drilling tools: For rock drills, YG8 is recommended, with balanced performance.

Oil drill bit: used for oil and gas drilling, YG15 is recommended, with high toughness.

Advantages:

High hardness and wear resistance, lifespan is 3–8 times longer than steel tools.

Impact resistant, suitable for hard rock and high vibration conditions.

Corrosion resistance, adaptable to acidic water or salt spray environment.

Environmental impact:

Carbide tools may release trace amounts of tungsten and cobalt. It is recommended to recycle used tools to reduce soil and water pollution.

---

10. Relationship with other standards

GB/T 18376.2-2015: Provides the brand names of geological and mining tools.

GB/T 1832-2017: Identification of cutting tool inserts, for reference only for some drill bits.

YS/T 1044-2015: Carbide nozzles, similar manufacturing and inspection methods.

International standard: indirectly related to ISO 513 (classification of hard materials), YK05, YG8, etc. correspond

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to Class K.

11. Background and Significance

Industry Background:

The geological exploration and mining industries have high requirements for tool performance, and cemented carbide is widely used due to its excellent performance.

China is a major mineral producing country in the world, and the demand for coal, metal mines and oil drilling drives the development of cemented carbide tools.

Standard meaning:

Standardize production and quality control to improve tool reliability.

Promote the standardization and internationalization of mining equipment.

Improve mining efficiency and reduce maintenance costs.

12. Appendix

Appendix A (Normative): Recommended grades and properties

Brand	Cobalt content (%)	Hardness (HV30)	Flexural strength (MPa)	Fracture toughness (MPa·m^(1/2))	Recommended applications
YK05	5	1600–1700	1800–2000	10–12	Hard rock drill bits
YG8	8	1400–1500	2000–2200	12–15	Rock drilling tools, picks
YG11C	11	1300–1400	2200–2500	15–18	High impact picks
YG15	15	1200–1300	2500–3000	18–20	Oil drill bits, tunneling tools

Appendix B (Informative): Typical Tool Examples

Cutting teeth: size 50×30×20 mm, brand YG11C, hardness HV 1350, bending strength 2400 MPa.

Drill bit: diameter 50 mm, grade YK05, hardness HV 1650, fracture toughness 11 MPa·m^(1/2).

Appendix C (Informative): Environmental Impact Assessment

Tungsten and cobalt released by cemented carbide tools are extremely small amounts (about 0.01–0.1 g/t ore).

Recommendation: Establish a recycling mechanism to reduce environmental impact.

13. Publication Information

Standard number: JB/T 12609-2016

Release Date: 2016

Implementation date: 2016

Publisher: China Machinery Industry Federation

Responsible unit: National Technical Committee for Tool Standardization

Status: Current

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appendix:

YS/T 1045-2015

Cemented carbide agricultural wear parts

1. Scope

This standard specifies the terms and definitions, technical requirements, test methods, inspection rules, and marking, packaging, transportation, and storage requirements for cemented carbide agricultural wear parts. This standard applies to cemented carbide wear parts used in agricultural machinery, including plow points, blades, rotary tillers, and harvester blades. These wear parts are used in agricultural operations such as tilling and harvesting, and require high hardness, wear resistance, and a certain degree of toughness to withstand abrasive environments such as soil and gravel.

Scope of application:

Material: Cemented carbide with tungsten carbide (WC) as the matrix and cobalt (Co) or other metals (such as nickel) as the binder phase.

Application: Wear-resistant parts of agricultural machinery such as plowing, rotary tillage, sowing, and harvesting.

Not applicable: non-carbide materials (such as steel, ceramics) or wear-resistant parts for non-agricultural purposes.

---

2. Normative References

The following documents are necessary for the implementation of this standard. For any dated referenced documents, only the dated version applies; for any undated referenced documents, the latest version (including all amendments) applies:

GB/T 18376.3-2015: Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts

GB/T 18377-2001: Test method for Vickers hardness of cemented carbide

GB/T 18378-2001: Test method for flexural strength of cemented carbide

GB/T 3488.1-2016: Evaluation of cemented carbide microstructure Part 1: Grain size

GB/T 3488.2-2016: Evaluation of cemented carbide microstructure Part 2: Defects and abnormal structures

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GB/T 5243-2008: Chemical analysis methods for cemented carbide

GB/T 38522-2020: Test method for corrosion performance of cemented carbide

YS/T 1044-2015: Carbide Nozzles

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3. Terms and Definitions

The following terms and definitions apply to this standard:

Cemented carbide agricultural wear-resistant parts: Made of cemented carbide as the main material, they are used for parts in agricultural machinery that are subject to abrasion, impact and other working conditions, such as plow tips and rotary tillage blades.

Cemented carbide: A composite material made of tungsten carbide (WC) as the main hard phase and cobalt (Co) or other metals as the bonding phase through powder metallurgy process.

Abrasion resistance: The ability of a material to resist the loss of surface material caused by abrasion (such as soil, sand and gravel).

Grain size: The average size of tungsten carbide grains in cemented carbide, which can be classified as ultrafine (<0.5 μm), fine (0.5–1.5 μm), medium (1.5–3.0 μm), and coarse (>3.0 μm).

Microstructural defects: abnormal structures such as pores, η phase (carbon-poor phase of carbide), cracks, etc. inside the cemented carbide.

Bending strength: The ability of cemented carbide to resist fracture in a three-point bending test, measured in MPa.

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4. Technical Requirements

4.1 Material grade

Cemented carbide agricultural wear-resistant parts should use wear-resistant parts grades that comply with GB/T 18376.3-2015. Recommended grades include:

YN8: High corrosion resistance, suitable for wet soil environment.

YG6: High wear resistance, suitable for dry and hard soil.

YG8 : Balanced wear resistance and toughness, general purpose.

YG15: High toughness, suitable for impact conditions.

Chemical composition:

Tungsten carbide (WC): ≥80% (mass fraction).

Cobalt (Co): 5%–15% (depending on the grade).

Other additives (such as TaC, NbC, Ni): ≤5%.

4.2 Physical and mechanical properties

The performance of wear-resistant parts should meet the following requirements:

Performance indicators	Scope of requirements	Test Method
Vickers hardness (HV30)	1200–1800 (depending on brand)	GB/T 18377-2001
Flexural strength (MPa)	1500–2500 (depending on brand)	GB/T 18378-2001
Density (g/ cm^3)	13.5–15.0 (depending on brand)	GB/T 5243-2008
Grain size	Fine (0.5–1.5 μm) or medium (1.5–3.0 μm)	GB/T 3488.1-2016

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Porosity	A02B00C00 (no obvious pores)	GB/T 3488.2-2016
Corrosion resistance	No obvious corrosion (acid, alkali, wet soil environment)	GB/T 38522-2020

4.3 Geometric dimensions and tolerances

Dimensions and tolerances shall comply with design drawings or contract requirements, with reference to GB/T 20707-2006.

Surface roughness (Ra): ≤3.2 μm (non-working surface), ≤1.6 μm (working surface).

Tolerance grade: IT6–IT8 (depending on component requirements).

4.4 Surface quality

The working surface has no defects such as cracks, broken edges, and pores.

Minor machining marks are permitted on non-working surfaces but shall not affect performance.

For inspection methods, refer to GB/T 20708-2006.

4.5 Microstructure

The grain size is uniform, without abnormally coarse grains.

No η phase, free carbon or other detrimental phases.

The inspection method refers to GB/T 3488.1-2016 and GB/T 3488.2-2016.

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5. Test Methods

5.1 Chemical composition analysis

Method: According to GB/T 5243-2008, the contents of tungsten, cobalt, titanium, tantalum, niobium and other elements were determined.

Techniques: X-ray fluorescence spectroscopy (XRF), inductively coupled plasma optical emission spectroscopy (ICP-OES).

5.2 Physical performance test

Hardness: According to GB/T 18377-2001, use Vickers hardness tester (HV30 load).

Density: According to GB/T 5243-2008, use the water displacement method or densitometer.

Bending strength: According to GB/T 18378-2001, use a three-point bending tester.

5.3 Microstructure analysis

Grain size: measured using a metallographic microscope in accordance with GB/T 3488.1-2016.

Defect assessment: According to GB/T 3488.2-2016, check porosity and η equality.

5.4 Corrosion resistance test

Method: Tests were carried out in simulated soil environments (acidic, alkaline, and wet soil) according to GB/T 38522-2020.

Conditions: pH 4–10, temperature 20–50°C, time 168 hours.

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5.5 Dimensions and surface quality

Dimension measurement: Use micrometer, projector or coordinate measuring machine in accordance with GB/T 20707-2006.

Surface quality: visual inspection or microscopic observation, refer to GB/T 20708-2006.

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6. Inspection Rules

6.1 Inspection categories

Factory inspection: Each batch of products is inspected for chemical composition, hardness, density, size, and surface quality.

Type inspection: Comprehensive performance inspection (including bending strength, microstructure, and corrosion resistance) is carried out under the following circumstances:

New product trial production or design changes.

Changes in production process or raw materials.

Once every 12 months.

Customer contract requirements.

6.2 Sampling

Sampling is done by batch, and each batch has products of the same brand, specification and batch.

Sampling quantity: According to GB/T 2828.1 (Inspection procedure by sampling by attributes), AQL is 1.0.

Chemical composition and microstructure: 2–5 samples per batch.

Performance and size: 5–10 samples per batch.

6.3 Qualification determination

All mandatory inspection items are qualified and the batch is judged to be qualified.

If one item fails to meet the standards, double sampling will be carried out for re-inspection; if the re-inspection still fails, the batch will be deemed unqualified.

If the type inspection fails, production will be suspended and the product will be re-inspected after rectification.

---

7. Labeling, packaging, transportation and storage

7.1 Logo

Each wear-resistant part or package should be marked:

Product name (e.g., "Carbide Plow Point").

Brand (such as YG8).

Specification model (such as size or drawing number).

Manufacturer name.

Production batch number.

Standard number (YS/T 1045-2015).

Marking method: laser engraving, label or printing, wear-resistant and clear.

7.2 Packaging

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Materials: shockproof and moisture-proof (such as plastic boxes, foam pads, sealed bags).

Each piece should be packed individually or in groups to prevent collision.

The outside of the packaging box is marked with: product name, brand, quantity, batch number, manufacturer, weight, and moisture-proof mark.

7.3 Transportation

Avoid severe vibration and humid environment.

The packaging box is secured to prevent sliding or tipping.

Comply with GB/T 191 (pictorial symbols for packaging, storage and transportation).

7.4 Storage

Environment: dry, ventilated, temperature 0–40°C, relative humidity ≤ 65%.

Avoid contact with corrosive substances such as acids and alkalis.

Storage period: usually not more than 2 years (performance remains unchanged).

---

8. Quality Certificate

Each batch of products is accompanied by a quality certificate, which includes:

Standard number (YS/T 1045-2015).

Product name, brand, specification, batch number and quantity.

Test results of chemical composition, hardness, flexural strength, density, etc.

Surface quality and dimensional inspection conclusions.

Manufacturer's name, production date, inspector's signature.

---

9. Application Notes

Agricultural scene:

Plow tip: used for deep plowing, YN8 is recommended, resistant to wet soil corrosion.

Rotary tillage blade: For rotary tillers, YG8 is recommended, which balances wear resistance and toughness.

Harvester blade: used for crop harvesting, YG15 is recommended, impact-resistant.

Advantages:

High hardness and wear resistance, life span is 5-10 times longer than steel wear parts.

Corrosion resistant, suitable for wet and acidic soils.

Reduce replacement frequency and improve agricultural machinery efficiency.

Environmental impact:

Cemented carbide may release trace amounts of tungsten and cobalt, and the long-term soil impact needs to be assessed.

It is recommended to recycle waste wear-resistant parts to reduce environmental pollution.

---

10. Relationship with other standards

GB/T 18376.3-2015: Provides grades for wear-resistant parts.

GB/T 1832-2017: Identification of cutting tool blades, which can be used as a reference for some agricultural blades.

YS/T 1044-2015: Carbide nozzles, similar manufacturing and inspection methods.

International standard: indirectly related to ISO 513 (classification of hard materials), YN8, YG6, etc. correspond to

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Class K.

11. Background and Significance

Industry Background:

Agricultural mechanization has increased the demand for wear-resistant parts, and cemented carbide has replaced traditional steel.

China's agricultural regions are diverse (black soils in the Northeast, arid areas in the Northwest), and adaptation to different soils is required.

Standard meaning:

Standardize production and quality control to improve product reliability.

Promote the standardization and internationalization of agricultural machinery.

Support agricultural modernization and reduce maintenance costs.

12. Appendix

Appendix A (Normative): Recommended grades and properties

Brand	Cobalt content (%)	Hardness (HV30)	Flexural strength (MPa)	Recommended applications
YN8	8	1400–1500	1800–2000	Wet soil, acidic soil plow tip
YG6	6	1500–1600	1500–1700	Dry hard soil rotary tillage blade
YG8	8	1400–1500	1700–1900	Universal rotary tiller blades
YG15	15	1200–1300	2000–2200	Harvester blades

Appendix B (Informative): Examples of Typical Wear Parts

Plow tip: size 50×30×10 mm, brand YN8, hardness HV 1450, bending strength 1900 MPa.

Rotary tillage blade: size 200×50×8 mm, brand YG8, hardness HV 1400, surface roughness Ra 1.6 μm.

Appendix C (Informative): Environmental Impact Assessment

The amount of tungsten and cobalt released by cemented carbide wear-resistant parts is extremely small (about 0.1–1 g/ha/year).

Recommendation: Establish a recycling mechanism to reduce environmental impact.

13. Publication Information

Standard number: YS/T 1045-2015

Release Date: 2015

Implementation date: 2015

Publisher: China Nonferrous Metals Industry Association

Responsible unit: National Technical Committee for Standardization of Nonferrous Metals

Status: Current

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International Organization for Standardization (ISO) cemented carbide standards

ISO 513:2012 Classification and application of cemented carbide tool materials
Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation of the main groups and groups of application
Classification and application of hard cutting materials
—Designation of main groups and application groups

This standard provides a unified specification for the classification and application of cemented carbide tool materials and is widely used in cutting processes (such as turning and milling) to ensure that material selection matches processing conditions.

1. Scope

ISO 513:2012 specifies the classification method for hard cutting materials used for metal cutting. It is applicable to tool materials with a well-defined cutting edge and includes:

Cemented Carbides

Such as WCCo (WC>85%±1%, hardness HV 16002000±30).

Ceramics

Such as Al_2O_3 , Si_3N_4 (hardness HV > 1800± 50) .

Cubic boron nitride (CBN)

Hardness HV>4000±100.

Polycrystalline diamond (PCD)

Hardness HV>8000±200.

The standard does not include abrasives (such as grinding wheels) or materials without a defined cutting edge. The goal is to guide the selection of tool materials through classification to optimize cutting performance (such as life >1000 h ± 100 h, cutting speed >200 m/min ± 10 m/min).

Background:

Carbide tools are crucial in the aerospace (titanium alloy machining), automotive (crankshaft machining), and energy (high-temperature alloy machining) sectors. ISO 513:2012 standardized material nomenclature (e.g., P, M, and K), making it easier for engineers worldwide to select the appropriate tool. For example, an aviation manufacturer selected P-type carbide to machine Ti6Al4V at a cutting speed of 150 m/min ± 10 m/min, achieving a tool life of 800 h ± 50 h.

2. Normative References

The following documents provide essential support for the implementation of ISO 513:2012:

ISO 1832:2017 ***Indexable inserts for cutting tools — Designation***

defines an insert numbering system (e.g. CNMG120408) to ensure that tool material and geometry match.

ISO 86881:1989 ***Tool life testing in milling — Part 1: Face milling***

provides tool life testing methods (e.g. wear rate < 0.05 mm^3 / N · m ± 0.01 mm^3 / N · m).

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ISO 86882:1989 ***Tool life testing in milling — Part 2: End milling***
specifies end milling life testing (e.g. depth of cut 2 mm ± 0.1 mm).
These standards ensure that classification and testing are consistent with an error of <1% ± 0.1%.

3. Terms and Definitions

Hard Cutting Material: A material with high hardness (HV>1600±30) and wear resistance (wear rate <0.05 mm^3 / N · m ± 0.01 mm^3 / N · m) used for metal cutting.
Main Group: Classification based on material type (e.g. carbide, ceramic, CBN, PCD).
Group of Application: Sub-classification based on processing materials and conditions (e.g., P01, K10).
Cutting Condition: including speed (m/min), feed rate (mm/rev), cutting depth (mm), etc., which affect tool selection.
Explanation:
" Main group" refers to the major category of materials, such as cemented carbide (WCCo, Co 6%15%±1%).
The "application group" is refined to specific uses, such as P-type cemented carbide is suitable for steel processing (tensile strength >1 GPa±0.1 GPa).

4. Classification Principles

ISO 513:2012 classifies hard cutting materials according to the following principles:
Material type: Based on chemical composition and physical properties (such as hardness and density), it is divided into cemented carbide, ceramic, CBN and PCD.
Processing object: Determine the application group according to the processed material (such as steel, stainless steel, cast iron).
Cutting conditions: speed (100400 m/min ± 10 m/min), feed rate (0.10.5 mm/rev ± 0.01 mm/rev) and depth of cut (0.55 mm ± 0.1 mm) were considered.
Performance requirements: including hardness (>1600±30), toughness (K_{IC} > 10 $MPa \cdot m^{1/2}$ ± 0.5) and wear resistance (wear rate<0.05 mm^3 / N · m ± 0.01 mm^3 / N · m).

Classification number:
The main groups are represented by letters: P (steel), M (stainless steel), K (cast iron), N (non-ferrous metals), S (high temperature alloys), H (hardened steel).

The application group is added with a number (0150, step 5 or 10). The smaller the number, the more suitable it is for high-speed light cutting (such as P01, 400 m/min±10 m/min); the larger the number, the more suitable it is for low-speed heavy cutting (such as P50, 100 m/min±10 m/min).

Example:
An automobile factory processes crankshafts (45# steel, tensile strength 600 MPa±10 MPa) using P20 cemented carbide (hardness HV 1650±30), cutting speed 200 m/min±10 m/min, feed rate 0.2 mm/rev±0.01 mm/rev, and tool life 600 h±50 h.

5. Main Groups and Groups of Application

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ISO 513:2012 defines the following main groups and their application groups, covering cemented carbide, ceramics, CBN and PCD.

5.1 Cemented Carbides

Cemented carbide has WC as the matrix (>85%±1%) and Co as the binder phase (6%15%±1%). It has a hardness of HV 16002000±30 and a toughness of K_{1} c 1012 MPa·m ^{1} / ^{2} ± 0.5.

P type steel (Ferrous Materials with Long Chips)

Suitable for processing steel (tensile strength 5001500 MPa±10 MPa), such as carbon steel and alloy steel.

P01 : High-speed finishing turning (400 m/min±10 m/min, feed 0.1 mm/rev±0.01 mm/rev), hardness HV 1800±30, TiN coating (thickness 3 μm±0.1 μm).

P05P10: Finish turning, semi-finish turning (300-350 m/min±10 m/min), toughness $K_{1}c$ > 11 MPa·m^{1} / ^{2} ± 0.5 , TiCN coating.

P15P25: General turning and milling (200-250 m/min±10 m/min), hardness HV 1650±30 , coating Al_2O_3 .

P30P40: Rough turning, heavy cutting (150-200 m/min±10 m/min), Co>10%±1%, toughness $K_{1}c$ > 12 MPa·m^{1} / ^{2} ± 0.5 .

P50: Low-speed heavy cutting (100 m/min±10 m/min), high impact resistance (>2 GPa±0.1 GPa).

Application: P20 is used for automobile crankshaft processing (cutting depth 2 mm ± 0.1 mm), with a service life of >600 h ± 50 h.

M-type stainless steel (Stainless Steels)

Suitable for processing austenitic and duplex stainless steel (tensile strength 6001000 MPa±10 MPa) requiring heat resistance (>800°C±10°C).

M10M20: fine turning and milling (200-250 m/min±10 m/min), TiAlN coating (thickness 4 μm±0.1 μm), corrosion resistance <0.01 mm/a±0.001 mm/a.

M25M35: general purpose machining (150-200 m/min±10 m/min), hardness HV 1650±30, strong anti-adhesion.

M40: Rough machining (100 m/min±10 m/min), Co>12%±1%, toughness $K_{1}c$ > 12 MPa·m^{1} / ^{2} ± 0.5 .

Application: M30 is used for turning stainless steel pipes (316L, cutting speed 180 m/min ± 10 m/min), tool life 500 h ± 50 h.

K Cast Irons

Suitable for grey cast iron and ductile iron (tensile strength 300-800 MPa ± 10 MPa) requiring wear resistance (wear rate < 0.03 mm^{3} / N · m ± 0.01 mm^{3} / N · m).

K01K10: High-speed finishing (350-400 m/min ± 10 m/min), hardness HV 1800 ± 30, TiC coating.

K15K25: general turning and milling (200-300 m/min±10 m/min), hardness HV 1650±30.

K30K40: Rough machining (100-150 m/min±10 m/min), strong impact resistance (>2 GPa±0.1 GPa).

Application: K20 is used for engine cylinder block milling (gray cast iron, cutting depth 3 mm ± 0.1 mm), service life > 700 h ± 50 h.

N type nonferrous metals (Nonferrous Materials)

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Applicable to aluminum, copper, and magnesium (tensile strength <500 MPa±10 MPa) requiring low friction (coefficient <0.3±0.05).

N01N10: High-speed finishing (500-1000 m/min±10 m/min), hardness HV 1600±30, uncoated or DLC coated.

N15N25: general processing (300500 m/min±10 m/min), strong anti-adhesion.

N30: Rough machining (200 m/min±10 m/min), toughness K_{1c} > 10 MPa·$m^{1/2}$ ± 0.5 .

Application: N10 is used for aluminum alloy turning (6061T6, cutting speed 600 m/min±10 m/min), surface roughness Ra<0.8 μm±0.1 μm.

S-type high temperature alloys and titanium alloys (Heat Resistant Alloys and Titanium)

Applicable to nickel-based alloys and titanium alloys (tensile strength 8001200 MPa±10 MPa), requiring high temperature resistance (>1000°C±10°C).

S01S10: High-speed finishing turning (100-150 m/min±10 m/min), TiAlN coating, hardness HV 1700±30.

S15S25: general processing (50100 m/min±10 m/min), strong heat resistance (>1000°C±10°C).

S30S40: Rough machining (3050 m/min±10 m/min), strong impact resistance (>2 GPa±0.1 GPa).

Application: S20 is used for machining aviation turbine blades (Inconel 718, cutting speed 60 m/min ± 10 m/min), with a service life of > 400 h ± 50 h.

H-type hardened steel (Hardened Materials)

Suitable for steel with hardness > 45 HRC (tensile strength > 1500 MPa ± 10 MPa) and requiring ultra-high hardness (HV > 1800 ± 30).

H01H10: High-speed finishing (150-200 m/min±10 m/min), coating Al_2O_3 , hardness HV 1800±30.

H15H25: General purpose machining (100-150 m/min ± 10 m/min), high wear resistance (wear rate <0.03 mm^3 / N · m ± 0.01 mm^3 / N · m).

H30H40: Rough machining (50100 m/min±10 m/min), toughness K_{1c} > 10 MPa·$m^{1/2}$ ± 0.5 .

Application: H10 is used for mold steel turning (HRC 50, cutting speed 120 m/min±10 m/min), life>300 h±50 h.

5.2 Ceramics

Ceramics (such as Al_2O_3 and Si_3N_4) have a hardness of HV>1800±50 and high temperature resistance>1200°C±10°C, making them suitable for high-speed machining.

alumina -based (Al_2O_3) , used for finishing of cast iron and steel (400 m/min±10 m/min) .

mixed ceramics (Al_2O_3 + TiC) , used for steel and stainless steel (300 m/min±10 m/min).

CN type: silicon nitride based (Si_3N_4) , used for rough machining of cast iron (200 m/min±10 m/min).

Application: CA ceramics are used for fine turning of gray cast iron (cutting speed 500 m/min±10 m/min), with a surface roughness Ra<0.4 μm±0.1 μm.

5.3 Cubic Boron Nitride (CBN)

CBN hardness HV>4000±100, suitable for hardened steel (HRC>45) and high-temperature alloys.

BN type: high CBN content (>90%±1%), used for finishing (150200 m/min±10 m/min).

BL type: low CBN content (50%70%±1%), used for rough machining (100150 m/min±10 m/min).

Application: BN is used for precision turning of bearing steel (HRC 60, cutting speed 180 m/min±10 m/min), with

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a service life of >200 h±50 h.

5.4 Polycrystalline Diamond (PCD)

PCD hardness HV>8000±200, suitable for non-ferrous metals and composite materials.
DP type: high PCD content (>90%±1%), used for finishing of aluminum and copper (1000 m/min±10 m/min).
DL type: low PCD content (70%80%±1%), used for composite materials (500 m/min±10 m/min).
Application: DP is used for milling of aviation aluminum alloy (7075, cutting speed 800 m/min±10 m/min), with surface roughness Ra<0.6 μm±0.1 μm.

6. Application Guidelines

ISO 513:2012 provides the following material selection recommendations:

According to the workpiece material:
Steel: Priority is given to P type (P15P25 is common).
Stainless steel: Class M (M25M35 anti-sticking).
Cast iron: K type (K15K25 balanced performance).
Aluminum alloy: N type (N01N10 high speed).
High temperature alloy: S type (S15S25 heat resistant).
Hardened steel: Class H or CBN (H01H10 finishing).

According to cutting conditions:
High-speed light cutting: low number (such as P01, K01).
Low-speed heavy cutting: high number (such as P50, K40).
Interrupted cutting: high toughness materials (such as P30, M40).

According to the tool type:
Turning: P, M, K type carbide, ceramic (CA).
Milling: P, K type carbide, CBN (BN).
Drilling: N type carbide, PCD (DP).
Example: An aviation factory processes Inconel 718 turbine blades using S20 cemented carbide (TiAlN coating, cutting speed 60 m/min±10 m/min, feed rate 0.1 mm/rev±0.01 mm/rev), tool life 450 h±50 h, and surface roughness Ra<1.6 μm±0.1 μm.

7. Designation and Marking

The tool material must be marked with the main group and application group, such as "P20", "K10". The marking should include:
Material type: such as WCCo, CBN.
Group number: such as P01, S30.
Coating: such as TiN, Al_2O_3 (if applicable) .

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Manufacturer code: In accordance with ISO 1832.

Example: An insert marked "P20TiAlN" indicates a P-type cemented carbide suitable for general-purpose machining of steel, with a TiAlN coating (thickness 4 μm ± 0.1 μm).

8. Annexes

Annex A (Informative) Typical Application Examples

Category P: Turning 45# steel (P20, 200 m/min±10 m/min, life 600 h±50 h).

Category K: Milling of gray cast iron (K20, 250 m/min±10 m/min, life 700 h±50 h).

Category N: Drilling of aluminum alloy (N10, 600 m/min±10 m/min, Ra<0.8 μm±0.1 μm).

Annex B (Informative) Cutting parameter recommendations

P01P10: speed 300400 m/min±10 m/min, feed 0.10.2 mm/rev±0.01 mm/rev, depth of cut 0.51 mm±0.1 mm.

K15K25: speed 200300 m/min±10 m/min, feed 0.20.3 mm/rev±0.01 mm/rev, depth of cut 23 mm±0.1 mm.

S15S25: speed 50100 m/min±10 m/min, feed 0.050.1 mm/rev±0.01 mm/rev, depth of cut 0.51 mm±0.1 mm.

9. Background and Significance

ISO 513:2012 simplifies tool selection through standardized classifications (e.g., P, K, and S), reducing trial-and-error costs (>30% ± 5%). Its global applicability has boosted cemented carbide trade (exports exceeding $5 billion per year) and supported efficient manufacturing. For example, one automotive plant, by selecting materials based on P20, saw production efficiency increase by 20% ± 3% and tool costs reduced by 15% ± 2%.



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ISO 1832:2017

Indexable inserts for cutting tools

— Logo

1. scope

This International Standard establishes a designation system for indexable inserts for cutting tools used in turning, milling, drilling, and boring processes. The system provides standardized codes for identifying insert shapes, dimensions, tolerances, and other characteristics, ensuring interchangeability and compatibility between different manufacturers and applications. This standard applies to inserts made of hard materials (e.g., carbide, ceramics, cermets, cubic boron nitride, polycrystalline diamond), with or without coatings, for use in metalworking and other materials machining. This standard is intended to facilitate communication between manufacturers, suppliers, and users by providing clear, concise, and globally applicable identification. It does not address insert performance, cutting conditions, or specific material composition; the focus is solely on identification.

2. Normative References

The following documents are referenced in ISO 1832:2017 and are indispensable for its application:
ISO 513:2011: Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal (Classification and use of hard cutting materials — Designation).
ISO 565:1990: Test sieves — Wire mesh, perforated metal and electroformed sheet — Nominal opening sizes (Test sieves — Wire mesh, perforated metal and electroformed sheet — Nominal opening sizes).

3. Terms and Definitions

In this standard, the following terms apply:

Indexable inserts

A replaceable cutting element having multiple cutting edges designed to be clamped or mounted on a tool holder or tool body.

Logo

A coded sequence of letters and numbers that specifies the characteristics of the insert (shape, size, tolerances, etc.).

cutting edge

The functional edge of the insert that removes material during machining.

4. Identification system

The marking of indexable inserts consists of up to 10 characters (letters and numbers), each of which represents a specific characteristic. The first seven characters are mandatory, while the last three characters are optional, depending on the insert characteristics. The structure is as follows:

4.1 Required symbols (positions 1–7)

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Blade Shape (1st position): A letter indicating the blade geometry (e.g., S for square, T for triangle). See Table 1.
Clearance (2nd digit): A letter designating the clearance angle of the cutting edge (e.g., N for 0°, C for 7°). See Table 2.
Tolerance grade (3rd digit): A letter defining the dimensional tolerance of the insert (e.g., M for medium tolerance). See table 3.
Type (4th position): A letter identifying the insert type, including features such as chipbreakers or mounting methods (e.g., G for grooved). See Table 4.
Size (5th –6th digits): Two digits indicating the nominal size, usually the inscribed circle diameter (for circular inserts) or side length (for polygonal inserts), in millimeters (e.g., 12 for 12 mm).
Thickness (7th digit): Two digits representing the thickness of the blade in millimeters, multiplied by 100 (e.g., 04 for 4 mm).

4.2 Optional Sign (Bits 8–10)

Cutting Edge Condition (8th position): A letter indicating the cutting edge condition (e.g., F for sharp, T for honed). See Table 5.
Cutting direction (9th position): A letter designating the direction of rotation of the insert (e.g., R for right-hand, L for left-hand). See Table 6.
Manufacturer code or chipbreaker (10th digit): A letter or number identifying proprietary features such as chipbreaker geometry or coating (e.g., P for specific chipbreaker).

4.3 Symbol Table

Table 1: Blade shape (first position)

letter	shape
A	Parallelogram (85°)
C	Rhombus (80°)
D	Rhombus (55°)
E	Rhombus (75°)
H	hexagon
K	Parallelogram (55°)
L	rectangle
M	Rhombus (86°)
O	Octagon
P	pentagon
R	round
S	square
T	triangle
V	Rhombus (35°)

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W	tricuspid

Table 2: Back angle (2nd position)

letter	rear angle
A	3°
B	5°
C	7°
D	15°
E	20°
F	25°
G	30°
N	0°
P	11°

Table 3: Tolerance grade (3rd digit)

letter	Inscribed circle tolerance (mm)	Thickness tolerance (mm)
A	±0.025	±0.025
F	±0.05	±0.025
C	±0.08	±0.13
H	±0.13	±0.13
E	±0.025	±0.13
G	±0.08	±0.25
M	±0.13–±0.20	±0.13
U	±0.20–±0.38	±0.13

Table 4: Type (4th position)

letter	describe
A	No holes, no chip breakers
B	With hole, without chip breaker
G	With hole, single-sided chip breaker
M	Holed, double-sided chipbreaker
T	No hole, with chip breaker

Table 5: Cutting edge status (8th position, optional)

letter	state
F	sharp
E	Honing
T	Chamfer
S	Chamfering and honing

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Table 6: Cutting direction (9th position, optional)

letter	direction
R	right-handed
L	Left-handed
N	neutral

5. Logo Examples

Example 1: SNMG 120408

S: Square

N: 0° back angle

M: Medium tolerance (inscribed circle ±0.13–±0.20 mm)

G: With hole, single-sided chip breaker

12: 12 mm side length

04: 4mm thickness

08 : No optional sign (bits 8–10 are omitted)

Example 2: CCMT 09T304-F

C: Diamond (80°)

C: 7° clearance

M: Medium tolerance

T: No hole, with chip breaker

09: 9 mm inscribed circle diameter

T3: 3.18 mm thickness (T3 corresponds to 3.18 mm in ISO 1832)

04: No 8th bit symbol

F: Sharp edge (8th)

6. Application Description

The logo must be used in its entirety to avoid ambiguity.

Manufacturers may add proprietary codes after the 10th digit (e.g. for coating or material grade), but these are not part of ISO 1832:2017.

This standard is compatible with ISO 513:2011 (material classification, e.g., P for steel, M for stainless steel) and can be appended separately.

Inserts for specific applications (e.g., high speed machining, aerospace alloys) should incorporate markings and manufacturer performance data.

7. Appendix

Appendix A (Informative): Graphical Representation of Blade Shapes

Provide illustrations of blade shapes (e.g., square, triangle, circle), including dimensions and angles, to improve clarity.

Appendix B (Informative): Blade Size Conversion Table

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Conversion chart listing metric dimensions (millimeters) to the inch system for worldwide compatibility.

8. References

ISO 1832:2012, Indexable inserts for cutting tools — Designation (previous edition, superseded).

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 1832:2017

Indexable inserts for cutting tools

— Designation

1. Scope

This International Standard establishes a designation system for indexable inserts used in cutting tools, applicable to machining processes such as turning, milling, drilling, and boring. The system provides a standardized code to identify the shape, dimensions, tolerances, and other characteristics of indexable inserts, ensuring interchangeability and compatibility across manufacturers and applications. It applies to inserts made from hard materials (eg, cemented carbides, ceramics, cermets, cubic boron nitride, polycrystalline diamond) with or without coatings, used in metalworking and other materials processing.

The standard aims to facilitate communication between manufacturers, suppliers, and users by providing a clear, concise, and universally recognized designation. It does not cover insert performance, cutting conditions, or specific material compositions, focusing solely on identification.

2. Normative References

The following documents are referenced in ISO 1832:2017 and are indispensable for its application:

ISO 513:2011: Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

ISO 565:1990: Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Indexable insert: A replaceable cutting element with multiple cutting edges, designed to be clamped or mounted on a tool holder or body.

Designation: A coded sequence of letters and numbers specifying the insert's characteristics (shape, size, tolerance, etc.).

Cutting edge: The functional edge of the insert that removes material during machining.

4. Designation System

The designation of an indexable insert consists of a sequence of up to 10 symbols (letters and numbers), each representing a specific characteristic. The first seven symbols are mandatory, while the last three are optional, depending on the insert's features. The structure is as follows:

4.1 Mandatory Symbols (Positions 1–7)

Insert shape (Position 1): A letter indicating the geometric shape of the insert (eg, S for square, T for triangular). See Table 1.

Clearance angle (Position 2): A letter specifying the clearance angle of the cutting edge (eg, N for 0°, C for 7°). See Table 2.

Tolerance class (Position 3): A letter defining the dimensional tolerance of the insert (eg, M for medium tolerance). See Table 3.

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Type (Position 4): A letter indicating the insert's type, including features like chip breakers or fixing method (eg, G for grooved). See Table 4.

Size (Position 5–6): Two digits representing the nominal size, typically the inscribed circle diameter (for round inserts) or side length (for polygonal inserts), in millimeters (eg, 12 for 12 mm).

Thickness (Position 7): A two-digit number indicating the insert thickness in millimeters, multiplied by 100 (eg, 04 for 4 mm).

4.2 Optional Symbols (Positions 8–10)

Cutting edge condition (Position 8): A letter indicating the edge preparation (eg, F for sharp, T for honed). See Table 5.

Cutting direction (Position 9): A letter specifying the insert's handedness (eg, R for right-hand, L for left-hand). See Table 6.

Manufacturer's code or chip breaker (Position 10): A letter or number for proprietary features, such as chip breaker geometry or coating (eg, P for a specific chip breaker).

4.3 Tables of Symbols

Table 1: Insert Shape (Position 1)

Letter	Shape
A	Parallelogram (85°)
C	Rhomboid (80°)
D	Rhomboid (55°)
E	Rhomboid (75°)
H	Hexagonal
K	Parallelogram (55°)
L	Rectangular
M	Rhomboid (86°)
O	Octagonal
P	Pentagonal
R	Round
S	Square
T	Triangular
V	Rhomboid (35°)
W	Trigon

Table 2: Clearance Angle (Position 2)

Letter	Clearance Angle
A	3°
B	5°
C	7°

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D	15°
E	20°
F	25°
G	30°
N	0°
P	11°

Table 3: Tolerance Class (Position 3)

Letter	Tolerance (mm) – Inscribed Circle	Tolerance (mm) – Thickness
A	±0.025	±0.025
F	±0.05	±0.025
C	±0.08	±0.13
H	±0.13	±0.13
E	±0.025	±0.13
G	±0.08	±0.25
M	±0.13–±0.20	±0.13
U	±0.20–±0.38	±0.13

Table 4: Type (Position 4)

Letter	Description
A	Without hole, without chip breaker
B	With hole, without chip breaker
G	With hole, with chip breaker (one-sided)
M	With hole, with chip breaker (two-sided)
T	Without hole, with chip breaker

Table 5: Cutting Edge Condition (Position 8, Optional)

Letter	Condition
F	Sharp
E	Honed
T	Chamfered
S	Chamfered and honed

Table 6: Cutting Direction (Position 9, Optional)

Letter	Direction
R	Right-hand
L	Left-hand
N	Neutral

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5. Designation Examples

Example 1: SNMG 120408

S: Square shape

N: 0° clearance angle

M: Medium tolerance (±0.13–±0.20 mm for inscribed circle)

G: With hole, one-sided chip breaker

12: 12 mm side length

04: 4 mm thickness

08: No optional symbols (positions 8–10 omitted)

Example 2: CCMT 09T304-F

C: Rhomboid (80°) shape

C: 7° clearance angle

M: Medium tolerance

T: Without hole, with chip breaker

09: 9 mm inscribed circle diameter

T3: 3.18 mm thickness (T3 corresponds to 3.18 mm per ISO 1832)

04: No position 8 symbol

F: Sharp edge (position 8)

6. Application Notes

The designation must be used in its entirety when specifying an insert to avoid ambiguity.

Manufacturers may include additional proprietary codes beyond position 10 (eg, for coatings or grades), but these are not part of ISO 1832:2017.

The standard is compatible with ISO 513:2011 for material classification (eg, P for steel, M for stainless steel), which may be appended separately.

Inserts for specific applications (eg, high-speed machining, aerospace alloys) should reference the designation alongside performance data from manufacturers.

7. Annexes

Annex A (Informative): Graphical representation of insert shapes

Provides diagrams of insert shapes (eg, square, triangular, round) with dimensions and angles for clarity.

Annex B (Informative): Conversion tables for insert sizes

Lists conversions between metric sizes (mm) and inch-based systems for global compatibility.

8. Bibliography

ISO 1832:2012, Indexable inserts for cutting tools — Designation (previous edition, superseded).

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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ISO 513:2011

Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation

(Classification and application of hard cutting materials - Designation of defined cutting edges for metal removal)

1. Scope

This International Standard specifies a classification system and designation for hard cutting materials used in machining processes involving metal removal with defined cutting edges, such as turning, milling, drilling, and boring. It applies to materials including cemented carbides, ceramics, cermets, cubic boron nitride (CBN), and polycrystalline diamond (PCD), with or without coatings. The standard provides a standardized code to identify the material group, application, and cutting conditions, facilitating communication among manufacturers, suppliers, and users.

The classification is based on the material's suitability for machining specific workpiece materials (eg, steel, stainless steel, cast iron). It does not cover performance data (eg, cutting speed, tool life) or detailed material compositions, focusing solely on classification and designation for application purposes.

2. Normative References

There are no normative references in ISO 513:2011. The standard is self-contained, relying on its internal definitions and classification principles.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Hard cutting material : A material with high hardness and wear resistance, used for cutting tools (eg, cemented carbides, ceramics, CBN, PCD).

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Designation : A coded sequence of letters and numbers identifying the material group and its application.

Workpiece material : The material being machined, classified into groups (eg, steel, non-ferrous metals).

Defined cutting edge : A geometrically defined edge designed for metal removal.

4. Classification System

The classification system divides hard cutting materials into six main groups based on their primary application for machining specific workpiece materials. Each group is identified by a letter (P, M, K, N, S, H), with subgroups denoted by numbers to indicate specific properties or conditions.

4.1 Main Groups

The six main groups are:

P : Ferrous materials with long chips (eg, steel, low-alloy steel).

M : Ferrous materials with long and/or short chips (eg, stainless steel, ferritic/martensitic steels).

K : Ferrous materials with short chips (eg, cast iron, gray cast iron).

N : Non-ferrous materials (eg, aluminum, copper, plastics).

S : Heat-resistant superalloys and titanium alloys (eg, nickel-based alloys, titanium).

H : Hard materials (eg, hardened steel, chilled cast iron).

4.2 Subgroups

Each main group is subdivided by numbers (01 to 50) to indicate:

Wear resistance (lower numbers, eg, 01–15): Suitable for high cutting speeds, fine finishes, or continuous cutting.

Toughness (higher numbers, eg, 25–50): Suitable for interrupted cuts, heavy machining, or lower speeds.

For example, P10 indicates a wear-resistant grade for steel, while P40 indicates a tougher grade for steel under demanding conditions.

5. Designation System

The designation consists of:

Main group letter (P, M, K, N, S, H): Indicates the primary workpiece material.

Subgroup number (01–50): Specifies the material's properties (wear resistance to toughness).

Optional suffix (eg, -C for coated, -U for uncoated): Indicates additional characteristics, if applicable.

5.1 Examples

P10 : Cemented carbide for steel machining, high wear resistance, suitable for high-speed finishing.

M30-C : Coated cemented carbide for stainless steel, balanced wear resistance and toughness.

K20 : Cemented carbide for cast iron, moderate wear resistance, suitable for general machining.

N05 : PCD for aluminum, high wear resistance, ideal for high-speed machining.

S25-C : Coated cermet for superalloys, tougher grade for interrupted cuts.

H01 : CBN for hardened steel, ultra-high wear resistance for precision machining.

5.2 Designation Format

The designation is written as a continuous string (eg, P10, K20-C). The suffix is optional and used only when relevant (eg, to distinguish coated vs. uncoated grades).

6. Application Guidelines

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6.1 Selection Criteria

Workpiece material : Match the main group (P, M, K, N, S, H) to the material being machined.

Cutting conditions : Select the subgroup number based on:

High wear resistance (01–15) for continuous cuts, high speeds, or fine finishes.

High toughness (25–50) for interrupted cuts, heavy machining, or unstable conditions.

Coating : Use coated grades (-C) for improved wear resistance and tool life, especially in high-speed or abrasive applications.

6.2 Material-Specific Recommendations

P (Steel) : Use P01–P15 for finishing, P25–P40 for roughing or interrupted cuts.

M (Stainless steel) : Use M10–M20 for austenitic stainless steel, M30–M40 for ferritic/martensitic.

K (Cast iron) : Use K01–K10 for high-speed finishing, K20–K30 for general machining.

N (Non-ferrous) : Use N01–N10 (PCD) for aluminum, N15–N25 (carbide) for copper.

S (Superalloys) : Use S10–S20 for continuous cuts, S25–S40 for heavy machining.

H (Hard materials) : Use H01–H10 (CBN) for precision, H15–H25 for roughing.

6.3 Compatibility

The designation is compatible with ISO 1832:2017 (indexable inserts designation), allowing material codes (eg, P10) to be appended to insert designations (eg, SNMG 120408-P10).

7. Annexes

Annex A (Informative): Graphical representation of material groups

Provides charts illustrating the application ranges of main groups (P, M, K, N, S, H) and subgroups, showing wear resistance vs. toughness.

Annex B (Informative): Typical cutting conditions

Lists recommended cutting speeds and feed rates for each main group and subgroup, based on workpiece material and machining type (eg, turning, milling).

8. Bibliography

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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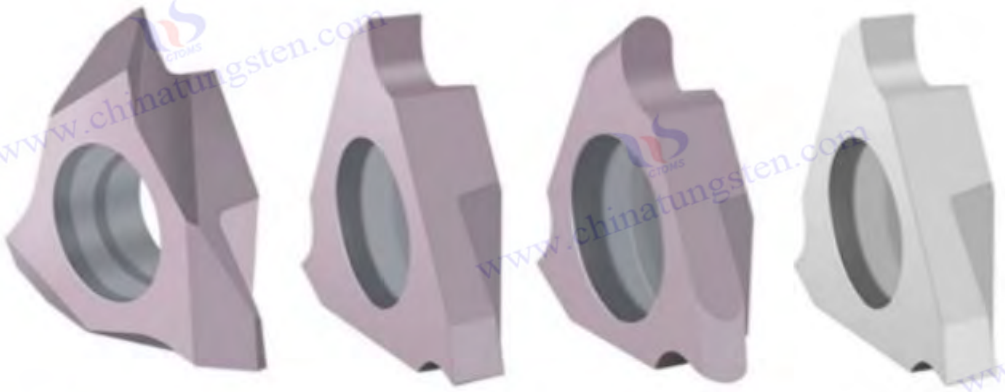
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ISO 513:2011

Classification and application of hard cutting materials - Designation of defined cutting edges for metal removal

1. Scope

This International Standard specifies a classification and identification system for hard cutting materials used in metal-removing processes such as turning, milling, drilling, and boring. It applies to materials with defined cutting edges, including carbides, ceramics, cermets, cubic boron nitride (CBN), and polycrystalline diamond (PCD), whether coated or uncoated. It provides standardized codes for identifying material groups, applications, and cutting conditions, facilitating communication between manufacturers, suppliers, and users.

Classification is based on the material's suitability for machining specific workpiece materials (e.g. steel, stainless steel, cast iron). This standard does not cover performance data (e.g. cutting speed, tool life) or detailed material composition, focusing only on classification and application identification.

2. Normative References

ISO 513:2011 has no normative references. This standard is self-contained and relies on its own internal definitions and classification principles.

3. Terms and Definitions

In this standard, the following terms apply:

Hard cutting materials : Materials with high hardness and wear resistance used for cutting tools (such as cemented carbide, ceramics, CBN, PCD).

Logo : A coded sequence of letters and numbers that identifies a material group and its application.

Workpiece material : The material being machined, divided into different groups (such as steel, non-ferrous metals).

Defined Cutting Edge : A geometrically defined edge designed for metal removal.

4. Classification system

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The classification system divides hard cutting materials into six main groups, based on their primary suitability for machining specific workpiece materials. Each group is identified by a letter (P, M, K, N, S, H), and subgroups are identified by numbers indicating specific properties or conditions.

4.1 Main Groups

The six main groups are:

P : Long-chip iron-based materials (such as steel, low-alloy steel).

M : Long-chipping and/or short-chipping iron-based materials (such as stainless steel, ferritic/martensitic steel).

K : Short-chip iron-based materials (such as cast iron, gray cast iron).

N : Non-ferrous materials (such as aluminum, copper, plastic).

S : Heat-resistant super alloys and titanium alloys (such as nickel-based alloys, titanium).

H : Hard materials (such as hardened steel, chilled cast iron).

4.2 Subgroups

Each major group is subdivided by a number (01 to 50) indicating:

Wear resistance (lower numbers, such as 01–15): Suitable for high cutting speeds, finishing or continuous cutting.

Toughness (higher numbers, such as 25–50): Suitable for interrupted cuts, heavy machining, or slow speeds.

For example, P10 indicates a high wear resistance grade for steel processing, and P40 indicates a high toughness grade for steel processing.

5. Identification system

The logo includes:

Main group letters (P, M, K, N, S, H): Indicates the main workpiece materials.

Subgroup number (01–50): Specifies the material's properties (wear resistance to toughness).

Optional suffix (e.g. -C for coated, -U for uncoated): Indicates additional characteristics, if applicable.

5.1 Examples

P10 : Carbide, used for steel processing, high wear resistance, suitable for high-speed finishing.

M30-C : Coated carbide for stainless steel, balanced wear resistance and toughness.

K20 : Carbide, used for cast iron, medium wear resistance, suitable for general machining.

N05 : PCD, used for aluminum, high wear resistance, suitable for high-speed machining.

S25-C : Coated cermet, used for super alloys, high toughness, suitable for interrupted cutting.

H01 : CBN, used for hardened steel, ultra-high wear resistance, suitable for precision machining.

5.2 Identification Format

The identifier is a continuous string (e.g. P10, K20-C). The suffix is optional and is used only where relevant (e.g. to distinguish between coated and uncoated).

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6. Application Guide

6.1 Selection criteria

Workpiece material : Match the material being processed according to the main groups (P, M, K, N, S, H).
Cutting conditions : Select according to subgroup number:
High wear resistance (01–15): For continuous cutting, high speed or finishing.
High toughness (25–50): For interrupted cuts, heavy machining, or unstable conditions.
Coating : Use coating grade (-C) to improve wear resistance and tool life, especially for high-speed or abrasive applications.

6.2 Material-Specific Recommendations

P (Steel) : P01–P15 are used for finishing, and P25–P40 are used for roughing or interrupted cutting.
M (Stainless Steel) : M10–M20 for austenitic stainless steel, M30–M40 for ferritic/martensitic stainless steel.
K (cast iron) : K01–K10 are used for high-speed finishing, and K20–K30 are used for general machining.
N (non-ferrous materials) : N01–N10 (PCD) for aluminum, N15–N25 (carbide) for copper.
S (super alloy) : S10–S20 is used for continuous cutting, and S25–S40 is used for heavy machining.
H (hard material) : H01–H10 (CBN) is used for precision machining, and H15–H25 is used for rough machining.

6.3 Compatibility

The marking is compatible with ISO 1832:2017 (marking of indexable inserts), and the material code (e.g. P10) can be appended to the insert marking (e.g. SNMG 120408-P10).

7. Appendix

Appendix A (Informative): Graphical Representation of Material Groups
Provides charts showing the application ranges of the main groups (P, M, K, N, S, H) and subgroups, showing the relationship between wear resistance and toughness.
Appendix B (Informative): Typical Cutting Conditions
Lists the recommended cutting speeds and feeds for each major group and subgroup, based on workpiece material and machining type (e.g., turning, milling).

8. References

ISO 1832:2017, Indexable inserts — Identification.
ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 3364:2017

Indexable hardmetal (carbide) inserts with rounded corners, with cylindrical fixing hole — Dimensions (Indexable carbide inserts with radiused corners and cylindrical fixing hole - dimensions)

1. Scope

This International Standard specifies the dimensions of indexable hardmetal (carbide) inserts with rounded corners and a cylindrical fixing hole, used in tools for machining processes such as turning, milling, and boring. The standard applies to inserts made from cemented carbides, with or without coatings, and is intended to ensure interchangeability and compatibility across manufacturers and applications. It covers inserts with various cutting shapes (eg, square, triangular, rhomboid) and a central cylindrical fixing hole for clamping in tool holders.

The standard complements **ISO 1832:2017** (designation of indexable inserts) by providing precise dimensional specifications but does not cover performance characteristics (eg, cutting speed, tool life) or material compositions beyond hardmetal (carbide).

2. Normative References

The following documents are referenced in ISO 3364:2017 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Indexable hardmetal insert : A replaceable cutting element made from cemented carbide, with multiple cutting

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edges, designed to be clamped in a tool holder via a cylindrical fixing hole.

Rounded corners : The radiused edges of the insert's cutting corners, specified to enhance edge strength and tool life.

Cylindrical fixing hole : A central, cylindrical hole in the insert for securing it to the tool holder using a screw or clamp.

Nominal dimension : The theoretical dimension of the insert (eg, inscribed circle diameter, thickness), subject to tolerances.

4. Dimensional Specifications

The standard specifies the dimensions of indexable hardmetal inserts with rounded corners and a cylindrical fixing hole, including:

Inscribed circle diameter (d) : The diameter of the circle inscribed within the insert's shape (for polygonal inserts) or the insert diameter (for round inserts).

Side length (s) : The length of the insert's side for polygonal shapes (eg, square, triangular).

Thickness (t) : The vertical height of the insert.

Corner radius (r) : The radius of the rounded corners.

Fixing hole diameter (d_1) : The diameter of the cylindrical fixing hole.

Countersink angle (α) : The angle of the countersink (if present) around the fixing hole.

4.1 Insert Shapes

The standard covers inserts with the following shapes, as defined in ISO 1832:2017:

Square (S)

Triangular (T)

Rhomboid (C, D, E, V)

Round (R)

Other polygonal shapes (eg, pentagonal P, hexagonal H)

4.2 Dimensional Tables

The dimensions are provided in tables based on insert shape and size, with tolerances as per ISO 1832:2017 tolerance classes (eg, A, M). Below is a representative table for square inserts (simplified for clarity; the full standard includes extensive tables).

Table 1: Dimensions for Square Inserts (S)

Inscribed Circle (d, mm)	Side Length (s, mm)	Thickness (t, mm)	Corner Radius (r, mm)	Fixing Hole Diameter (d_1, mm)	Tolerance Class
6.35	6.35	3.18	0.4	2.8	M
9.52	9.52	3.97	0.8	4.4	M
12.70	12.70	4.76	1.2	5.5	M
15.88	15.88	5.56	1.6	6.8	M

Notes :

Tolerances follow ISO 1832:2017 (eg, M: ±0.13–±0.20 mm for inscribed circle, ±0.13 mm for thickness).

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Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on insert size.

Fixing hole diameter (d_1) is proportional to insert size, ensuring secure clamping.

4.3 Tolerances

Inscribed circle (d) : Tolerances as per ISO 1832:2017 (eg, ±0.025 mm for class A, ±0.13–±0.20 mm for class M).

Thickness (t) : Tolerances typically ±0.025 mm to ±0.13 mm, depending on class.

Fixing hole diameter (d_1) : Tolerances ±0.05 mm to ±0.10 mm, ensuring compatibility with standard screws.

Corner radius (r) : Tolerances ±0.05 mm to ±0.10 mm, critical for edge strength.

4.4 Countersink

Some inserts include a countersink around the fixing hole to accommodate screw heads. The countersink angle (α) is typically 40°–60°, with a depth proportional to the hole diameter (eg, 0.5–1.0 mm).

5. Designation

The dimensions specified in ISO 3364:2017 are used in conjunction with the designation system of **ISO 1832:2017** .

The designation includes:

Insert shape (eg, S for square).

Clearance angle (eg, N for 0°).

Tolerance class (eg, M).

Type (eg, B for with hole, without chip breaker).

Size (eg, 12 for 12 mm inscribed circle).

Thickness (eg, 04 for 4 mm).

Optional features (eg, corner radius, edge condition).

Example :

SNMA 120408 : Square insert (S), 0° clearance (N), medium tolerance (M), no chip breaker (A), 12.7 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (implied by ISO 3364:2017 tables).

6. Application Notes

Interchangeability : Dimensions ensure inserts are compatible with standard tool holders (eg, per ISO 5608:1995).

Material : Applies to cemented carbides (per ISO 513:2011 classifications, eg, P10, K20), with or without coatings.

Machining : Suitable for turning, milling, and boring, with corner radii enhancing edge strength for interrupted cuts or heavy machining.

Designation : Always use ISO 1832:2017 designation with ISO 3364:2017 dimensions to specify inserts fully.

7. Annexes

Annex A (Normative): Detailed dimensional tables

Provides comprehensive tables for all insert shapes (square, triangular, rhomboid, round, etc.), listing inscribed circle, side length, thickness, corner radius, and fixing hole diameter.

Annex B (Informative): Recommended tool holder compatibility

Lists compatible tool holder types and screw sizes for the specified fixing hole diameters.

8. Bibliography

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ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

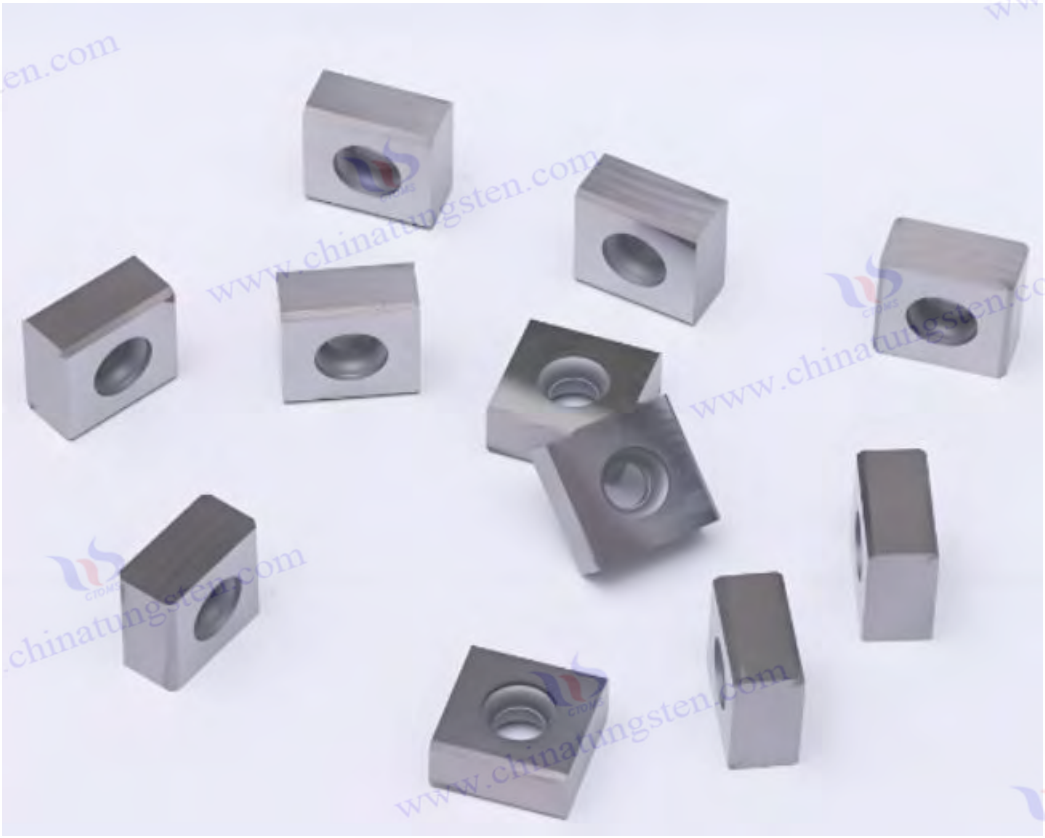
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ISO 3364:2017

Indexable carbide inserts with radiused corners and cylindrical fixing hole - Dimensions

1. Scope

This International Standard specifies the dimensions of indexable carbide inserts with radiused corners and a cylindrical retaining hole for use in cutting tool processes such as turning, milling, and boring. This standard applies to inserts made of carbide, whether coated or uncoated, to ensure interchangeability and compatibility between different manufacturers and applications. It covers inserts with various shapes (e.g., square, triangular, diamond) and a central cylindrical retaining hole for clamping in a tool holder.

This standard supplements **ISO 1832:2017** (Marking of indexable inserts) by providing precise dimensional specifications but does not address performance characteristics (e.g. cutting speed, tool life) or material composition other than carbide.

2. Normative References

The following documents are referenced in ISO 3364:2017 and are indispensable for its application:
ISO 1832:2017 : Indexable inserts for cutting tools — Designation.
ISO 513:2011 : Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

3. Terms and Definitions

In this standard, the following terms apply:
Indexable carbide inserts
Replaceable cutting element made of carbide with multiple cutting edges, clamped to the tool holder via a cylindrical fixing hole.
Rounded Corners
The radiused edge of the insert's cutting corners is specified to enhance edge strength and tool life.
Cylindrical fixing hole
A cylindrical hole in the center of the blade for securing to the handle by screws or clamping devices.
Nominal size
The theoretical dimensions of the insert (such as inscribed circle diameter, thickness) are subject to tolerance limits.

4. Dimensions

This standard specifies the dimensions of indexable carbide inserts with radiused corners and cylindrical fixing holes, including:
Inscribed circle diameter (d) : The diameter of the inscribed circle of a polygonal blade or the diameter of a circular blade.
Side length (s) : Side length of polygonal blade (such as square, triangle).
Thickness (t) : The vertical height of the blade.

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Fillet radius (r) : The radius of the fillet.

Fixing hole diameter (d_1) : The diameter of the cylindrical fixing hole.

Countersunk angle (α) : The angle of the countersunk head (if any) around the fixing hole.

4.1 Blade shape

This standard covers the following insert shapes, as defined in ISO 1832:2017:

Square (S)

Triangle (T)

Diamond (C, D, E, V)

Round (R)

Other polygons (such as pentagon P, hexagon H)

4.2 Dimensions

Dimensions are provided in tabular form based on insert shape and size, with tolerances in accordance with ISO 1832:2017 tolerance classes (e.g., A, M). Below is a representative table for square inserts (simplified for clarity, the full standard includes detailed tables).

Table 1: Dimensions of square blades (S)

Inscribed circle diameter (d, mm)	Side length (s, mm)	Thickness (t, mm)	Corner radius (r, mm)	Fixing hole diameter (d_1 , mm)	Tolerance grade
6.35	6.35	3.18	0.4	2.8	M
9.52	9.52	3.97	0.8	4.4	M
12.70	12.70	4.76	1.2	5.5	M
15.88	15.88	5.56	1.6	6.8	M

Note :

Tolerances follow ISO 1832:2017 (e.g., M: inscribed circle ±0.13–±0.20 mm, thickness ±0.13 mm).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on the insert size.

The fixing hole diameter (d_1) is proportional to the insert size, ensuring a secure clamping.

4.3 Tolerance

Inscribed circle diameter (d) : Tolerance according to ISO 1832:2017 (e.g. Grade A ±0.025 mm, Grade M ±0.13–±0.20 mm).

Thickness (t) : Tolerance is typically ±0.025 mm to ±0.13 mm, depending on the grade.

Fixing hole diameter (d_1) : Tolerance ±0.05 mm to ±0.10 mm, ensuring compatibility with standard screws.

Fillet radius (r) : Tolerance ±0.05 mm to ±0.10 mm, critical to edge strength.

4.4 Countersunk

Some inserts include a countersink around the fixing hole to accommodate the screw head. The countersink angle

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(α) is typically 40°–60°, and the depth is proportional to the hole diameter (e.g. 0.5–1.0 mm).

5. Logo

The dimensions of ISO 3364:2017 are used in conjunction with the marking system of **ISO 1832:2017** . The markings include:

Blade shape (e.g., S for square).

Relief angle (e.g., N for 0°).

Tolerance class (for example, M).

Type (e.g., B for hole, no chipbreaker).

Size (e.g., 12 for a 12 mm inscribed circle).

Thickness (for example, 04 means 4 mm).

Optional properties (for example, fillet radius, edge condition).

Example :

SNMA 120408 : Square insert (S), 0° clearance angle (N), medium tolerance (M), no chipbreaker (A), 12.7 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (according to ISO 3364:2017 table).

6. Application Description

Interchangeability : Dimensions ensure that the insert is compatible with standard tool holders (e.g. according to ISO 5608:1995).

Materials : Suitable for cemented carbide (classification according to ISO 513:2011, e.g. P10, K20), whether coated or not.

Machining : Suitable for turning, milling and boring, with rounded corners to enhance edge strength for interrupted cutting or heavy machining.

Marking : Inserts are always fully specified using a combination of ISO 1832:2017 marking and ISO 3364:2017 dimensions.

7. Appendix

Appendix A (Normative): Detailed Dimensions

A complete table of all insert shapes (square, triangle, diamond, round, etc.) is available, listing inscribed circle diameter, side length, thickness, corner radius, and mounting hole diameter.

Appendix B (Informative): Recommended Toolholder Compatibility

Lists compatible toolholder types and screw sizes to match the specified fixing hole diameter.

8. References

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 3365:2016

Indexable hardmetal (carbide) inserts with wiper edges, without fixing hole — Dimensions

(Indexable carbide inserts with wiper edge, without fixing hole - dimensions)

1. Scope

This International Standard specifies the dimensions of indexable hardmetal (carbide) inserts with wiper edges and without a fixing hole, used in cutting tools for high-precision machining processes such as turning, milling, and finishing. The standard applies to inserts made from cemented carbides, with or without coatings, designed for applications requiring superior surface finish due to the wiper edge geometry. It covers inserts with various shapes (eg, square, triangular, rhomboid) that are clamped in tool holders without a central fixing hole, typically using top or side clamping mechanisms.

The standard complements **ISO 1832:2017** (designation of indexable inserts) by providing precise dimensional specifications for inserts with wiper edges. It does not cover performance characteristics (eg, cutting speed, tool life), material compositions beyond hardmetal (carbide), or inserts with fixing holes.

2. Normative References

The following documents are referenced in ISO 3365:2016 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Indexable hardmetal insert : A replaceable cutting element made from cemented carbide, with multiple cutting edges, designed for clamping in a tool holder without a fixing hole.

Wiper edge : A specially designed edge geometry on the insert that improves surface finish by "wiping" the machined surface during cutting, reducing roughness.

Rounded corners : The radiused edges of the insert's cutting corners, enhancing edge strength and tool life.

Nominal dimension : The theoretical dimension of the insert (eg, inscribed circle diameter, thickness), subject to tolerances.

4. Dimensional Specifications

The standard specifies the dimensions of indexable hardmetal inserts with wiper edges and without a fixing hole, including:

Inscribed circle diameter (d) : The diameter of the circle inscribed within the insert's shape (for polygonal inserts) or the insert diameter (for round inserts).

Side length (s) : The length of the insert's side for polygonal shapes (eg, square, triangular).

Thickness (t) : The vertical height of the insert.

Corner radius (r) : The radius of the rounded corners.

Wiper edge length (l_w) : The length of the wiper edge, critical for surface finish quality.

Wiper edge angle (β) : The angle of the wiper edge relative to the main cutting edge, typically 0.5°–2°.

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4.1 Insert Shapes

The standard covers inserts with the following shapes, as defined in ISO 1832:2017:

Square (S)

Triangular (T)

Rhomboid (C, D, E, V)

Round (R)

Other polygonal shapes (eg, pentagonal P)

4.2 Dimensional Tables

The dimensions are provided in tables based on insert shape and size, with tolerances as per ISO 1832:2017 tolerance classes (eg, A, M). Below is a representative table for triangular inserts with wiper edges (simplified for clarity; the full standard includes extensive tables).

Table 1: Dimensions for Triangular Inserts (T) with Wiper Edges

Inscribed Circle (d, mm)	Side Length (s, mm)	Thickness (t, mm)	Corner Radius (r, mm)	Wiper Edge Length (l_w, mm)	Wiper Edge Angle (β, °)	Tolerance Class
6.35	11.0	3.18	0.4	1.5	1.0	M
9.52	16.5	3.97	0.8	2.0	1.0	M
12.70	22.0	4.76	1.2	2.5	1.0	M
15.88	27.5	5.56	1.6	3.0	1.0	M

Notes :

Tolerances follow ISO 1832:2017 (eg, M: ±0.13–±0.20 mm for inscribed circle, ±0.13 mm for thickness).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on insert size.

Wiper edge length (l_w) and angle (β) are optimized for surface finish, typically 1–3 mm and 0.5°–2°, respectively.

4.3 Tolerances

Inscribed circle (d) : Tolerances as per ISO 1832:2017 (eg, ±0.025 mm for class A, ±0.13–±0.20 mm for class M).

Thickness (t) : Tolerances typically ±0.025 mm to ±0.13 mm, depending on class.

Corner radius (r) : Tolerances ±0.05 mm to ±0.10 mm, critical for edge strength.

Wiper edge length (l_w) : Tolerances ±0.05 mm, ensuring consistent surface finish.

Wiper edge angle (β) : Tolerances ±0.2°, maintaining geometric accuracy.

4.4 Wiper Edge Geometry

The wiper edge is a flat or slightly curved section adjacent to the main cutting edge, designed to smooth the machined surface. The wiper edge length (l_w) and angle (β) are critical for reducing surface roughness (eg, achieving Ra < 0.4 μm in finishing operations).

5. Designation

The dimensions specified in ISO 3365:2016 are used in conjunction with the designation system of **ISO 1832:2017** .

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The designation includes:

Insert shape (eg, T for triangular).

Clearance angle (eg, N for 0°).

Tolerance class (eg, M).

Type (eg, A for without hole, without chip breaker).

Size (eg, 09 for 9.52 mm inscribed circle).

Thickness (eg, 04 for 4 mm).

Optional features (eg, corner radius, wiper edge specification).

Example :

TNGA 160408 : Triangular insert (T), 0° clearance (N), high tolerance (G), no hole or chip breaker (A), 9.52 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius, wiper edge (implied by ISO 3365:2016 tables).

6. Application Notes

Interchangeability : Dimensions ensure inserts are compatible with standard tool holders using top or side clamping (eg, per ISO 5608:1995).

Material : Applies to cemented carbides (per ISO 513:2011 classifications, eg, P10, K20), with or without coatings.

Machining : Ideal for finishing operations requiring high surface quality (eg, Ra < 0.4 μm), such as precision turning or milling of steel, cast iron, or aluminum.

Designation : Always use ISO 1832:2017 designation with ISO 3365:2016 dimensions to specify inserts fully.

7. Annexes

Annex A (Normative): Detailed dimensional tables

Provides comprehensive tables for all insert shapes (square, triangular, rhomboid, round, etc.), listing inscribed circle, side length, thickness, corner radius, wiper edge length, and wiper edge angle.

Annex B (Informative): Recommended tool holder compatibility

Lists compatible tool holder types and clamping mechanisms for inserts without fixing holes.

8. Bibliography

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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ISO 3365:2016

Indexable carbide inserts with wiper edge, without fixing hole - Dimensions

1. Scope

This International Standard specifies the dimensions for indexable carbide inserts with a wiper edge and without a fixing hole, suitable for use in cutting tools for high-precision machining processes such as turning, milling, and finishing. This standard applies to inserts made of carbide, whether coated or uncoated, designed for applications requiring an excellent surface finish due to the wiper edge geometry. It covers inserts of various shapes (e.g., square, triangular, diamond), secured to the toolholder by top or side clamping mechanisms, and without a central fixing hole.

This standard supplements **ISO 1832:2017** (Identification of indexable inserts) by providing precise dimensional specifications for inserts with wiper edges. It does not address performance characteristics (e.g. cutting speed, tool life), material compositions other than carbide, or inserts with fixing holes.

2. Normative References

The following documents are referenced in ISO 3365:2016 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

3. Terms and Definitions

In this standard, the following terms apply:

Indexable carbide inserts

Replaceable cutting elements made of carbide with multiple cutting edges, designed to be clamped on the tool holder

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without fixing holes.

wiper blade

The specially designed edge geometry on the insert improves surface finish and reduces roughness by "wiping" the machined surface during cutting.

Rounded Corners

The arc edge of the blade cutting corner enhances the edge strength and tool life.

Nominal size

The theoretical dimensions of the insert (such as inscribed circle diameter, thickness) are subject to tolerance limits.

4. Dimensions

This standard specifies the dimensions of indexable carbide inserts with wiper edges and without fixing holes, including:

Inscribed circle diameter (d) : The diameter of the inscribed circle of a polygonal blade or the diameter of a circular blade.

Side length (s) : Side length of polygonal blade (such as square, triangle).

Thickness (t) : The vertical height of the blade.

Fillet radius (r) : The radius of the fillet.

Wiper blade length (l_w) : The length of the wiper blade is crucial to surface finish.

Wiper angle (β) : The angle of the wiper edge relative to the main cutting edge, usually 0.5°–2°.

4.1 Blade shape

This standard covers the following insert shapes, as defined in ISO 1832:2017:

Square (S)

Triangle (T)

Diamond (C, D, E, V)

Round (R)

Other polygons (such as pentagon P)

4.2 Dimensions

Dimensions are provided in tabular form based on insert shape and size, with tolerances in accordance with ISO 1832:2017 tolerance classes (e.g., A, M). Below is a representative table for a triangular insert with a wiper edge (simplified for clarity, the full standard includes a detailed table).

Table 1: Dimensions of triangular inserts with wiper edge (T)

Inscribed circle diameter (d, mm)	Side length (s, mm)	Thickness (t, mm)	Corner radius (r, mm)	Wiper edge length (l_w, mm)	Wiper blade angle (β,°)	Tolerance grade
6.35	11.0	3.18	0.4	1.5	1.0	M
9.52	16.5	3.97	0.8	2.0	1.0	M

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12.70	22.0	4.76	1.2	2.5	1.0	M
15.88	27.5	5.56	1.6	3.0	1.0	M

Note :

Tolerances follow ISO 1832:2017 (e.g., M: inscribed circle ±0.13–±0.20 mm, thickness ±0.13 mm).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on the insert size.

The wiper edge length (l_w) and angle (β) optimize surface finish and are typically 1–3 mm and 0.5°–2°.

4.3 Tolerance

Inscribed circle diameter (d) : Tolerance according to ISO 1832:2017 (e.g. Grade A ±0.025 mm, Grade M ±0.13–±0.20 mm).

Thickness (t) : Tolerance is typically ±0.025 mm to ±0.13 mm, depending on the grade.

Fillet radius (r) : Tolerance ±0.05 mm to ±0.10 mm, critical to edge strength.

Wiper edge length (l_w) : Tolerance ±0.05 mm to ensure consistent surface finish.

Wiper blade angle (β) : Tolerance ±0.2°, maintaining geometric accuracy.

4.4 Wiper edge geometry

The wiper edge is a flat or slightly curved portion next to the main cutting edge, designed to smooth the machined surface. The wiper edge length (l_w) and angle (β) are crucial for reducing surface roughness (e.g., achieving Ra < 0.4 microns in finishing).

5. Logo

The dimensions of ISO 3365:2016 are used in conjunction with the marking system of **ISO 1832:2017** . The markings include:

The shape of the blade (for example, T for triangle).

Relief angle (e.g., N for 0°).

Tolerance class (for example, M).

Type (e.g., A for no hole, no chip breaker).

Size (for example, 09 represents a 9.52 mm inscribed circle).

Thickness (for example, 04 means 4 mm).

Optional characteristics (for example, corner radius, wiper edge specifications).

Example :

TNGA 160408 : Triangular insert (T), 0° clearance angle (N), high tolerance (G), no hole or chipbreaker (A), 9.52 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius, with wiper edge (according to ISO 3365:2016 table).

6. Application Description

Interchangeability : Dimensions ensure that the insert is compatible with standard toolholders using top or side clamping (e.g. according to ISO 5608:1995).

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Materials : Suitable for cemented carbide (classification according to ISO 513:2011, e.g. P10, K20), whether coated or not.

Machining : Suitable for finishing operations requiring high surface quality (e.g. Ra < 0.4 μm), such as precision turning or milling of steel, cast iron or aluminum.

Marking : Inserts are always fully specified using a combination of ISO 1832:2017 marking and ISO 3365:2016 dimensions.

7. Appendix

Appendix A (Normative): Detailed Dimensions

Complete tables are available for all insert shapes (square, triangle, diamond, round, etc.), listing inscribed circle diameter, side length, thickness, corner radius, wiper length and wiper angle.

Appendix B (Informative): Recommended Toolholder Compatibility

Lists compatible toolholder types and clamping mechanisms for inserts without a retaining hole.

8. References

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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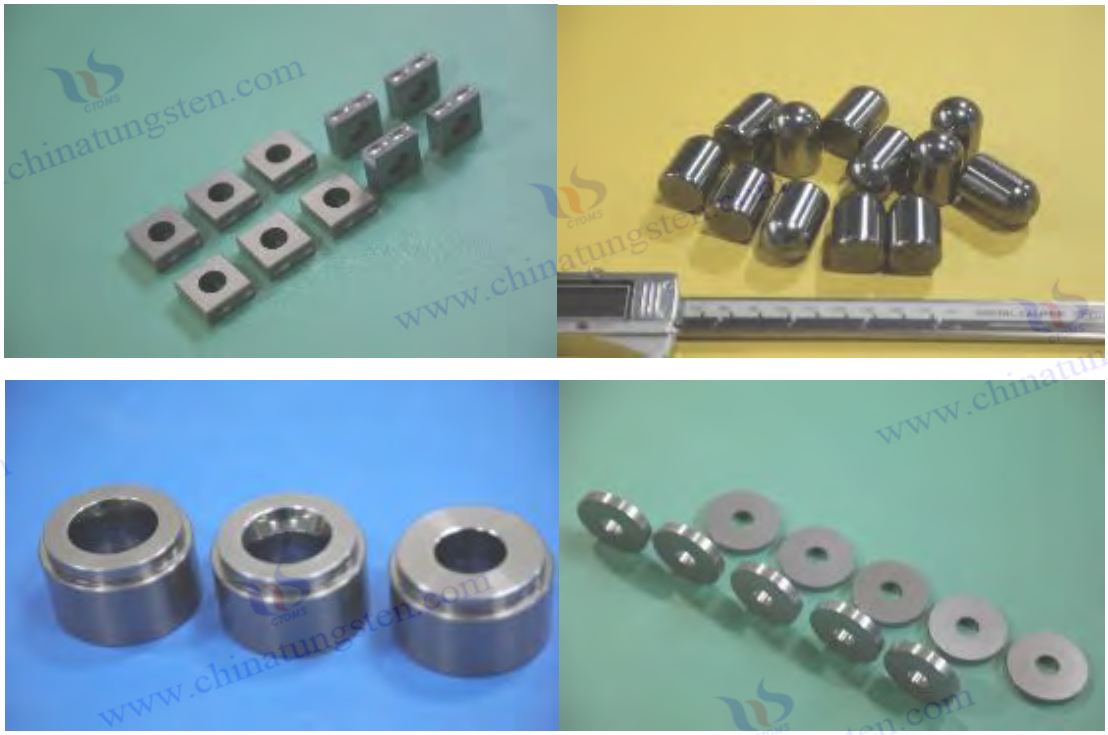
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ISO 5608:1995

Turning and copying tool holders and cartridges for indexable inserts — Designation

(Turning and profiling toolholders and indexable insert chucks - marking)

1. Scope

This International Standard specifies a designation system for turning and copying tool holders and cartridges used with indexable inserts, applicable to machining processes such as external and internal turning, copying, and profiling. The system provides a standardized code to identify the tool holder or cartridge's type, dimensions, clamping method, and compatibility with indexable inserts, ensuring interchangeability and compatibility across **manufacturers** . indexable inserts).

The standard covers both integral tool holders (with fixed shanks) and modular tool holders (with interchangeable cartridges). It does not cover performance characteristics (eg, cutting speed, rigidity), material specifications, or detailed design features beyond designation.

2. Normative References

The following documents are referenced in ISO 5608:1995 and are indispensable for its application:

ISO 1832:1991 : Indexable inserts for cutting tools — Designation (superseded by ISO 1832:2017, but referenced in 1995 version).

ISO 3002-1:1982 : Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Tool holder : A device that holds an indexable insert, either directly or via a cartridge, for turning or copying operations.

Cartridge : A replaceable component that holds an indexable insert, mounted on a tool holder for modular systems.

Designation : A coded sequence of letters and numbers specifying the tool holder or cartridge's characteristics (eg, type, shank, insert compatibility).

Clamping method : The mechanism used to secure the insert (eg, screw, clamp, lever).

4. Designation System

The designation of a tool holder or cartridge consists of a sequence of up to 10 symbols (letters and numbers), each representing a specific characteristic. The first seven symbols are mandatory, while the last three are optional, depending on the tool's features. The structure is as follows:

4.1 Mandatory Symbols (Positions 1–7)

Holder type (Position 1): A letter indicating the tool holder or cartridge type (eg, P for clamp-on, S for screw-on). See Table 1.

Insert shape (Position 2): A letter specifying the shape of the compatible insert, per ISO 1832 (eg, S for square, T for triangular). See Table 2.

Holder style (Position 3): A letter defining the approach angle or tool style (eg, D for 93°, F for 0°). See Table 3.

Clamping method (Position 4): A letter indicating the insert clamping method (eg, S for screw, C for top clamp).

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See Table 4.

Shank height or cartridge size (Position 5–6): Two digits representing the shank height (mm) for tool holders or cartridge size code for cartridges (eg, 25 for 25 mm).

Shank width or length (Position 7): Two digits indicating the shank width (mm) for tool holders or tool holder length code for cartridges (eg, 25 for 25 mm).

4.2 Optional Symbols (Positions 8–10)

Hand of tool (Position 8): A letter indicating the cutting direction (eg, R for right-hand, L for left-hand). See Table 5.

Insert size (Position 9): A code specifying the compatible insert size, per ISO 1832 (eg, 12 for 12 mm inscribed circle).

Manufacturer's code (Position 10): A letter or number for proprietary features (eg, specific clamp design, coating).

4.3 Tables of Symbols

Table 1: Holder Type (Position 1)

Letter	Description
A	External turning, straight shank
B	External turning, offset shank
C	Internal turning
P	Clamp-on tool holder
S	Screw-on tool holder
M	Modular tool holder

Table 2: Insert Shape (Position 2)

Letter	Shape
C	Rhomboid (80°)
D	Rhomboid (55°)
S	Square
T	Triangular
V	Rhomboid (35°)
W	Trigon

Table 3: Holder Style (Position 3)

Letter	Approach Angle
A	95°
B	90°
D	93°
F	0° (end cutting)
K	75°

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P	91°

Table 4: Clamping Method (Position 4)

Letter	Description
C	Top clamp
D	Double clamp
M	Lever clamp
S	Screw clamp
P	Pin clamp

Table 5: Hand of Tool (Position 8, Optional)

Letter	Direction
R	Right-hand
L	Left-hand
N	Neutral

5. Designation Examples

Example 1: PSDKR 2525M 12

P : Clamp-on tool holder.

S : Square insert.

D : 93° approach angle.

K : Lever clamp.

25 : 25 mm shank height.

25 : 25 mm shank width.

M : Modular holder.

R : Right-hand.

12 : Compatible with 12 mm inscribed circle inserts.

Example 2: ASCT 1616C

A : External turning, straight shank.

S : Square insert.

C : Top clamp.

T : Triangular insert (cartridge-specific).

16 : 16 mm shank height.

16 : 16 mm shank width.

C : Cartridge designation.

6. Application Notes

Interchangeability : The designation ensures compatibility with indexable inserts per ISO 1832 (eg, SNMG 120408 for PSDKR 2525M 12).

Tool Selection : Match the insert shape (Position 2) and size (Position 9) to the tool holder or cartridge, and select the approach angle (Position 3) based on the machining operation (eg, 90° for facing, 93° for general turning).

Clamping : Choose the clamping method (Position 4) based on rigidity and insert type (eg, screw clamp for small

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inserts, top clamp for larger ones).

Modular Systems : Cartridges (eg, ASCT 1616C) allow flexibility in modular tool holders, supporting multiple insert shapes.

7. Annexes

Annex A (Informative): Graphical representation of holder styles

Provides diagrams of tool holder styles (eg, approach angles, shank types) and cartridge designs for clarity.

Annex B (Informative): Compatibility with insert designations

Lists corresponding ISO 1832 insert designations for each tool holder or cartridge type.

8. Bibliography

ISO 1832:1991, Indexable inserts for cutting tools — Designation.

ISO 3002-1:1982, Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers.

ISO 5609:1985, Tool holders for internal turning operations with cylindrical shank (withdrawn, but referenced for historical context).

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ISO 5608:1995

Turning and profiling toolholders and indexable insert chucks - marking

1. Scope

This International Standard specifies a marking system for turning and profiling toolholders and indexable insert holders for processes such as external and internal turning, profiling, and contouring. The system provides standardized codes for identifying the type, size, clamping method, and compatibility with indexable inserts, ensuring interchangeability and compatibility between manufacturers. This standard applies to toolholders and holders for inserts that comply with **ISO 1832** (Marking of indexable inserts).

This standard covers both solid toolholders (fixed shanks) and modular toolholders (with replaceable collets). It does not address performance characteristics (e.g., cutting speed, rigidity), material specifications, or detailed design features other than identification.

2. Normative References

The following documents are referenced in ISO 5608:1995 and are indispensable for its application:

ISO 1832:1991 : Indexable inserts for cutting tools — Designation (superseded by ISO 1832:2017, but referenced in the 1995 edition).

ISO 3002-1:1982 : Fundamental quantities for cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and machining angles, chipbreakers.

3. Terms and Definitions

In this standard, the following terms apply:

Toolholder : A device that holds an indexable insert, either directly or through a collet, for turning or profiling operations.

Collet : The replaceable component that holds the indexable insert and is mounted on a modular toolholder.

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Identification : A coded sequence of letters and numbers that specifies the characteristics of a toolholder or collet (e.g., type, shank, insert compatibility).

Clamping method : The mechanism that secures the blade (e.g., screw, clamp, lever).

4. Identification system

The identification of the tool holder or collet consists of up to 10 characters (letters and numbers), each of which represents a specific characteristic. The first seven characters are mandatory, and the last three characters are optional, depending on the characteristics of the tool. The structure is as follows:

4.1 Required symbols (positions 1–7)

Shank Type (1st digit): A letter indicating the shank or collet type (e.g., P for clamping, S for screw). See Table 1.

Insert shape (second digit): A letter designating the shape of compatible inserts, according to ISO 1832 (e.g., S for square, T for triangular). See Table 2.

Shank Style (3rd position): A letter defining the tool angle or tool style (e.g., D for 93°, F for 0°). See Table 3.

Clamping method (4th digit): A letter indicating the insert clamping method (e.g., S for screw, C for top clamp). See Table 4.

Shank Height or Collet Size (5th–6th digits): Two digits representing the shank height in millimeters or a collet size code (e.g., 25 for 25 mm).

Shank Width or Length (7th digit): Two digits indicating the shank width in millimeters or the shank length code for the collet (e.g., 25 for 25 mm).

4.2 Optional Sign (Bits 8–10)

Tool rotation direction (8th position): A letter indicating the cutting direction (e.g., R for right-hand, L for left-hand). See Table 5.

Insert size (9th digit): A code designating the compatible insert size according to ISO 1832 (e.g., 12 for a 12 mm inscribed circle).

Manufacturer code (10th digit): A letter or number indicating proprietary features (e.g., specific clamping design, coating).

4.3 Symbol Table

Table 1: Toolholder type (1st digit)

letter	describe
A	External turning, straight shank
B	External turning, offset shank
C	Internal turning
P	Clamping tool holder

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S	Screw type handle
M	Modular toolholders

Table 2: Blade shape (second position)

letter	shape
C	Rhombus (80°)
D	Rhombus (55°)
S	square
T	triangle
V	Rhombus (35°)
W	tricuspid

Table 3: Shank Style (3rd Digit)

letter	Feed angle
A	95°
B	90°
D	93°
F	0° (end face cutting)
K	75°
P	91°

Table 4: Clamping method (4th position)

letter	describe
C	Top clamping
D	Double clamping
M	Lever clamping
S	Screw clamping
P	Pin clamping

Table 5: Tool rotation direction (8th digit, optional)

letter	direction
R	right-handed
L	Left-handed
N	neutral

5. Logo Examples

Example 1: PSDKR 2525M 12

P : Clamping type tool holder.

S : Square blade.

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D : 93° feed angle.

K : Lever clamping.

25 : 25 mm shank height.

25 : 25 mm handle width.

M : Modular handle.

R : right-handed.

12 : Compatible with 12mm inscribed circular blades.

Example 2: ASCT 1616C

A : External turning, straight shank.

S : Square blade.

C : Top clamping.

T : Triangular insert (chuck specific).

16 : 16 mm shank height.

16 : 16 mm handle width.

C : Chuck identification.

6. Application Description

Interchangeability : Marking ensures compatibility with indexable inserts according to ISO 1832 (eg PSDKR 2525M 12 is compatible with SNMG 120408).

Tool selection : Match the toolholder or collet based on insert shape (digit 2) and size (digit 9), and select the feed angle based on the machining operation (digit 3, e.g., 90° for facing, 93° for general turning).

Clamping : Select the clamping method according to the rigidity and insert type (position 4, e.g. screw clamping for small inserts, top clamping for large inserts).

Modular system : Collets (e.g., ASCT 1616C) provide flexibility for modular toolholders, supporting a variety of insert shapes.

7. Appendix

Appendix A (Informative): Graphical Representation of Tool Handle Styles

Provides illustrations of toolholder styles (e.g., entry angle, shank type) and collet designs for improved clarity.

Appendix B (Informative): Blade Marking Compatibility

Lists the ISO 1832 insert designation for each holder or collet type.

8. References

ISO 1832:1991, Indexable inserts for cutting tools — Designation.

ISO 3002-1:1982, Fundamental quantities for cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terminology, reference systems, tool and machining angles, chipbreakers.

ISO 5609:1985, Tool holders with cylindrical shank for internal turning operations (withdrawn but included for historical purposes).

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ISO 883:2013

Indexable hardmetal (carbide) inserts with rounded corners, with partly cylindrical fixing hole — Dimensions

(Indexable carbide inserts with radiused, partially cylindrical fixing holes - dimensions)

1. Scope

This International Standard specifies the dimensions of indexable hardmetal (carbide) inserts with rounded corners and a partly cylindrical fixing hole, used in tools for machining processes such as turning, milling, and boring. The standard applies to inserts made from cemented carbides, with or without coatings, designed for specific clamping systems that utilize a partly cylindrical cutting fixing hole (eg, for pin or lever clamping). It ensures interchangeability and compatibility across manufacturers and applications, covering inserts with various shapes (eg, square, triangular, rhomboid).

The standard complements **ISO 1832:2017** (designation of indexable inserts) by providing precise dimensional specifications. It does not cover performance characteristics (eg, cutting speed, tool life), material compositions beyond hardmetal (carbide), or inserts with fully cylindrical or other fixing hole types.

2. Normative References

The following documents are referenced in ISO 883:2013 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Indexable hardmetal insert : A replaceable cutting element made from cemented carbide, with multiple cutting edges, designed to be clamped in a tool holder via a partly cylindrical fixing hole.

Rounded corners : The radiused edges of the insert's cutting corners, specified to enhance edge strength and tool life.

Partly cylindrical fixing hole : A fixing hole with a partially cylindrical shape (eg, with flat or tapered sections), used for specific clamping mechanisms such as pin or lever systems.

Nominal dimension : The theoretical dimension of the insert (eg, inscribed circle diameter, thickness), subject to tolerances.

4. Dimensional Specifications

The standard specifies the dimensions of indexable hardmetal inserts with rounded corners and a partly cylindrical fixing hole, including:

Inscribed circle diameter (d) : The diameter of the circle inscribed within the insert's shape (for polygonal inserts) or the insert diameter (for round inserts).

Side length (s) : The length of the insert's side for polygonal shapes (eg, square, triangular).

Thickness (t) : The vertical height of the insert.

Corner radius (r) : The radius of the rounded corners.

Fixing hole diameter (d_1) : The diameter of the partly cylindrical fixing hole, measured at its cylindrical portion.

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Fixing hole depth (h) : The depth of the fixing hole, including any flat or tapered sections.

4.1 Insert Shapes

The standard covers inserts with the following shapes, as defined in ISO 1832:2017:

Square (S)

Triangular (T)

Rhomboid (C, D, E, V)

Round (R)

Other polygonal shapes (eg, pentagonal P, hexagonal H)

4.2 Dimensional Tables

The dimensions are provided in tables based on insert shape and size, with tolerances as per ISO 1832:2017 tolerance classes (eg, A, M). Below is a representative table for square inserts (simplified for clarity; the full standard includes extensive tables).

Table 1: Dimensions for Square Inserts (S) with Partly Cylindrical Fixing Hole

Inscribed Circle (d, mm)	Side Length (s, mm)	Thickness (t, mm)	Corner Radius (r, mm)	Fixing Hole Diameter (d_1, mm)	Fixing Hole Depth (h, mm)	Tolerance Class
6.35	6.35	3.18	0.4	2.8	2.0	M
9.52	9.52	3.97	0.8	4.0	2.5	M
12.70	12.70	4.76	1.2	5.0	3.0	M
15.88	15.88	5.56	1.6	6.0	3.5	M

Notes :

Tolerances follow ISO 1832:2017 (eg, M: ±0.13–±0.20 mm for inscribed circle, ±0.13 mm for thickness).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on insert size.

Fixing hole diameter (d_1) and depth (h) are designed for pin or lever clamping, with flat or tapered sections as specified.

4.3 Tolerances

Inscribed circle (d) : Tolerances as per ISO 1832:2017 (eg, ±0.025 mm for class A, ±0.13–±0.20 mm for class M).

Thickness (t) : Tolerances typically ±0.025 mm to ±0.13 mm, depending on class.

Fixing hole diameter (d_1) : Tolerances ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.

Fixing hole depth (h) : Tolerances ±0.10 mm, critical for secure clamping.

Corner radius (r) : Tolerances ±0.05 mm to ±0.10 mm, ensuring edge strength.

4.4 Partly Cylindrical Fixing Hole

The partly cylindrical fixing hole includes a cylindrical portion with additional flat or tapered sections to accommodate specific clamping mechanisms (eg, pin or lever systems). The hole's geometry is designed to enhance clamping stability and insert retention compared to fully cylindrical holes.

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5. Designation

The dimensions specified in ISO 883:2013 are used in conjunction with the designation system of **ISO 1832:2017** .

The designation includes:

Insert shape (eg, S for square).

Clearance angle (eg, N for 0°).

Tolerance class (eg, M).

Type (eg, P for pin-clamped with hole).

Size (eg, 12 for 12 mm inscribed circle).

Thickness (eg, 04 for 4 mm).

Optional features (eg, corner radius, edge condition).

Example :

SPMN 120408 : Square insert (S), 0° clearance (N), medium tolerance (M), pin-clamped with hole (P), 12.7 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (implied by ISO 883:2013 tables).

6. Application Notes

Interchangeability : Dimensions ensure inserts are compatible with specific tool holders using pin or lever clamping (eg, per ISO 5608:1995).

Material : Applies to cemented carbides (per ISO 513:2011 classifications, eg, P10, K20), with or without coatings.

Machining : Suitable for turning, milling, and boring, with rounded corners enhancing edge strength for interrupted cuts or heavy machining.

Designation : Always use ISO 1832:2017 designation with ISO 883:2013 dimensions to specify inserts fully.

7. Annexes

Annex A (Normative): Detailed dimensional tables

Provides comprehensive tables for all insert shapes (square, triangular, rhomboid, round, etc.), listing inscribed circle, side length, thickness, corner radius, fixing hole diameter, and depth.

Annex B (Informative): Recommended clamping systems

Lists compatible clamping mechanisms (eg, pin, lever) and tool holder types for the specified partly cylindrical fixing hole.

8. Bibliography

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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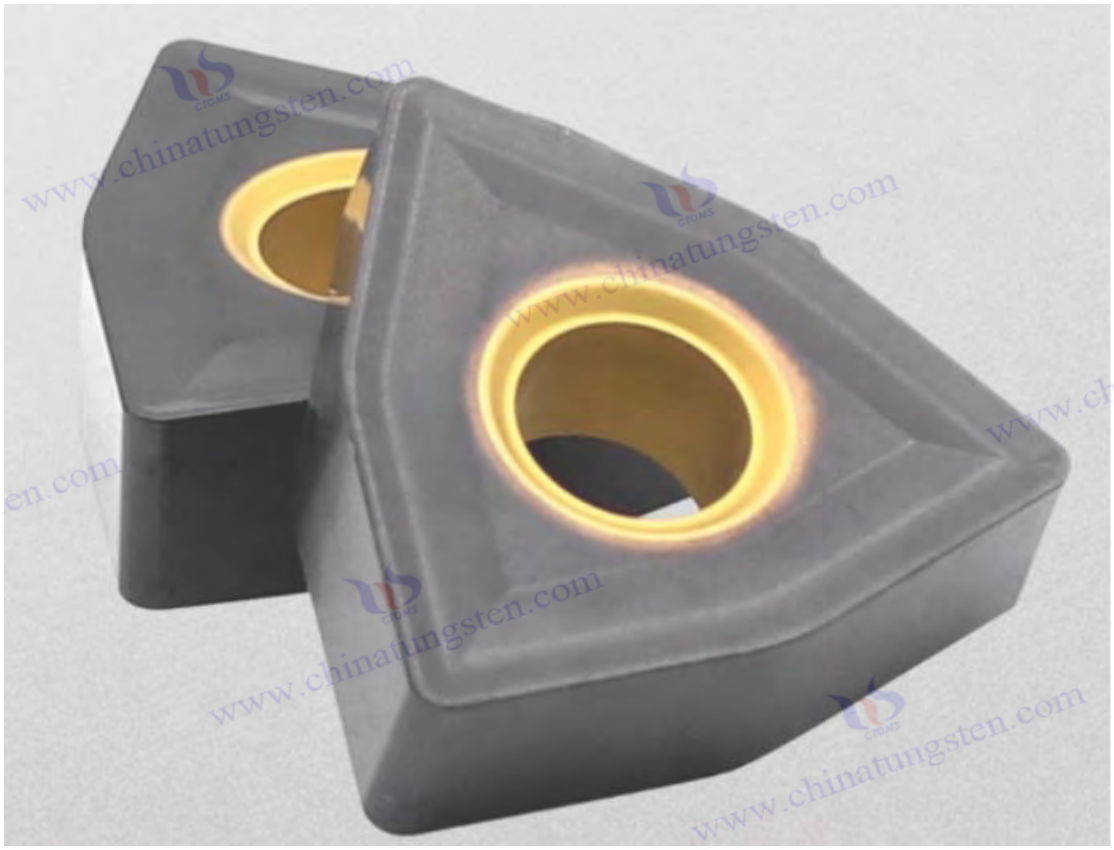
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ISO 883:2013

Indexable carbide inserts with radiused, partially cylindrical fixing holes - Dimensions

1. Scope

This International Standard specifies the dimensions of indexable carbide inserts with a radiused, part-cylindrical retaining bore, suitable for use in cutting tool processes such as turning, milling, and boring. This standard applies to inserts made of carbide, whether coated or uncoated, designed for use with a specific clamping system (e.g., pin or lever clamping) utilizing a part-cylindrical retaining bore. It ensures interchangeability and compatibility between different manufacturers and applications and covers a wide range of insert shapes (e.g., square, triangular, diamond). This standard supplements **ISO 1832:2017** (Marking of indexable inserts) by providing precise dimensional specifications but does not address performance characteristics (e.g. cutting speed, tool life), material composition other than carbide, or inserts with fully cylindrical or other fixed bore types.

2. Normative References

The following documents are referenced in ISO 883:2013 and are indispensable for its application:
ISO 1832:2017 : Indexable inserts for cutting tools — Designation.
ISO 513:2011 : Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

3. Terms and Definitions

In this standard, the following terms apply:
Indexable Carbide Insert : A replaceable cutting element made of carbide, having multiple cutting edges, clamped to the toolholder via a partially cylindrical fixing hole.
Corner Fillet: The rounded edge of the cutting corner of the insert, specified to enhance edge strength and tool life.
Part-cylindrical fixing hole : A fixing hole with a partial cylindrical shape (e.g., with a flat or tapered section) used for certain clamping mechanisms such as pin or lever systems.
Nominal size : The theoretical size of the insert (such as inscribed circle diameter, thickness), subject to tolerance limits.

4. Dimensions

This standard specifies the dimensions of indexable carbide inserts with rounded corners and partially cylindrical fixing holes, including:
Inscribed circle diameter (d) : The diameter of the inscribed circle of a polygonal blade or the diameter of a circular blade.
Side length (s) : Side length of polygonal blade (such as square, triangle).
Thickness (t) : The vertical height of the blade.
Fillet radius (r) : The radius of the fillet.
Fixing hole diameter (d_1) : The diameter of the cylindrical portion of a partially cylindrical fixing hole.

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Fixing Hole Depth (h) : The depth of the fixing hole, including any flat or tapered portions.

4.1 Blade shape

This standard covers the following insert shapes, as defined in ISO 1832:2017:

Square (S)

Triangle (T)

Diamond (C, D, E, V)

Round (R)

Other polygons (such as pentagon P, hexagon H)

4.2 Dimensions

Dimensions are provided in tabular form based on insert shape and size, with tolerances in accordance with ISO 1832:2017 tolerance classes (e.g., A, M). Below is a representative table for square inserts (simplified for clarity, the full standard includes detailed tables).

Table 1: Dimensions of square inserts (S) with partially cylindrical fixing holes

Inscribed circle diameter (d, mm)	Side length (s, mm)	Thickness (t, mm)	Corner radius (r, mm)	Fixing hole diameter (d_1 , mm)	Fixing hole depth (h, mm)	Tolerance grade
6.35	6.35	3.18	0.4	2.8	2.0	M
9.52	9.52	3.97	0.8	4.0	2.5	M
12.70	12.70	4.76	1.2	5.0	3.0	M
15.88	15.88	5.56	1.6	6.0	3.5	M

Note :

Tolerances follow ISO 1832:2017 (e.g., M: inscribed circle ±0.13–±0.20 mm, thickness ±0.13 mm).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on the insert size.

Fixing hole diameter (d_1) and depth (h) are designed for pin or lever clamping, with specified flat or tapered section.

4.3 Tolerance

Inscribed circle diameter (d) : Tolerance according to ISO 1832:2017 (e.g. Grade A ±0.025 mm, Grade M ±0.13–±0.20 mm).

Thickness (t) : Tolerance is typically ±0.025 mm to ±0.13 mm, depending on the grade.

Fixing hole diameter (d_1) : Tolerance ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.

Fixing hole depth (h) : Tolerance ±0.10 mm, critical for secure clamping.

Corner radius (r) : Tolerance ±0.05 mm to ±0.10 mm to ensure edge strength.

4.4 Partial cylindrical fixing holes

Partial cylindrical retaining holes consist of a cylindrical portion with an additional flat or tapered section to accommodate specific clamping mechanisms (e.g., pin or lever systems). The hole geometry is designed to enhance

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clamping stability and insert retention over fully cylindrical holes.

5. Logo

The dimensions of ISO 883:2013 are used in conjunction with the marking system of **ISO 1832:2017** . The markings include:

Blade shape (e.g., S for square).

Clearance angle (e.g., N for 0°).

Tolerance class (for example, M).

Type (e.g., P for pin clamping with hole).

Size (e.g., 12 for a 12 mm inscribed circle).

Thickness (for example, 04 means 4 mm).

Optional properties (for example, fillet radius, edge condition).

Example :

SPMN 120408 : Square insert (S), 0° clearance angle (N), medium tolerance (M), pin clamping with hole (P), 12.7 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (according to ISO 883:2013 table).

6. Application Description

Interchangeability : Dimensions ensuring that the insert is compatible with a specific toolholder clamped using a pin or lever (e.g. according to ISO 5608:1995).

Materials : Suitable for cemented carbide (classification according to ISO 513:2011, e.g. P10, K20), whether coated or not.

Machining : Suitable for turning, milling and boring, with rounded corners to enhance edge strength for interrupted cutting or heavy machining.

Marking : Inserts are always fully specified using a combination of ISO 1832:2017 marking and ISO 883:2013 dimensions.

7. Appendix

Appendix A (Normative): Detailed Dimensions

A complete table of all insert shapes (square, triangle, diamond, round, etc.) is available, listing inscribed circle diameter, side length, thickness, corner radius, fixing hole diameter, and depth.

Appendix B (Informative): Recommended Clamping Systems

Lists compatible clamping mechanisms (e.g., pin, lever) and toolholder types that match the specified partial cylindrical fixing hole.

8. References

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

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ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 6987:2012

Indexable hardmetal (carbide) inserts with rounded corners, with partly cylindrical fixing hole — Dimensions

(Indexable carbide inserts with radiused, partially cylindrical fixing holes - dimensions)

1. Scope

This International Standard specifies the dimensions of indexable hardmetal (carbide) inserts with rounded corners and a partly cylindrical fixing hole, used in tools for machining processes such as turning, milling, and boring. The standard applies to inserts made from cemented carbides, with or without coatings, designed for specific clamping systems utilizing a partly cylindrical fixing hole (eg, for pin or lever clamping). It ensures interchangeability and compatibility across manufacturers and applications, covering a range of insert shapes (eg, square, triangular, rhomboid) and sizes optimized for precision machining.

The standard complements **ISO 1832:2017** (designation of indexable inserts) by providing precise dimensional specifications. It is closely related to **ISO 883:2013** , but ISO 6987:2012 includes additional dimensional variations and specific insert shapes for specialized applications. It does not cover performance characteristics (eg, cutting speed, tool life), material compositions beyond hardmetal (carbide), or inserts with fully cylindrical or other fixing hole types.

2. Normative References

The following documents are referenced in ISO 6987:2012 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Indexable hardmetal insert : A replaceable cutting element made from cemented carbide, with multiple cutting edges, designed to be clamped in a tool holder via a partly cylindrical fixing hole.

Rounded corners : The radiused edges of the insert's cutting corners, specified to enhance edge strength and tool life.

Partly cylindrical fixing hole : A fixing hole with a partially cylindrical shape (eg, with flat or tapered sections), used for specific clamping mechanisms such as pin or lever systems.

Nominal dimension : The theoretical dimension of the insert (eg, inscribed circle diameter, thickness), subject to tolerances.

4. Dimensional Specifications

The standard specifies the dimensions of indexable hardmetal inserts with rounded corners and a partly cylindrical fixing hole, including:

Inscribed circle diameter (d) : The diameter of the circle inscribed within the insert's shape (for polygonal inserts) or the insert diameter (for round inserts).

Side length (s) : The length of the insert's side for polygonal shapes (eg, square, triangular).

Thickness (t) : The vertical height of the insert.

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Corner radius (r) : The radius of the rounded corners.

Fixing hole diameter (d_1) : The diameter of the partly cylindrical fixing hole, measured at its cylindrical portion.

Fixing hole depth (h) : The depth of the fixing hole, including any flat or tapered sections.

4.1 Insert Shapes

The standard covers inserts with the following shapes, as defined in ISO 1832:2017:

Square (S)

Triangular (T)

Rhomboid (C, D, E, V)

Round (R)

Pentagonal (P)

Hexagonal (H)

4.2 Dimensional Tables

The dimensions are provided in tables based on insert shape and size, with tolerances as per ISO 1832:2017 tolerance classes (eg, A, M). Below is a representative table for triangular inserts (simplified for clarity; the full standard includes extensive tables covering additional shapes and sizes compared to ISO 883:2013).

Table 1: Dimensions for Triangular Inserts (T) with Partly Cylindrical Fixing Hole

Inscribed Circle (d, mm)	Side Length (s, mm)	Thickness (t, mm)	Corner Radius (r, mm)	Fixing Hole Diameter (d_1, mm)	Fixing Hole Depth (h, mm)	Tolerance Class
6.35	11.0	3.18	0.4	2.6	1.8	M
9.52	16.5	3.97	0.8	3.8	2.3	M
12.70	22.0	4.76	1.2	4.8	2.8	M
15.88	27.5	5.56	1.6	5.8	3.3	M

Notes :

Tolerances follow ISO 1832:2017 (eg, M: ±0.13–±0.20 mm for inscribed circle, ±0.13 mm for thickness).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on insert size.

Fixing hole diameter (d_1) and depth (h) are optimized for pin or lever clamping, with flat or tapered sections to enhance stability.

4.3 Tolerances

Inscribed circle (d) : Tolerances as per ISO 1832:2017 (eg, ±0.025 mm for class A, ±0.13–±0.20 mm for class M).

Thickness (t) : Tolerances typically ±0.025 mm to ±0.13 mm, depending on class.

Fixing hole diameter (d_1) : Tolerances ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.

Fixing hole depth (h) : Tolerances ±0.10 mm, critical for secure clamping.

Corner radius (r) : Tolerances ±0.05 mm to ±0.10 mm, ensuring edge strength.

4.4 Partly Cylindrical Fixing Hole

The partly cylindrical fixing hole includes a cylindrical portion with flat or tapered sections to accommodate specific clamping mechanisms (eg, pin or lever systems). The geometry enhances clamping stability and insert retention,

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particularly for precision machining applications.

5. Designation

The dimensions specified in ISO 6987:2012 are used in conjunction with the designation system of **ISO 1832:2017** .

The designation includes:

Insert shape (eg, T for triangular).

Clearance angle (eg, N for 0°).

Tolerance class (eg, M).

Type (eg, P for pin-clamped with hole).

Size (eg, 16 for 9.52 mm inscribed circle).

Thickness (eg, 04 for 4 mm).

Optional features (eg, corner radius, edge condition).

Example :

TPMN 160408 : Triangular insert (T), 0° clearance (N), medium tolerance (M), pin-clamped with hole (P), 9.52 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (implied by ISO 6987:2012 tables).

6. Application Notes

Interchangeability : Dimensions ensure inserts are compatible with specific tool holders using pin or lever clamping (eg, per ISO 5608:1995).

Material : Applies to cemented carbides (per ISO 513:2011 classifications, eg, P10, K20), with or without coatings.

Machining : Suitable for precision turning, milling, and boring, with rounded corners enhancing edge strength for interrupted cuts or heavy machining.

Designation : Always use ISO 1832:2017 designation with ISO 6987:2012 dimensions to specify inserts fully.

7. Annexes

Annex A (Normative): Detailed dimensional tables

Provides comprehensive tables for all insert shapes (square, triangular, rhomboid, round, pentagonal, hexagonal), listing inscribed circle, side length, thickness, corner radius, fixing hole diameter, and depth.

Annex B (Informative): Recommended clamping systems

Lists compatible clamping mechanisms (eg, pin, lever) and tool holder types for the specified partly cylindrical fixing hole.

8. Bibliography

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

ISO 883:2013, Indexable hardmetal (carbide) inserts with rounded corners, with partly cylindrical fixing hole — Dimensions.

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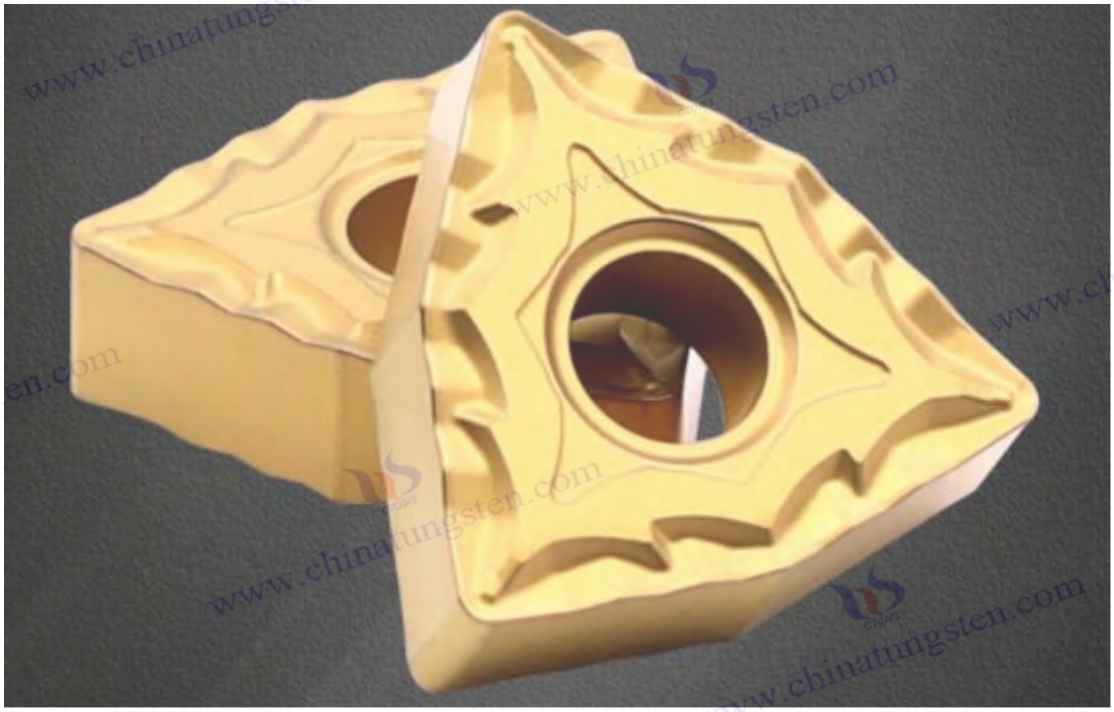
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ISO 6987:2012

Indexable carbide inserts with radiused, partially cylindrical fixing holes - Dimensions

1. Scope

This International Standard specifies the dimensions of indexable carbide inserts with a radiused, part-cylindrical fixing bore for use in cutting tool processes such as turning, milling, and boring. This standard applies to inserts made of carbide, whether coated or uncoated, designed for use with a specific clamping system (e.g., pin or lever clamping) utilizing a part-cylindrical fixing bore. It ensures interchangeability and compatibility across manufacturers and applications, covering a wide range of shapes (e.g., square, triangular, diamond) and sizes optimized for precision machining.

This standard supplements **ISO 1832:2017** (Identification of indexable inserts) by providing precise dimensional specifications. It is closely related to **ISO 883:2013** , but ISO 6987:2012 includes additional dimensional variations and specific insert shapes for specialized applications. This standard does not address performance characteristics (e.g., cutting speed, tool life), material compositions other than carbide, or inserts with fully cylindrical or other fixed bore types.

2. Normative References

The following documents are referenced in ISO 6987:2012 and are indispensable for its application:
ISO 1832:2017 : Indexable inserts for cutting tools — Designation.
ISO 513:2011 : Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

3. Terms and Definitions

In this standard, the following terms apply:
Indexable Carbide Insert : A replaceable cutting element made of carbide, having multiple cutting edges, clamped to the toolholder via a partially cylindrical fixing hole.
Corner Fillet: The rounded edge of the cutting corner of the insert, specified to enhance edge strength and tool life.
Part-cylindrical fixing hole : A fixing hole with a partial cylindrical shape (e.g., with a flat or tapered section) used for certain clamping mechanisms such as pin or lever systems.
Nominal size : The theoretical size of the insert (such as inscribed circle diameter, thickness), subject to tolerance limits.

4. Dimensions

This standard specifies the dimensions of indexable carbide inserts with rounded corners and partially cylindrical fixing holes, including:
Inscribed circle diameter (d) : The diameter of the inscribed circle of a polygonal blade or the diameter of a circular blade.

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Side length (s) : Side length of polygonal blade (such as square, triangle).

Thickness (t) : The vertical height of the blade.

Fillet radius (r) : The radius of the fillet.

Fixing hole diameter (d_1) : The diameter of the cylindrical portion of a partially cylindrical fixing hole.

Fixing Hole Depth (h) : The depth of the fixing hole, including any flat or tapered portions.

4.1 Blade shape

This standard covers the following insert shapes, as defined in ISO 1832:2017:

Square (S)

Triangle (T)

Diamond (C, D, E, V)

Round (R)

Pentagon (P)

Hexagon (H)

4.2 Dimensions

Dimensions are provided in tabular form based on insert shape and size, with tolerances in accordance with ISO 1832:2017 tolerance classes (e.g., A, M). Below is a representative table for triangular inserts (simplified for clarity; the full standard contains detailed tables for many more shapes and sizes and is more extensive than ISO 883:2013).

Table 1: Dimensions of triangular inserts (T) with partially cylindrical fixing holes

Inscribed circle diameter (d, mm)	Side length (s, mm)	Thickness (t, mm)	Corner radius (r, mm)	Fixing hole diameter (d_1 , mm)	Fixing hole depth (h, mm)	Tolerance grade
6.35	11.0	3.18	0.4	2.6	1.8	M
9.52	16.5	3.97	0.8	3.8	2.3	M
12.70	22.0	4.76	1.2	4.8	2.8	M
15.88	27.5	5.56	1.6	5.8	3.3	M

Note :

Tolerances follow ISO 1832:2017 (e.g., M: inscribed circle ±0.13–±0.20 mm, thickness ±0.13 mm).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on the insert size.

Fixing hole diameter (d_1) and depth (h) optimized for pin or lever clamping, with flat or tapered sections for enhanced stability.

4.3 Tolerance

Inscribed circle diameter (d) : Tolerance according to ISO 1832:2017 (e.g. Grade A ±0.025 mm, Grade M ±0.13–±0.20 mm).

Thickness (t) : Tolerance is typically ±0.025 mm to ±0.13 mm, depending on the grade.

Fixing hole diameter (d_1) : Tolerance ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.

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Fixing hole depth (h) : Tolerance ±0.10 mm, critical for secure clamping.

Corner radius (r) : Tolerance ±0.05 mm to ±0.10 mm to ensure edge strength.

4.4 Partial cylindrical fixing holes

Partial cylindrical fixing holes consist of a cylindrical portion and a flat or tapered section to accommodate specific clamping mechanisms (e.g., pin or lever systems). This geometry enhances clamping stability and insert retention, making it particularly suitable for precision machining applications.

5. Logo

The dimensions of ISO 6987:2012 are used in conjunction with the marking system of **ISO 1832:2017** . The markings include:

The shape of the blade (for example, T for triangle).

Relief angle (e.g., N for 0°).

Tolerance class (for example, M).

Type (e.g., P for pin clamping with hole).

Size (e.g., 16 for a 9.52 mm inscribed circle).

Thickness (for example, 04 means 4 mm).

Optional properties (for example, fillet radius, edge condition).

Example :

TPMN 160408 : Triangular insert (T), 0° clearance angle (N), medium tolerance (M), with hole for pin clamping (P), 9.52 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (according to ISO 6987:2012 table).

6. Application Description

Interchangeability : Dimensions ensuring that the insert is compatible with a specific toolholder clamped using a pin or lever (e.g. according to ISO 5608:1995).

Materials : Suitable for cemented carbide (classification according to ISO 513:2011, e.g. P10, K20), whether coated or not.

Processing : Suitable for precision turning, milling and boring, with rounded corners to enhance edge strength for interrupted cutting or heavy machining.

Marking : Inserts are always fully specified in combination with ISO 1832:2017 marking and ISO 6987:2012 dimensions.

7. Appendix

Appendix A (Normative): Detailed Dimensions

Complete tables are available for all insert shapes (square, triangle, diamond, circle, pentagon, hexagon) listing inscribed circle diameter, side length, thickness, corner radius, fixing hole diameter and depth.

Appendix B (Informative): Recommended Clamping Systems

Lists compatible clamping mechanisms (e.g., pin, lever) and toolholder types that match the specified partial cylindrical fixing hole.

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8. References

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

ISO 883:2013, Indexable carbide inserts with radiused, part-cylindrical fixing holes — Dimensions.

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ISO 16462:2014

Cubic boron nitride inserts, tipped or solid — Dimensions, types

(Cubic Boron Nitride Inserts, Pointed or Solid — Sizes, Types)

1. Scope

This International Standard specifies the dimensions and types of cubic boron nitride (CBN) inserts, either tipped or solid, used in cutting tools for machining hard materials such as hardened steels, cast irons, and superalloys. The standard applies to indexable inserts made from CBN, with or without coatings, designed for applications requiring high wear resistance and thermal stability. It covers inserts with various shapes (eg, square, triangular, round) and fixing methods (eg, with or without fixing holes), ensuring interchangeability and compatibility across manufacturers.

The standard complements **ISO 1832:2017** (designation of indexable inserts) by providing precise dimensional specifications and type classifications. It does not cover performance characteristics (eg, cutting speed, tool life), detailed material compositions beyond CBN, or inserts made from other materials (eg, cemented carbide, ceramics).

2. Normative References

The following documents are referenced in ISO 16462:2014 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Cubic boron nitride (CBN) insert : A cutting element made from CBN, either as a solid insert or a tipped insert (CBN layer brazed onto a substrate), designed for machining hard materials.

Tipped insert : An insert with a CBN cutting edge brazed onto a cemented carbide or other substrate.

Solid insert : An insert made entirely from CBN or a CBN composite.

Fixing hole : A hole (cylindrical or partly cylindrical) in the insert for clamping in a tool holder, if present.

Nominal dimension : The theoretical dimension of the insert (eg, inscribed circle diameter, thickness), subject to tolerances.

4. Types of Inserts

The standard classifies CBN inserts into two main categories based on construction:

Tipped inserts : A thin layer of CBN is brazed onto a cemented carbide substrate, providing cost-effective performance for specific applications.

Solid inserts : Made entirely from CBN or a CBN composite, offering superior wear resistance and thermal stability for demanding conditions.

Inserts are further categorized by:

Shape : Square (S), triangular (T), rhomboid (C, D, E, V), round (R), and others (eg, pentagonal P).

Fixing method : With fixing hole (for screw or pin clamping) or without fixing hole (for top or side clamping).

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5. Dimensional Specifications

The standard specifies the dimensions of CBN inserts, including:

Inscribed circle diameter (d) : The diameter of the circle inscribed within the insert's shape (for polygonal inserts) or the insert diameter (for round inserts).

Side length (s) : The length of the insert's side for polygonal shapes.

Thickness (t) : The vertical height of the insert.

Corner radius (r) : The radius of the rounded corners, if applicable.

Fixing hole diameter (d_1) : The diameter of the fixing hole (cylindrical or partly cylindrical), if present.

Fixing hole depth (h) : The depth of the fixing hole, if applicable.

5.1 Insert Shapes

The standard covers inserts with the following shapes, as defined in ISO 1832:2017:

Square (S)

Triangular (T)

Rhomboid (C, D, E, V)

Round (R)

Other polygonal shapes (eg, pentagonal P)

5.2 Dimensional Tables

The dimensions are provided in tables based on insert shape, type (tipped or solid), and fixing method, with tolerances as per ISO 1832:2017 tolerance classes (eg, A, M). Below is a representative table for tipped square inserts with a cylindrical fixing hole (simplified for clarity; the full standard includes extensive tables for both tipped and solid inserts).

Table 1: Dimensions for Tipped Square CBN Inserts (S) with Cylindrical Fixing Hole

Inscribed Circle (d, mm)	Side Length (s, mm)	Thickness (t, mm)	Corner Radius (r, mm)	Fixing Hole Diameter (d_1, mm)	Fixing Hole Depth (h, mm)	Tolerance Class
6.35	6.35	3.18	0.4	2.8	2.0	M
9.52	9.52	3.97	0.8	4.0	2.5	M
12.70	12.70	4.76	1.2	5.0	3.0	M
15.88	15.88	5.56	1.6	6.0	3.5	M

Notes :

Tolerances follow ISO 1832:2017 (eg, M: ±0.13–±0.20 mm for inscribed circle, ±0.13 mm for thickness).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on insert size.

Solid inserts may have slightly different dimensions (eg, thicker profiles) due to material properties.

5.3 Tolerances

Inscribed circle (d) : Tolerances as per ISO 1832:2017 (eg, ±0.025 mm for class A, ±0.13–±0.20 mm for class M).

Thickness (t) : Tolerances typically ±0.025 mm to ±0.13 mm, depending on class.

Fixing hole diameter (d_1) : Tolerances ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.

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Fixing hole depth (h) : Tolerances ±0.10 mm, critical for secure clamping.

Corner radius (r) : Tolerances ±0.05 mm to ±0.10 mm, ensuring edge strength.

5.4 Fixing Hole

Fixing holes, when present, are typically cylindrical or partly cylindrical, designed for screw or pin clamping. Inserts without fixing holes rely on top or side clamping mechanisms, common for solid CBN inserts due to their brittleness.

6. Designation

The dimensions and types specified in ISO 16462:2014 are used in conjunction with the designation system of **ISO 1832:2017** . The designation includes:

Insert shape (eg, S for square).

Clearance angle (eg, N for 0°).

Tolerance class (eg, M).

Type (eg, B for with hole, N for no hole).

Size (eg, 12 for 12 mm inscribed circle).

Thickness (eg, 04 for 4 mm).

Optional features (eg, corner radius, CBN type).

Example :

SNGA 120408 : Square CBN insert (S), 0° clearance (N), high tolerance (G), no chip breaker (A), 12.7 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (implied by ISO 16462:2014 tables).

7. Application Notes

Interchangeability : Dimensions ensure compatibility with standard tool holders (eg, per ISO 5608:1995) for screw, pin, or top clamping.

Material : Applies to CBN (per ISO 513:2011 classifications, eg, H01–H10), suitable for machining hardened steels (HRC > 45), cast irons, and superalloys.

Machining : Ideal for high-precision finishing and hard turning, with CBN's high hardness (second only to diamond) ensuring excellent wear resistance.

Designation : Always use ISO 1832:2017 designation with ISO 16462:2014 dimensions to specify inserts fully.

8. Annexes

Annex A (Normative): Detailed dimensional tables

Provides comprehensive tables for all insert shapes (square, triangular, rhomboid, round, etc.) and types (tipped, solid), listing inscribed circle, side length, thickness, corner radius, fixing hole diameter, and depth.

Annex B (Informative): Recommended tool holder compatibility

Lists compatible tool holder types and clamping mechanisms for tipped and solid CBN inserts.

9. Bibliography

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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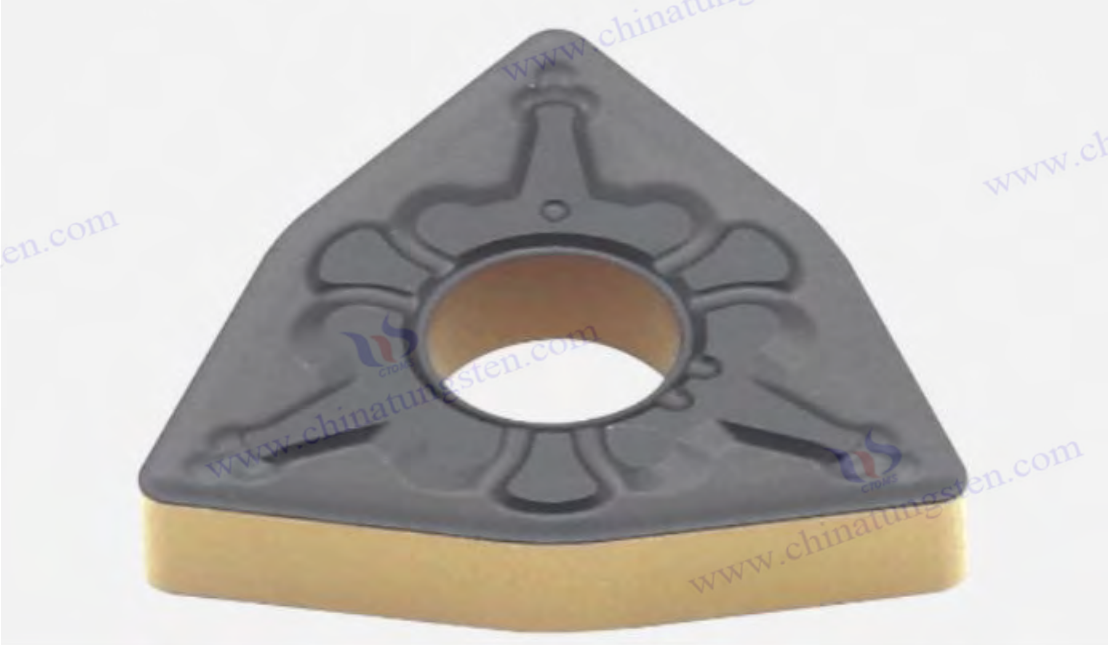
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ISO 16462:2014

Cubic boron nitride inserts, pointed or solid — sizes, types

1. Scope

This International Standard specifies the sizes and types of cubic boron nitride (CBN) inserts, either tipped or solid, for use in cutting tools for machining hard materials such as hardened steels, cast irons, and superalloys. This standard applies to indexable inserts made of CBN, whether coated or uncoated, designed for applications requiring high wear resistance and thermal stability. It covers a wide range of insert shapes (e.g., square, triangular, round) and fixing methods (e.g., with or without fixing holes), ensuring interchangeability and compatibility between different manufacturers.

This standard supplements **ISO 1832:2017** (Identification of indexable inserts) by providing precise dimensional specifications and type classifications. It does not address performance characteristics (e.g. cutting speed, tool life), detailed material composition other than CBN, or inserts made of other materials (e.g. carbide, ceramic).

2. Normative References

The following documents are referenced in ISO 16462:2014 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

3. Terms and Definitions

In this standard, the following terms apply:

Cubic Boron Nitride (CBN) Inserts : Cutting elements made of CBN, either solid or with a tip (CBN layer brazed to a substrate), designed for machining hard materials.

Tipped insert : A blade with a CBN cutting edge brazed on a carbide or other substrate.

Solid insert : A blade made entirely of CBN or CBN composite material.

Fixing Hole : The hole (cylindrical or partially cylindrical) in the insert used for clamping to the tool holder (if present).

Nominal size : The theoretical size of the insert (such as inscribed circle diameter, thickness), subject to tolerance limits.

4. Blade type

This standard divides CBN inserts into two categories according to their structure:

Tipped inserts : A thin layer of CBN brazed onto a carbide substrate, providing cost-effectiveness for specific applications.

Solid inserts : Made entirely of CBN or CBN composite materials, they provide excellent wear resistance and thermal stability under harsh conditions.

The blades are further categorized as follows:

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Shapes : Square (S), Triangle (T), Rhombus (C, D, E, V), Circle (R), and others (e.g., Pentagon P).

Fixing method : with fixing holes (for screw or pin clamping) or without fixing holes (for top or side clamping).

5. Dimensions

This standard specifies the dimensions of CBN inserts, including:

Inscribed circle diameter (d) : The diameter of the inscribed circle of a polygonal blade or the diameter of a circular blade.

Side length (s) : Side length of polygonal blade.

Thickness (t) : The vertical height of the blade.

Fillet Radius (r) : The radius of the fillet (if applicable).

Fixing hole diameter (d_1) : Diameter of the fixing hole (cylindrical or partially cylindrical, if present).

Fixing hole depth (h) : Depth of the fixing hole (if applicable).

5.1 Blade shape

This standard covers the following insert shapes, as defined in ISO 1832:2017:

Square (S)

Triangle (T)

Diamond (C, D, E, V)

Round (R)

Other polygons (such as pentagon P)

5.2 Dimensions

Dimensions are provided in tabular form based on insert shape, type (pointed or solid), and fixing method, with tolerances in accordance with ISO 1832:2017 tolerance classes (e.g., A, M). Below is a representative table for a pointed square insert with a cylindrical fixing hole (simplified for clarity; the full standard includes detailed tables for both pointed and solid inserts).

Table 1: Dimensions of pointed square CBN inserts (S) with cylindrical fixing hole

Inscribed circle diameter (d, mm)	Side length (s, mm)	Thickness (t, mm)	Corner radius (r, mm)	Fixing hole diameter (d_1 , mm)	Fixing hole depth (h, mm)	Tolerance grade
6.35	6.35	3.18	0.4	2.8	2.0	M
9.52	9.52	3.97	0.8	4.0	2.5	M
12.70	12.70	4.76	1.2	5.0	3.0	M
15.88	15.88	5.56	1.6	6.0	3.5	M

Note :

Tolerances follow ISO 1832:2017 (e.g., M: inscribed circle ±0.13–±0.20 mm, thickness ±0.13 mm).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on the insert size.

Solid blades may have slightly different dimensions (e.g., thicker profile) depending on the material properties.

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5.3 Tolerance

Inscribed circle diameter (d) : Tolerance according to ISO 1832:2017 (e.g. Grade A ±0.025 mm, Grade M ±0.13–±0.20 mm).
Thickness (t) : Tolerance is typically ±0.025 mm to ±0.13 mm, depending on the grade.
Fixing hole diameter (d_1) : Tolerance ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.
Fixing hole depth (h) : Tolerance ±0.10 mm, critical for secure clamping.
Corner radius (r) : Tolerance ±0.05 mm to ±0.10 mm to ensure edge strength.

5.4 Fixing holes

The fixing hole (if any) is usually cylindrical or partially cylindrical and designed for screw or pin clamping. Inserts without a fixing hole rely on a top or side clamping mechanism, which is common in solid CBN inserts due to their brittleness.

6. Logo

The sizes and types of ISO 16462:2014 are used in conjunction with the marking system of **ISO 1832:2017** . The markings include:
Insert shape (e.g., S for square). Relief angle (e.g., N for 0°). Tolerance class (e.g., M).
Type (e.g. B for with hole, N for without hole). Size (e.g. 12 for a 12 mm inscribed circle).
Thickness (e.g., 04 for 4 mm). Optional characteristics (e.g., corner radius, CBN type).
Example :
SNGA 120408 : Square CBN insert (S), 0° clearance angle (N), high tolerance (G), no chipbreaker (A), 12.7 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (according to ISO 16462:2014 table).

7. Application Description

Interchangeability : Dimensions ensure compatibility with standard toolholders (e.g. according to ISO 5608:1995) suitable for screw, pin or top clamping.
Materials : Suitable for CBN (classification according to ISO 513:2011, e.g. H01–H10), suitable for machining hardened steel (HRC > 45), cast iron and super alloys.
Machining : Suitable for high-precision finishing and hard turning, the high hardness of CBN (second only to diamond) ensures excellent wear resistance.
Marking : Inserts are always fully specified using a combination of ISO 1832:2017 marking and ISO 16462:2014 dimensions.

8. Appendix

Appendix A (Normative): Detailed Dimensions
Complete tables are available for all insert shapes (square, triangle, diamond, round, etc.) and types (pointed, solid), listing inscribed circle diameter, side length, thickness, corner radius, fixing hole diameter and depth.

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Appendix B (Informative): Recommended Toolholder Compatibility

Lists compatible toolholder types and clamping mechanisms for both pointed and solid CBN inserts.

9. References

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 16463:2014

Polycrystalline diamond inserts, tipped — Dimensions, types

(Polycrystalline diamond blades, pointed - size, type)

1. Scope

This International Standard specifies the dimensions and types of polycrystalline diamond (PCD) tipped inserts used in cutting tools for machining non-ferrous metals (eg, aluminum, copper, magnesium), non-metallic materials (eg, plastics, composites), and abrasive materials (eg, fiber-reinforced composites). The standard applies to indexable inserts with a PCD cutting edge brazed onto a cemented carbide substrate, designed for applications requiring high wear resistance and excellent surface finish. It covers inserts with various shapes (eg, square, triangular, round) and fixing methods (eg, with or without fixing holes), ensuring interchangeability and compatibility across manufacturers.

The standard complements **ISO 1832:2017** (designation of indexable inserts) by providing precise dimensional specifications and type classifications. It does not cover performance characteristics (eg, cutting speed, tool life), detailed material compositions beyond PCD, solid PCD inserts, or inserts made from other materials (eg, cemented carbide, CBN).

2. Normative References

The following documents are referenced in ISO 16463:2014 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Polycrystalline diamond (PCD) insert : A cutting element with a PCD cutting edge brazed onto a cemented carbide substrate, designed for machining non-ferrous and non-metallic materials.

Tipped insert : An insert with a PCD layer brazed onto a substrate, typically cemented carbide, for cost-effective performance.

Fixing hole : A hole (cylindrical or partly cylindrical) in the insert for clamping in a tool holder, if present.

Nominal dimension : The theoretical dimension of the insert (eg, inscribed circle diameter, thickness), subject to tolerances.

4. Types of Inserts

The standard focuses on PCD tipped inserts, classified by:

Shape : Square (S), triangular (T), rhomboid (C, D, E, V), round (R), and others (eg, pentagonal P).

Fixing method : With fixing hole (for screw or pin clamping) or without fixing hole (for top or side clamping).

PCD layer thickness : Typically 0.5–1.0 mm, optimized for wear resistance and edge sharpness.

PCD inserts are not produced as solid inserts due to cost and manufacturing constraints; the tipped design balances performance and economy.

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5. Dimensional Specifications

The standard specifies the dimensions of PCD tipped inserts, including:

Inscribed circle diameter (d) : The diameter of the circle inscribed within the insert's shape (for polygonal inserts) or the insert diameter (for round inserts).

Side length (s) : The length of the insert's side for polygonal shapes.

Thickness (t) : The vertical height of the insert, including the substrate and PCD layer.

Corner radius (r) : The radius of the rounded corners, if applicable.

Fixing hole diameter (d_1) : The diameter of the fixing hole (cylindrical or partly cylindrical), if present.

Fixing hole depth (h) : The depth of the fixing hole, if applicable.

5.1 Insert Shapes

The standard covers inserts with the following shapes, as defined in ISO 1832:2017:

Square (S)

Triangular (T)

Rhomboid (C, D, E, V)

Round (R)

Other polygonal shapes (eg, pentagonal P)

5.2 Dimensional Tables

The dimensions are provided in tables based on insert shape and fixing method, with tolerances as per ISO 1832:2017 tolerance classes (eg, A, M). Below is a representative table for tipped triangular inserts with a cylindrical fixing hole (simplified for clarity; the full standard includes extensive tables for various shapes).

Table 1: Dimensions for Tipped Triangular PCD Inserts (T) with Cylindrical Fixing Hole

Inscribed Circle (d, mm)	Side Length (s, mm)	Thickness (t, mm)	Corner Radius (r, mm)	Fixing Hole Diameter (d_1, mm)	Fixing Hole Depth (h, mm)	Tolerance Class
6.35	11.0	3.18	0.4	2.6	1.8	M
9.52	16.5	3.97	0.8	3.8	2.3	M
12.70	22.0	4.76	1.2	4.8	2.8	M
15.88	27.5	5.56	1.6	5.8	3.3	M

Notes :

Tolerances follow ISO 1832:2017 (eg, M: ±0.13–±0.20 mm for inscribed circle, ±0.13 mm for thickness).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on insert size.

The PCD layer thickness is typically 0.5–1.0 mm, not separately specified in the table but critical for performance.

5.3 Tolerances

Inscribed circle (d) : Tolerances as per ISO 1832:2017 (eg, ±0.025 mm for class A, ±0.13–±0.20 mm for class M).

Thickness (t) : Tolerances typically ±0.025 mm to ±0.13 mm, depending on class.

Fixing hole diameter (d_1) : Tolerances ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.

Fixing hole depth (h) : Tolerances ±0.10 mm, critical for secure clamping.

Corner radius (r) : Tolerances ±0.05 mm to ±0.10 mm, ensuring edge sharpness.

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5.4 Fixing Hole

Fixing holes, when present, are typically cylindrical or partly cylindrical, designed for screw or pin clamping. Inserts without fixing holes rely on top or side clamping mechanisms, suitable for applications requiring minimal clamping interference.

6. Designation

The dimensions and types specified in ISO 16463:2014 are used in conjunction with the designation system of **ISO 1832:2017** . The designation includes:

Insert shape (eg, T for triangular).

Clearance angle (eg, N for 0°).

Tolerance class (eg, M).

Type (eg, B for with hole, N for no hole).

Size (eg, 16 for 9.52 mm inscribed circle).

Thickness (eg, 04 for 4 mm).

Optional features (eg, corner radius, PCD grade).

Example :

TPGN 160408 : Triangular PCD insert (T), 0° clearance (N), high tolerance (G), no chip breaker (N), 9.52 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (implied by ISO 16463:2014 tables).

7. Application Notes

Interchangeability : Dimensions ensure compatibility with standard tool holders (eg, per ISO 5608:1995) for screw, pin, or top clamping.

Material : Applies to PCD (per ISO 513:2011 classifications, eg, D01–D10), ideal for non-ferrous metals (aluminum, copper), composites, and abrasive materials.

Machining : Suitable for high-speed finishing and precision machining, with PCD's extreme hardness ensuring excellent surface finish (eg, Ra < 0.2 μm) and wear resistance.

Designation : Always use ISO 1832:2017 designation with ISO 16463:2014 dimensions to specify inserts fully.

8. Annexes

Annex A (Normative): Detailed dimensional tables

Provides comprehensive tables for all insert shapes (square, triangular, rhomboid, round, etc.), listing inscribed circle, side length, thickness, corner radius, fixing hole diameter, and depth.

Annex B (Informative): Recommended tool holder compatibility

Lists compatible tool holder types and clamping mechanisms for PCD tipped inserts.

9. Bibliography

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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ISO 16463:2014

Polycrystalline diamond blades, tipped - sizes, types

1. Scope

This International Standard specifies the dimensions and types of polycrystalline diamond (PCD)-tipped inserts suitable for use in cutting tools for machining non-ferrous metals (e.g., aluminum, copper, magnesium), non-metallic materials (e.g., plastics, composites), and abrasive materials (e.g., fiber-reinforced composites). This standard applies to indexable inserts with PCD cutting edges brazed onto a carbide substrate, designed for applications requiring high wear resistance and excellent surface finish. It covers a variety of insert shapes (e.g., square, triangular, round) and mounting methods (e.g., with or without mounting holes), ensuring interchangeability and compatibility between manufacturers.

This standard supplements **ISO 1832:2017** (Marking of indexable inserts) by providing precise dimensional specifications and type classifications. It does not address performance characteristics (e.g. cutting speed, tool life), detailed material composition other than PCD, solid PCD inserts, or inserts made from other materials (e.g. carbide, CBN).

2. Normative References

The following documents are referenced in ISO 16463:2014 and are indispensable for its application:

ISO 1832:2017 : Indexable inserts for cutting tools — Designation.

ISO 513:2011 : Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

3. Terms and Definitions

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In this standard, the following terms apply:

Polycrystalline diamond (PCD) inserts : Cutting elements with PCD cutting edges brazed onto a carbide substrate, designed for machining non-ferrous and non-metallic materials.

Tipped inserts : Cost-effective inserts with a PCD layer brazed onto a substrate (usually carbide).

Fixing Hole : The hole (cylindrical or partially cylindrical) in the insert used for clamping to the tool holder (if present).

Nominal size : The theoretical size of the insert (such as inscribed circle diameter, thickness), subject to tolerance limits.

4. Blade type

This standard focuses on PCD tipped inserts, which are classified as follows:

Shapes : Square (S), Triangle (T), Rhombus (C, D, E, V), Circle (R), and others (e.g., Pentagon P).

Fixing method : with fixing holes (for screw or pin clamping) or without fixing holes (for top or side clamping).

PCD layer thickness : typically 0.5–1.0 mm, optimizes wear resistance and edge sharpness.

Due to cost and manufacturing limitations, PCD inserts are not produced as solid inserts; the tipped design balances performance and economy.

5. Dimensions

This standard specifies the dimensions of PCD tipped inserts, including:

Inscribed circle diameter (d) : The diameter of the inscribed circle of a polygonal blade or the diameter of a circular blade.

Side length (s) : Side length of polygonal blade.

Thickness (t) : The vertical height of the insert, including the substrate and PCD layer.

Fillet Radius (r) : The radius of the fillet (if applicable).

Fixing hole diameter (d_1) : Diameter of the fixing hole (cylindrical or partially cylindrical, if present).

Fixing hole depth (h) : Depth of the fixing hole (if applicable).

5.1 Blade shape

This standard covers the following insert shapes, as defined in ISO 1832:2017:

Square (S)

Triangle (T)

Diamond (C, D, E, V)

Round (R)

Other polygons (such as pentagon P)

5.2 Dimensions

Dimensions are provided in tabular form based on insert shape and mounting method, with tolerances in accordance

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with ISO 1832:2017 tolerance classes (e.g., A, M). Below is a representative table for a pointed triangular insert with a cylindrical mounting hole (simplified for clarity; the full standard includes detailed tables for multiple shapes).

Table 1: Dimensions of pointed triangular PCD inserts (T) with cylindrical fixing holes

Inscribed circle diameter (d, mm)	Side length (s, mm)	Thickness (t, mm)	Corner radius (r, mm)	Fixing hole diameter (d_1, mm)	Fixing hole depth (h, mm)	Tolerance grade
6.35	11.0	3.18	0.4	2.6	1.8	M
9.52	16.5	3.97	0.8	3.8	2.3	M
12.70	22.0	4.76	1.2	4.8	2.8	M
15.88	27.5	5.56	1.6	5.8	3.3	M

Note :

Tolerances follow ISO 1832:2017 (e.g., M: inscribed circle ±0.13–±0.20 mm, thickness ±0.13 mm).

Corner radius (r) options include 0.2, 0.4, 0.8, 1.2, 1.6 mm, depending on the insert size.

The PCD layer thickness is typically 0.5–1.0 mm and is not specified separately in the table but is critical to performance.

5.3 Tolerance

Inscribed circle diameter (d) : Tolerance according to ISO 1832:2017 (e.g. Grade A ±0.025 mm, Grade M ±0.13–±0.20 mm).

Thickness (t) : Tolerance is typically ±0.025 mm to ±0.13 mm, depending on the grade.

Fixing hole diameter (d_1) : Tolerance ±0.05 mm to ±0.10 mm, ensuring compatibility with clamping systems.

Fixing hole depth (h) : Tolerance ±0.10 mm, critical for secure clamping.

Corner radius (r) : Tolerance ±0.05 mm to ±0.10 mm to ensure sharpness of the cutting edge.

5.4 Fixing holes

The fixing hole, if present, is typically cylindrical or partially cylindrical and designed for screw or pin clamping. Inserts without a fixing hole rely on top or side clamping mechanisms and are suitable for applications requiring minimal clamping interference.

6. Logo

The sizes and types of ISO 16463:2014 are used in conjunction with the marking system of **ISO 1832:2017** . The markings include:

The shape of the blade (for example, T for triangle).

Clearance angle (e.g., N for 0°).

Tolerance class (for example, M).

Type (for example, B for with holes, N for without holes).

Size (e.g., 16 for a 9.52 mm inscribed circle).

Thickness (for example, 04 means 4 mm).

Optional characteristics (e.g., corner radius, PCD grade).

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Example :

TPGN 160408 : Triangular PCD insert (T), 0° clearance angle (N), high tolerance (G), no chipbreaker (N), 9.52 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius (according to ISO 16463:2014 table).

7. Application Description

Interchangeability : Dimensions ensure compatibility with standard toolholders (e.g. according to ISO 5608:1995) suitable for screw, pin or top clamping.

Materials : Suitable for PCD (classification according to ISO 513:2011, e.g. D01–D10), ideal for use on non-ferrous metals (aluminum, copper), composites and abrasive materials.

Machining : Suitable for high-speed finishing and precision machining, the extremely high hardness of PCD ensures excellent surface finish (e.g., Ra < 0.2 microns) and wear resistance.

Marking : Inserts are always fully specified using a combination of ISO 1832:2017 marking and ISO 16463:2014 dimensions.

8. Appendix

Appendix A (Normative): Detailed Dimensions

A complete table of all insert shapes (square, triangle, diamond, round, etc.) is available, listing inscribed circle diameter, side length, thickness, corner radius, fixing hole diameter, and depth.

Appendix B (Informative): Recommended Toolholder Compatibility

Lists compatible toolholder types and clamping mechanisms for PCD-tipped inserts.

9. References

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 513:2011, Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 3002-1:1982

Basic quantities in cutting and grinding

— Part 1: Geometry of the active part of cutting tools

— General terms, reference systems, tool and working angles, chip breakers

(Fundamentals of cutting and grinding - Part 1: Geometry of the active part of the cutting tool

— General terminology, reference systems, tool and machining angles, chipbreakers)

1. Scope

This International Standard specifies the basic quantities, general terms, reference systems, tool and working angles, and chip breaker configurations related to the geometry of the active part of tools used in machining processes such as turning, milling, drilling, and grinding. It applies to single-point and multi-point cutting tools, including those with indexable inserts, and covers both metal cutting and grinding operations. The standard establishes a standardized nomenclature and reference cutting framework to ensure consistency in tool design, manufacturing, and application across industries.

The standard does not cover performance characteristics (eg, cutting forces, tool life), material properties, or detailed design specifications beyond geometry. It is intended for use by tool designers, manufacturers, and engineers to facilitate clear communication and interoperability.

2. Normative References

No normative references are explicitly listed in ISO 3002-1:1982, as it is a foundational standard defining basic quantities. However, related standards (eg, ISO 1832 for insert designations) are implicitly relevant for practical application.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Active part : The portion of the cutting tool that directly engages the workpiece to remove material (eg, cutting edge, rake face).

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Cutting edge : The edge of the tool that performs material removal, formed by the intersection of the rake face and flank.

Rake face : The surface of the tool over which the chip flows during cutting.

Flank : The surface of the tool adjacent to the cutting edge, facing the machined surface.

Chip breaker : A geometric feature (eg, groove, step) on the rake face designed to control chip formation and breakage.

Reference system : A coordinate system used to define tool and working angles relative to the tool, workpiece, or cutting motion.

Tool angle : An angle defined in the tool's reference system, independent of the cutting process (eg, rake angle, clearance angle).

Working angle : An angle defined during the cutting process, accounting for the tool's position relative to the workpiece and cutting motion.

4. Reference Systems

The standard defines three primary reference systems to describe the geometry of cutting tools:

Tool-in-hand system : A static coordinate system fixed to the tool, used to define tool angles (eg, rake, clearance) independent of the machining setup. Axes are aligned with the tool's shank or major cutting edge.

Tool-in-use system : A dynamic coordinate system accounting for the tool's orientation in the machine during cutting, used to define working angles.

Machine system : A coordinate system fixed to the machine tool, aligning with the workpiece and cutting motion (eg, feed, cutting velocity).

4.1 Coordinate Axes

X-axis : Typically aligned with the direction of primary cutting motion (eg, tangential to the workpiece in turning).

Y-axis : Perpendicular to the X-axis, often aligned with the feed direction.

Z-axis : Perpendicular to the XY plane, often aligned with the tool's radial direction or depth of cut.

4.2 Planes

Base plane : A plane parallel to the tool's base or shank, used as a reference for angle measurements.

Cutting edge plane : A plane containing the cutting edge and perpendicular to the base plane.

Rake face plane : A plane containing the rake face, used to define rake angles.

Flank plane : A plane containing the flank, used to define clearance angles.

5. Tool and Working Angles

The standard defines key angles that describe the geometry of the active part of cutting tools, categorized as tool angles (static, tool-in-hand) and working angles (dynamic, tool-in-use).

5.1 Tool Angles

Rake angle (γ) : The angle between the rake face and a plane perpendicular to the base plane, measured in the cutting edge plane. Positive if the rake face slopes toward the chip flow, negative if away.

Example : γ = +10° (positive rake for easy chip flow), γ = -5° (negative rake for stronger edge).

Clearance angle (α) : The angle between the flank and a plane parallel to the base plane, measured in the cutting

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edge plane. Ensures clearance between the tool and workpiece.

Example : α = 6° (typical for turning inserts).

Wedge angle (β) : The angle between the rake face and flank, measured in the cutting edge plane. β = 90° - (γ + α).

Example : If γ = 10°, α = 6°, then β = 74°.

Cutting edge inclination angle (λ) : The angle between the cutting edge and a plane perpendicular to the cutting velocity, measured in the cutting edge plane.

Example : λ = 0° (neutral for straight edges), λ = +5° (inclined for chip curling).

Included angle (ε) : The angle between two cutting edges (eg, in a single-point tool), measured in the base plane.

Example : ε = 90° for square inserts, ε = 60° for triangular inserts.

5.2 Working Angles

Effective rake angle (γ_e) : The rake angle in the tool-in-use system, adjusted for the tool's orientation and feed direction.

Effective clearance angle (α_e) : The clearance angle in the tool-in-use system, accounting for the tool's position relative to the workpiece.

Effective cutting edge inclination angle (λ_e) : The inclination angle in the tool-in-use system, influenced by tool setup and cutting motion.

5.3 Angle Relationships

The standard provides equations to relate tool and working angles, accounting for tool orientation (eg, side and back rake angles) and machining parameters (eg, feed, depth of cut). For example:

$\gamma_e = \gamma + \arctan(\tan(\kappa) \cdot \sin(\varphi))$, where κ is the tool cutting edge angle and φ is the feed angle.

6. Chip Breakers

Chip breakers are geometric features on the rake face designed to control chip formation, curling, and breakage, improving machining efficiency and safety. The standard classifies chip breakers by:

Type :

Groove type : A continuous groove parallel to the cutting edge (eg, for long chips in soft materials).

Step type : A raised step or ridge (eg, for short chips in brittle materials).

Combined type : A combination of grooves and steps for versatile chip control.

Dimensions :

Width (w) : The width of the groove or step, typically 0.5–3 mm.

Depth (h) : The depth of the groove, typically 0.1–1 mm.

Radius (r) : The radius of curvature at the groove's edge, typically 0.2–1 mm.

Position : Distance from the cutting edge (eg, 0.2–2 mm), critical for chip curling.

Table 1: Typical Chip Breaker Dimensions

Chip Breaker Type	Width (w, mm)	Depth (h, mm)	Radius (r, mm)	Distance from Edge (mm)
Groove	1.0–2.0	0.2–0.5	0.3–0.6	0.5–1.5
Step	0.8–1.5	0.3–0.7	0.2–0.5	0.3–1.0
Combined	1.2–2.5	0.3–0.6	0.3–0.7	0.5–1.8

7. Application Notes

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Tool Design : Use tool angles (eg, rake, clearance) to optimize cutting performance for specific materials (eg, positive rake for aluminum, negative for hardened steel).

Machining Setup : Adjust working angles (eg, effective rake) based on tool holder orientation and machining parameters to control chip flow and surface finish.

Chip Control : Select chip breaker type and dimensions based on workpiece material and cutting conditions (eg, groove for ductile materials, step for brittle materials).

Interchangeability : The standardized nomenclature ensures compatibility with tool holders (eg, per ISO 5608:1995) and inserts (eg, per ISO 1832:2017).

8. Annexes

Annex A (Informative): Diagrams of reference systems

Provides textual descriptions of the tool-in-hand, tool-in-use, and machine coordinate systems, with labeled axes (X, Y, Z) and planes (base, cutting edge, rake).

Annex B (Informative): Angle measurement methods

Describes techniques for measuring tool angles (eg, using goniometers, optical comparators) and working angles (eg, in-situ measurements during machining).

Annex C (Informative): Chip breaker design guidelines

Lists recommended chip breaker geometries for common materials (eg, steel, aluminum, cast iron) and cutting conditions (eg, roughing, finishing).

9. Bibliography

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation. ISO 3002-2:1982, Basic quantities in cutting and grinding — Part 2: Geometry of the active part of cutting tools — General conversion formulae.

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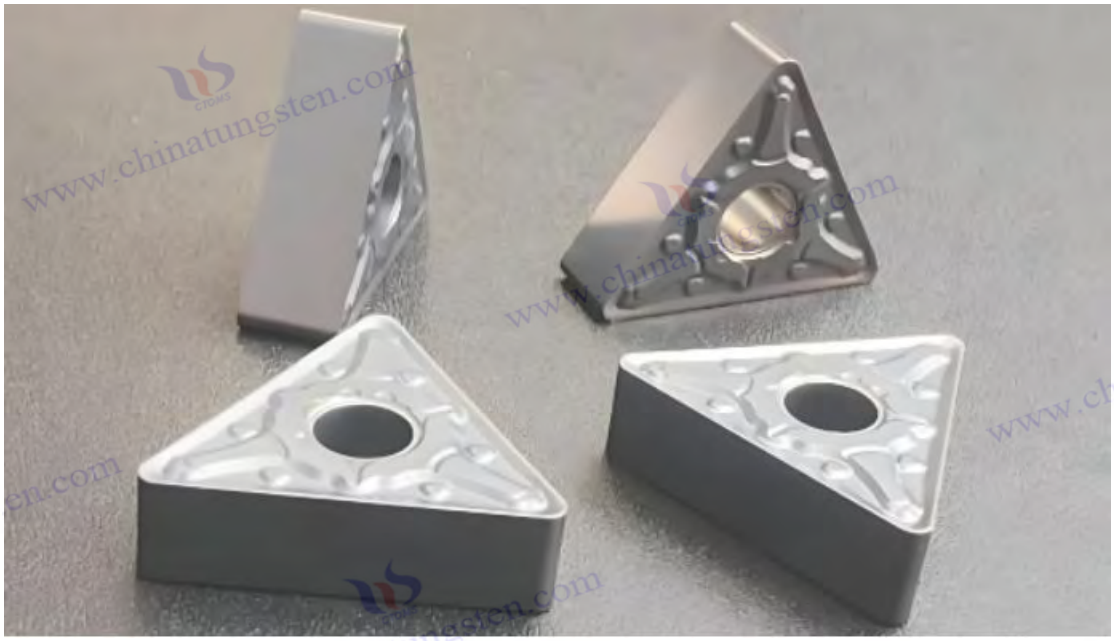
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ISO 3002-1:1982

Basic cutting and grinding

— Part 1:

Geometry of the active part of the cutting tool

— General terminology, reference systems, tool and machining angles, chipbreakers

1. Scope

This International Standard specifies fundamental quantities, common terminology, reference systems, tool and tool angles, and chipbreaker configurations related to the geometry of the active part of cutting tools for turning, milling, drilling, and grinding processes. It applies to single-point and multi-point cutting tools, including those with indexable inserts, covering metal cutting and grinding operations. It establishes a standardized terminology and reference framework to ensure industry consistency in tool design, manufacture, and application.

This standard does not address performance characteristics (e.g., cutting forces, tool life), material properties, or detailed design specifications other than geometry. It is intended for use by tool designers, manufacturers, and engineers to promote clear communication and interoperability.

2. Normative References

ISO 3002-1:1982 does not explicitly list normative references, as it is a foundational standard defining basic quantities. However, related standards (such as ISO 1832 for blade marking) are implicitly relevant in practical applications.

3. Terms and Definitions

In this standard, the following terms apply:

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Active part : The part of the cutting tool that directly contacts the workpiece to remove material (e.g., cutting edge, rake face).

Cutting Edge : The edge of a tool where material is removed, formed by the intersection of the rake and flank faces.

Rake face : The surface of the tool through which the chips flow during cutting.

Flank : The surface of the tool closest to the cutting edge that faces the machined surface.

Chipbreaker : A geometric feature on the rake face (e.g., groove, step) that controls chip formation and breakage.

Reference Frame : A coordinate system used to define the tool and machining angles in relation to the workpiece or cutting motion.

Tool angle : An angle defined in the tool reference frame that is independent of the cutting process (e.g., rake angle, relief angle).

Machining angle : Angle defined during the cutting process, taking into account the position of the tool relative to the workpiece and the cutting motion.

4. Reference Frame

This standard defines three main reference frames to describe cutting tool geometry:

Tool Static Reference System : A static coordinate system fixed to the tool that defines tool angles (e.g., rake angle, relief angle) regardless of the machining setup. The coordinate axes are aligned with the tool shank or main cutting edge.

Tool dynamic reference system : A dynamic coordinate system that takes into account the orientation of the tool when cutting in the machine tool, used to define the machining angle.

Machine tool reference frame : A coordinate system fixed to the machine tool that is aligned with the workpiece and cutting motion (e.g., feed, cutting speed).

4.1 Coordinate Axes

X-axis : Usually aligned with the primary cutting motion direction (e.g., tangential to the workpiece in turning).

Y-axis : perpendicular to the X-axis, usually aligned with the feed direction.

Z -axis : Perpendicular to the XY plane, usually aligned with the tool's radial or depth of cut direction.

4.2 Plane

Base Plane : A plane parallel to the base or shank of a tool used as a reference for angle measurements.

Cutting edge plane : The plane containing the cutting edge and perpendicular to the base plane.

Rake plane : The plane containing the rake face, used to define the rake angle.

Flank plane : The plane containing the flank face, used to define the clearance angle.

5. Tool and processing angle

This standard defines the key angles that describe the geometry of the active part of the cutting tool, which are divided into tool angles (static, tool static reference system) and machining angles (dynamic, tool dynamic reference system).

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5.1 Tool Angle

Rake angle (γ) : The angle between the rake face and a plane perpendicular to the base plane, measured in the plane of the cutting edge. If the rake face is tilted in the direction of chip flow, it is positive, and if it is tilted in the opposite direction, it is negative.

Example : γ = +10° (positive rake angle, good chip flow), γ = -5° (negative rake angle, stronger cutting edge).

Relief Angle (α) : The angle between the flank face and a plane parallel to the base plane, measured in the plane of the cutting edge. Ensures clearance between the tool and the workpiece.

Example : α = 6° (typical value for turning inserts).

Wedge angle (β) : The angle between the rake and flank faces, measured in the plane of the cutting edge. β = 90° - (γ + α).

Example : If γ = 10°, α = 6°, then β = 74°.

Cutting edge inclination (λ) : The angle between the cutting edge and the plane perpendicular to the cutting speed, measured in the cutting edge plane.

Examples : λ = 0° (straight edge, neutral), λ = +5° (inclined to favor chip curling).

Included angle (ε) : The angle between two cutting edges in a single-point tool, measured in the base plane.

Examples : ε = 90° (square blade), ε = 60° (triangular blade).

5.2 Processing Angle

Effective rake angle (γ_e) : The rake angle after adjustment in the tool's dynamic reference frame, taking into account the tool orientation and feed direction.

Effective clearance angle (α_e) : The clearance angle adjusted in the dynamic reference frame of the tool, taking into account the position of the tool relative to the workpiece.

Effective cutting edge inclination angle (λ_e) : The inclination angle adjusted in the tool's dynamic reference frame, which is affected by tool settings and cutting motion.

5.3 Angle Relationship

This standard provides an equation for the relationship between tool angle and machining angle, taking into account tool orientation (e.g., side rake angle, back rake angle) and machining parameters (e.g., feed, depth of cut). For example:

$\gamma_e = \gamma + \arctan(\tan(\kappa) \cdot \sin(\varphi))$, where κ is the tool cutting edge angle and φ is the feed angle.

6. Chipbreaker

Chipbreakers are geometric features on the rake face designed to control chip formation, curling and breakage, improving machining efficiency and safety. This standard classifies chipbreakers in the following ways:

type :

Geometry : Continuous grooves parallel to the cutting edge (e.g. suitable for long chips in soft materials).

Step type : Raised steps or ridges (e.g., suitable for short chips in brittle materials).

Combination type : A combination of grooves and steps, suitable for multi-purpose chip breaking.

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size :

Width (w) : The width of the groove or step, typically 0.5–3 mm.

Depth (h) : The depth of the groove, typically 0.1–1 mm.

Radius (r) : The radius of curvature of the groove edge, typically 0.2–1 mm.

Position : The distance from the cutting edge (e.g., 0.2–2 mm) that is critical for chip curling.

Table 1: Typical chipbreaker dimensions

Chipbreaker type	Width (w, mm)	Depth (h, mm)	Radius (r, mm)	Distance from cutting edge (mm)
Groove type	1.0–2.0	0.2–0.5	0.3–0.6	0.5–1.5
Step type	0.8–1.5	0.3–0.7	0.2–0.5	0.3–1.0
Combination	1.2–2.5	0.3–0.6	0.3–0.7	0.5–1.8

7. Application Description

Tool design : Use tool angles (e.g., rake angle, relief angle) to optimize cutting performance for specific materials (e.g., positive rake angle for aluminum, negative rake angle for hardened steel).

Machining setup : Adjust machining angles (e.g., effective rake angle) based on toolholder orientation and machining parameters to control chip flow and surface finish.

Chip control : Select chipbreaker type and size based on the workpiece material and cutting conditions (e.g., groove type for ductile materials, step type for brittle materials).

Interchangeability : Standardized terminology ensures compatibility with tool holders (e.g., according to ISO 5608:1995) and inserts (e.g., according to ISO 1832:2017).

8. Appendix

Appendix A (Informative): Reference Frame Diagram

Provide text descriptions of the tool's static reference system, dynamic reference system, and machine tool coordinate system, indicating coordinate axes (X, Y, Z) and planes (base plane, cutting edge plane, rake face).

Appendix B (Informative): Angle Measurement Methods

Describe methods for measuring tool angles (e.g., using goniometers, optical comparators) and machining angles (e.g., in-situ measurement during machining).

Appendix C (Informative): Chipbreaker Design Guidelines

Lists recommended chipbreaker geometries for common materials (e.g., steel, aluminum, cast iron) and cutting conditions (e.g., roughing, finishing).

9. References

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

ISO 3002-2:1982, Fundamental quantities for cutting and grinding — Part 2: Geometry of the active part of cutting tools — General conversion formulae.

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ISO/TS 13399-80:2017

Cutting tool data representation and exchange

— Part 80: Creation and exchange of 3D models

— Overview and principles

Cutting tool data representation and exchange

— Part 80:

3D Model Creation and Exchange — Overview and Principles

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1. Scope

This Technical Specification provides an overview and principles for the creation and exchange of 3D models of cutting tools, including their components and assemblies, used in manufacturing processes such as turning, milling, drilling, and grinding. It defines standardized methods for representing tool geometry, dimensions, and associated data in a digital 3D format, enabling interoperability among computer-aided design (CAD), computer-aided manufacturing (CAM), and manufacturing execution systems (MES). The specification applies to cutting tools with defined cutting edges, including solid cutting edges tools, indexable inserts, and tool assemblies, and is part of the ISO 13399 series for cutting tool data representation and exchange.

The standard focuses on:

Principles for creating 3D models with consistent geometry and metadata.

Protocols for exchanging 3D models across software platforms.

Integration with other ISO 13399 parts (eg, ISO 13399-2 for terminology, ISO 13399-3 for geometry).

It does not cover:

Detailed performance characteristics (eg, cutting forces, tool life).

Specific manufacturing processes for producing tools.

Non-cutting tools (eg, fixtures, workholding devices).

2. Normative References

The following documents are referenced in ISO/TS 13399-80:2017 and are indispensable for its application:

ISO 13399-1:2006 : Cutting tool data representation and exchange

— Part 1: Overview, fundamental principles, and general information model.

ISO 13399-2:2005 : Cutting tool data representation and exchange

— Part 2: Reference dictionary for cutting items.

ISO 13399-3:2014 : Cutting tool data representation and exchange

— Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013 : Cutting tool data representation and exchange

— Part 50: Reference dictionary for reference systems and common concepts.

ISO 10303-21:2016 : Industrial automation systems and integration

— Product data representation and exchange

— Part 21: Implementation methods: Clear text encoding of the exchange structure (STEP).

ISO 10303-214:2010 : Industrial automation systems and integration

— Product data representation and exchange

— Part 214: Application protocol: Core data for automotive mechanical design processes.

3. Terms and Definitions

For the purposes of this technical specification, the following terms apply:

3D model : A digital representation of a cutting tool's geometry, including surfaces, edges, and features, in a three-dimensional coordinate system.

Cutting tool : A tool with defined cutting edges used to remove material from a workpiece (eg, drills, milling cutters, turning inserts).

Tool assembly : A complete cutting tool system, including the tool body, inserts, and clamping components.

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Metadata : Additional data associated with a 3D model, such as dimensions, material properties, or manufacturer information.

STEP (Standard for the Exchange of Product model data) : A standardized format (ISO 10303) for exchanging 3D model data between systems.

Reference system : A coordinate system used to define the position and orientation of the 3D model (per ISO/TS 13399-50).

Interoperability : The ability of different software systems (eg, CAD, CAM) to exchange and utilize 3D model data without loss of information.

4. Principles for 3D Model Creation

The creation of 3D models for cutting tools follows these principles to ensure consistency and usability:

Geometric accuracy : Models must accurately represent the tool's physical geometry, including cutting edges, rake faces, flanks, and clamping features.

Standardized reference systems : Models use coordinate systems defined in ISO/TS 13399-50, aligning with the tool's functional axes (eg, shank axis, cutting edge plane).

Metadata inclusion : Models include metadata (eg, tool type, dimensions, material) per ISO 13399-2 and ISO 13399-3 dictionaries.

Modularity : Models support modular representation of tool assemblies, separating components (eg, insert, holder) for flexibility.

Simplification : Non-functional details (eg, microscopic surface textures) may be simplified to reduce file size, provided functional geometry is preserved.

Format compatibility : Models are created in formats compatible with ISO 10303 (STEP), ensuring interoperability across CAD/CAM systems.

4.1 Model Components

A 3D model typically includes:

Tool body : The main structure (eg, shank, holder).

Cutting part : The active cutting edges (eg, inserts, solid tool tips).

Clamping features : Fixing holes, screws, or clamping surfaces.

Metadata : Embedded data such as tool designation (per ISO 1832:2017), material, and tolerances.

4.2 Reference Systems

Models use standardized reference systems (per ISO/TS 13399-50):

Global coordinate system : Aligns with the tool's shank or primary axis.

Local coordinate systems : Defined for individual components (eg, insert, cutting edge) to facilitate assembly and simulation.

5. Data Exchange Protocols

The specification outlines methods for exchanging 3D models to ensure interoperability:

STEP format (ISO 10303-21) : The primary format for encoding 3D geometry and metadata, using AP214 (automotive mechanical design) for cutting tools.

File structure :

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Geometry: Surfaces, edges, and vertices in STEP's boundary representation (B-Rep).

Metadata: Attributes linked to geometric entities (eg, tool type, dimensions).

Validation : Models must be validated for completeness (eg, no missing surfaces) and compliance with ISO 13399 dictionaries.

Interfacing : Models are exchanged via standardized interfaces (eg, STEP files) compatible with CAD, CAM, and MES software.

5.1 Example STEP File Structure

A simplified STEP file for a turning insert might include:

#10=PRODUCT('SPMN_120408','Turning Insert',$,(#11));

#11=PRODUCT_DEFINITION('design','',#12);

#12=PRODUCT_DEFINITION_FORMATION('1','',#10);

#20=ADVANCED_BREP_SHAPE_REPRESENTATION('',(#30,#40),#50);

#30=MANIFOLD_SURFACE_SHAPE_REPRESENTATION('',(#31));

#31=GEOMETRICALLY_BOUNDED_SURFACE_SHAPE_REPRESENTATION();

#40=AXIS2_PLACEMENT_3D('InsertCSYS',#41,#42,#43);

#50=REPRESENTATION_CONTEXT('3D','');

Note : This is a textual description; actual STEP files are machine-readable and include detailed geometry data.

6. Integration with ISO 13399 Series

The 3D models created under ISO/TS 13399-80 integrate with other parts of the ISO 13399 series:

ISO 13399-1 : Provides the general information model for cutting tool data.

ISO 13399-2 and -3 : Supply dictionaries for cutting items (eg, inserts) and tool items (eg, holders), used for metadata.

ISO/TS 13399-50 : Defines reference systems and common concepts for positioning 3D models.

ISO/TS 13399-60 : Specifies connection codes for tool assemblies, ensuring compatibility.

This integration ensures that 3D models are part of a comprehensive digital ecosystem for cutting tool data.

7. Application Notes

Tool design : 3D models enable precise CAD modeling of tools, supporting virtual prototyping and simulation.

Manufacturing : CAM systems use 3D models for toolpath generation and collision detection.

Data exchange : Standardized STEP files facilitate seamless data sharing among manufacturers, suppliers, and end-users.

Interoperability : Ensures compatibility with software platforms (eg, Siemens NX, Autodesk Inventor) and manufacturing systems (eg, CNC machines).

Traceability : Metadata embedded in models supports tool identification and lifecycle management.

8. Annexes

Annex A (Informative): Example of a 3D model structure

Describes a sample 3D model of a milling cutter, including:

Geometry: Cylindrical shank, fluted cutting section, and insert pockets.

Metadata: Tool designation (eg, R390-018A20-11L), material (carbide), and dimensions.

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Coordinate systems: Global (shank axis), local (insert positions).

Annex B (Informative): Guidelines for STEP implementation

Provides recommendations for creating STEP files, including:

Structuring geometry using B-Rep.

Linking metadata to ISO 13399-2/-3 dictionaries.

Validating files for compliance.

Annex C (Informative): Interoperability testing

Outlines methods for testing 3D model exchange between CAD/CAM systems, ensuring no data loss.

9. Bibliography

ISO 13399-1:2006, Cutting tool data representation and exchange

— Part 1: Overview, fundamental principles, and general information model.

ISO 13399-2:2005, Cutting tool data representation and exchange

— Part 2: Reference dictionary for cutting items.

ISO 13399-3:2014, Cutting tool data representation and exchange

— Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange

— Part 50: Reference dictionary for reference systems and common concepts.

ISO 10303-21:2016, Industrial automation systems and integration

— Product data representation and exchange

— Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 10303-214:2010, Industrial automation systems and integration

— Product data representation and exchange

— Part 214: Application protocol: Core data for automotive mechanical design processes.

ISO 1832:2017, Indexable inserts for cutting tools

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ISO/TS 13399-80:2017

Cutting tool data representation and exchange

— Part 80: Creation and Exchange of 3D Models

— Overview and Principles

1. Scope

This technical specification provides an overview and principles for the creation and exchange of 3D models of cutting tools, their components, and assemblies, applicable to manufacturing processes such as turning, milling, drilling, and grinding. It defines methods for representing cutting tool geometry, dimensions, and related data in a standardized digital 3D format, facilitating interoperability between computer-aided design (CAD), computer-aided manufacturing (CAM), and manufacturing execution systems (MES). This specification applies to cutting tools with defined cutting edges, including solid tools, indexable inserts, and tool assemblies, and is part of the ISO 13399 series on the representation and exchange of cutting tool data.

This standard focuses on:

Principles for creating 3D models with consistent geometry and metadata.

A protocol for exchanging 3D models between different software platforms.

Integration with other parts of the ISO 13399 series (e.g. ISO 13399-2 for terminology, ISO 13399-3 for geometry).

This standard does not cover:

Detailed performance characteristics (e.g. cutting forces, tool life).

The specific manufacturing process of tool production.

Non-cutting tools (e.g., fixtures, workholding devices).

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2. Normative References

The following documents are referenced in ISO/TS 13399-80:2017 and are indispensable for its application:

ISO 13399-1:2006 : Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model.

ISO 13399-2:2005 : Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items.

ISO 13399-3:2014 : Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013 : Cutting tool data representation and exchange — Part 50: Reference dictionary of reference systems and common concepts.

ISO 10303-21:2016 : Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation method: Plain text encoding of the exchange structure (STEP).

ISO 10303-214:2010 : Industrial automation systems and integration — Product data representation and exchange — Part 214: Application protocol: Automotive mechanical design core data.

3. Terms and Definitions

In this technical specification, the following terms apply:

3D model : A digital representation of the cutting tool geometry, including surfaces, edges, and features, in a three-dimensional coordinate system.

Cutting Tool : A tool with a defined cutting edge used to remove material from a workpiece (e.g., drill, milling cutter, turning insert).

Tool Assembly : A complete cutting tool system including the tool body, insert, and clamping components.

Metadata : Additional data associated with a 3D model, such as dimensions, material properties, or manufacturer information.

STEP (Standard for the Exchange of Product Model Data) : A standardized format for exchanging 3D model data between systems (ISO 10303).

Reference system : A coordinate system used to define the position and orientation of a 3D model (according to ISO/TS 13399-50).

Interoperability : The ability of different software systems (e.g., CAD, CAM) to exchange and utilize 3D model data without loss of information.

4. 3D model creation principles

The creation of the cutting tool 3D model follows the following principles to ensure consistency and usability:

Geometric accuracy : The model must accurately represent the physical geometry of the tool, including the cutting edge, rake face, flank face, and clamping features.

Standardized reference system : The model uses the coordinate system defined by ISO/TS 13399-50, aligned with the functional axes of the tool (e.g., shank axis, cutting edge plane).

Metadata inclusion : The model includes metadata (eg tool type, dimensions, material) according to ISO 13399-2 and ISO 13399-3 dictionaries.

Modularity : The model supports modular representation of tool assemblies, separating components (e.g., blade,

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handle) to increase flexibility.

Simplification : Non-functional details (e.g., microscopic surface textures) can be simplified to reduce file size while preserving functional geometry.

Format compatibility : Models are created in an ISO 10303 (STEP) compliant format, ensuring interoperability between CAD/CAM systems.

4.1 Model Components

3D models typically include:

Tool Body : The primary structure (e.g., shank, handle).

Cutting part : Active cutting edge (e.g., insert, integral tool tip).

Clamping features : fixing holes, screws, or clamping surfaces.

Metadata : Embedded data such as tool identification (according to ISO 1832:2017), material and tolerances.

4.2 Reference Frame

The model uses a standardized reference system (according to ISO/TS 13399-50):

Global Coordinate System : Aligned with the tool handle or spindle.

Local coordinate systems : Defined for individual components (e.g., inserts, cutting edges) to facilitate assembly and simulation.

5. Data Exchange Protocol

This specification outlines a method for exchanging 3D models to ensure interoperability:

STEP format (ISO 10303-21) : The main format for encoding 3D geometry and metadata, used by AP214 (Automotive Mechanical Design) for cutting tools.

File structure :

Geometry: Surfaces, edges, and vertices in STEP's boundary representation (B-Rep).

Metadata: Attributes associated with a geometric entity (e.g., tool type, dimensions).

Validation : Models need to be verified for completeness (eg, no missing surfaces) and compliance with the ISO 13399 dictionary.

Interfaces : Exchange models via standardized interfaces (e.g. STEP files), compatible with CAD, CAM and MES software.

5.1 Example STEP File Structure

A simplified STEP file for a turning insert might include:

```
#10=PRODUCT('SPMN_120408','Turning insert',$,(#11));
#11=PRODUCT_DEFINITION('Design','',#12);
#12=PRODUCT_DEFINITION_FORMATION('1','',#10);
#20=ADVANCED_BREP_SHAPE_REPRESENTATION('',(#30,#40),#50);
#30=MANIFOLD_SURFACE_SHAPE_REPRESENTATION('',(#31));
```

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#31=GEOMETRICALLY_BOUNDED_SURFACE_SHAPE_REPRESENTATION();

#40=AXIS2_PLACEMENT_3D('Blade Coordinate System',#41,#42,#43);

#50=REPRESENTATION_CONTEXT('3D','');

NOTE : This is a text description; the actual STEP file is in a machine-readable format and contains detailed geometric data.

6. Integration with ISO 13399 series

The 3D models created by ISO/TS 13399-80 are integrated with other parts of the ISO 13399 series:

ISO 13399-1 : Provides a common information model for cutting tool data.

ISO 13399-2 and -3 : Provides dictionaries for cutting items (e.g., inserts) and tool items (e.g., tool holders) for use in metadata.

ISO/TS 13399-50 : Defines reference systems and common concepts for positioning 3D models.

ISO/TS 13399-60 : Specifies connection codes for tool assemblies to ensure compatibility.

This integration ensures that the 3D model is part of a comprehensive digital ecosystem of cutting tool data.

7. Application Description

Tool design : 3D models enable accurate CAD modeling and facilitate virtual prototyping and simulation.

Manufacturing : CAM systems use 3D models to generate tool paths and detect collisions.

Data exchange : Standardized STEP files facilitate seamless data sharing between manufacturers, suppliers, and users.

Interoperability : Ensure compatibility with software platforms (e.g., Siemens NX, Autodesk Inventor) and manufacturing systems (e.g., CNC machines).

Traceability : Metadata embedded in the model enables tool identification and lifecycle management.

8. Appendix

Appendix A (Informative): 3D Model Structure Examples

Example 3D model depicting a milling cutter, including:

Geometry: Cylindrical shank, fluted cutting part and insert pocket.

Metadata: Tool identification (for example, R390-018A20-11L), material (carbide), and dimensions.

Coordinate systems: global (shank axis), local (insert position).

Appendix B (Informative): STEP Implementation Guide

Provides advice on creating STEP files, including:

Structure the geometry using B-Rep.

Link metadata to ISO 13399-2/-3 dictionaries.

Verify document compliance.

Appendix C (Informative): Interoperability Testing

Outlines methods for testing 3D model exchange between CAD/CAM systems to ensure no data loss.

9. References

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ISO 13399-1:2006, Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model.

ISO 13399-2:2005, Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items.

ISO 13399-3:2014, Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange — Part 50: Reference dictionary of reference systems and common concepts.

ISO 10303-21:2016, Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Plain text encoding of exchange structures.

ISO 10303-214:2010, Industrial automation systems and integration — Product data representation and exchange — Part 214: Application protocol: Automotive mechanical design core data.

ISO 1832:2017, Indexable inserts for cutting tools — Designation.

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ISO 13399-1:2006

Cutting tool data representation and exchange

— Part 1: Overview, fundamental principles and general information model

Cutting tool data representation and exchange

— Part 1: Overview, basic principles and common information model

1. Scope

This International Standard provides an overview, fundamental principles, and a general information model for the representation and exchange of cutting tool data used in manufacturing processes such as turning, milling, drilling, and grinding. It establishes a standardized framework for describing tools, their components, and associated data (eg, geometry, dimensions, materials) in a digital format, enabling interoperability among computer-aided design (CAD), computer-aided manufacturing (CAM), manufacturing execution systems (MES), and other software platforms. The standard applies to cutting tools with defined cutting tools edges, including solid tools, indexable inserts, and tool assemblies, and is the foundational part of the ISO 13399 series.

The standard focuses on:

Defining a neutral data structure for cutting tool information.

Ensuring consistency and compatibility across different systems and manufacturers.

Supporting data exchange in formats such as XML or STEP (ISO 10303).

It does not cover:

Detailed performance characteristics (eg, cutting forces, tool life).

Manufacturing processes for producing tools.

Non-cutting tools (eg, fixtures, workholding devices).

2. Normative References

The following documents are referenced in ISO 13399-1:2006 and are indispensable for its application:

ISO 10303-1:1994 : Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles.

ISO 10303-11:2004 : Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual.

ISO 10303-21:2002 : Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 13584-1:2001 : Industrial automation systems and integration — Parts library — Part 1: Overview and fundamental principles.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Cutting tool : A tool with defined cutting edges used to remove material from a workpiece (eg, drills, milling cutters, turning inserts).

Tool assembly : A complete cutting tool system, including the tool body, inserts, and clamping components.

Data representation : The structured description of cutting tool characteristics (eg, geometry, material) in a digital format.

Data exchange : The process of transferring cutting tool data between systems (eg, CAD, CAM) without loss of

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information.

Information model : A formal structure defining the entities, attributes, and relationships for cutting tool data.

EXPRESS : A data modeling language (ISO 10303-11) used to define the information model.

STEP (Standard for the Exchange of Product model data) : A standardized format (ISO 10303) for exchanging product data, including cutting tool data.

Interoperability : The ability of different software systems to exchange and utilize cutting tool data consistently.

4. Fundamental Principles

The standard is based on the following principles to ensure effective data representation and exchange:

Neutrality : The data model is independent of specific software platforms or vendors, using neutral formats (eg, EXPRESS, STEP).

Modularity : The model supports modular descriptions of tool components (eg, insert, holder) and assemblies for flexibility.

Extensibility : The model allows for future expansions to include new tool types or attributes.

Consistency : Standardized definitions (eg, per ISO 13399-2, -3) ensure uniform data across systems.

Interoperability : The model enables seamless data exchange between CAD, CAM, MES, and other systems.

Traceability : Data includes metadata (eg, tool designation, manufacturer) to support identification and lifecycle management.

4.1 Key Objectives

Provide a common language for cutting tool data.

Reduce errors in data exchange due to proprietary formats.

Facilitate automation in tool selection, design, and manufacturing.

5. General Information Model

The general information model defines the structure for representing cutting tool data, using the EXPRESS language (ISO 10303-11). It organizes data into entities, attributes, and relationships, ensuring a comprehensive and flexible framework.

5.1 Model Components

The information model includes:

Entities : Core objects such as cutting tool, tool assembly, cutting item (eg, insert), and tool item (eg, holder).

Attributes : Properties of entities, such as dimensions (eg, diameter, length), material, and tolerances.

Relationships : Links between entities, such as a cutting item being part of a tool assembly.

Metadata : Additional data, such as tool designation (per ISO 1832:2004), manufacturer, and catalog number.

5.2 Entity Hierarchy

The model uses a hierarchical structure:

Cutting_tool : The top-level entity, representing a complete tool or assembly.

Tool_item : Non-cutting components (eg, shank, holder).

Cutting_item : Cutting components (eg, insert, solid tool tip).

Assembly_relationship : Defines how components (eg, insert, holder) are connected.

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Property : Attributes like geometry (eg, inscribed circle diameter), material, or functional parameters.

5.3 Example EXPRESS Schema (Simplified)

A simplified EXPRESS schema for a cutting tool might include:

ENTITY cutting_tool;
identifier : STRING;
designation : STRING; -- eg, SPMN 120408 per ISO 1832
tool_type : STRING; -- eg, turning, milling
material : STRING; -- eg, carbide
SUBTYPE OF (product);
HAS cutting_item : LIST [0:?] OF cutting_item;
HAS tool_item : LIST [0:?] OF tool_item;
END_ENTITY;

ENTITY cutting_item;
identifier : STRING;
geometry : geometry_specification;
material : STRING; -- eg, carbide, CBN
END_ENTITY;

ENTITY tool_item;
identifier : STRING;
geometry : geometry_specification;
clamping_method : STRING; -- eg, screw, lever
END_ENTITY;

ENTITY geometry_specification;
diameter : REAL; -- eg, inscribed circle diameter
length : REAL;
corner_radius : REAL;
END_ENTITY;

Note : This is a simplified representation; the full schema includes additional entities and constraints.

5.4 Data Formats

The model supports data exchange in:

STEP (ISO 10303-21) : For encoding geometry and metadata in a machine-readable format.

XML : For structured data exchange, especially for metadata.

Other formats : As agreed by users, provided they conform to the information model.

6. Data Exchange Protocols

The standard outlines protocols for exchanging cutting tool data:

STEP format : Uses ISO 10303-21 for encoding data, ensuring compatibility with CAD/CAM systems.

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XML schema : Provides a structured format for metadata, based on the EXPRESS model.

Validation : Data must be validated for completeness (eg, all required attributes present) and compliance with ISO 13399 dictionaries.

Interfacing : Data is exchanged via standardized interfaces compatible with software platforms (eg, Siemens NX, Autodesk Inventor).

6.1 Example STEP File Structure

A simplified STEP file for a turning insert might include:

#10=PRODUCT('SPMN_120408','Turning Insert',$,(#11));

#11=PRODUCT_DEFINITION('design','',#12);

#12=PRODUCT_DEFINITION_FORMATION('1','',#10);

#20=PROPERTY_DEFINITION('geometry','',#11);

#21=PROPERTY_VALUE('diameter','9.52',#20);

#22=PROPERTY_VALUE('thickness','4.76',#20);

#23=PROPERTY_VALUE('corner_radius','0.8',#20);

#30=PRODUCT('Carbide','Material',$,(#31));

Note : This is a textual description; actual STEP files are machine-readable and include detailed data.

7. Integration with ISO 13399 Series

The information model integrates with other parts of the ISO 13399 series:

ISO 13399-2:2005 : Provides a reference dictionary for cutting items (eg, inserts).

ISO 13399-3:2007 : Provides a reference dictionary for tool items (eg, holders).

ISO/TS 13399-50:2013 : Defines reference systems and common concepts.

ISO/TS 13399-80:2017 : Specifies 3D model creation and exchange, building on the information model.

This integration ensures a cohesive framework for cutting tool data across design, manufacturing, and lifecycle management.

8. Application Notes

Tool selection : Standardized data supports automated tool selection in CAM and MES systems.

Design and simulation : The model enables precise CAD modeling and virtual machining simulations.

Data exchange : Neutral formats (STEP, XML) facilitate seamless data sharing among manufacturers, suppliers, and users.

Interoperability : Ensures compatibility with diverse software and manufacturing systems.

Lifecycle management : Metadata supports tool identification, inventory tracking, and maintenance.

9. Annexes

Annex A (Informative): Overview of the EXPRESS language

Describes the EXPRESS language (ISO 10303-11) used to define the information model, including syntax and examples.

Annex B (Informative): Example information model instance

Provides a sample instance of the model for a turning tool assembly, including:

Entities: Cutting_tool, cutting_item (insert), tool_item (holder).

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Attributes: Dimensions (eg, 9.52 mm inscribed circle), material (carbide).

Relationships: Assembly of insert and holder.

Annex C (Informative): Guidelines for implementation

Outlines steps for implementing the information model in software systems, including:

Mapping EXPRESS to STEP or XML.

Validating data compliance.

Testing interoperability.

10. Bibliography

ISO 10303-1:1994, Industrial automation systems and integration

— Product data representation and exchange — Part 1: Overview and fundamental principles.

ISO 10303-11:2004, Industrial automation systems and integration

— Product data representation and exchange

— Part 11: Description methods: The EXPRESS language reference manual.

ISO 10303-21:2002, Industrial automation systems and integration

— Product data representation and exchange

— Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 13584-1:2001, Industrial automation systems and integration

— Parts library — Part 1: Overview and fundamental principles.

ISO 13399-2:2005, Cutting tool data representation and exchange

— Part 2: Reference dictionary for cutting items.

ISO 13399-3:2007, Cutting tool data representation and exchange

— Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange

— Part 50: Reference dictionary for reference systems and common concepts.

ISO 1832:2004, Indexable inserts for cutting tools

— Designation.

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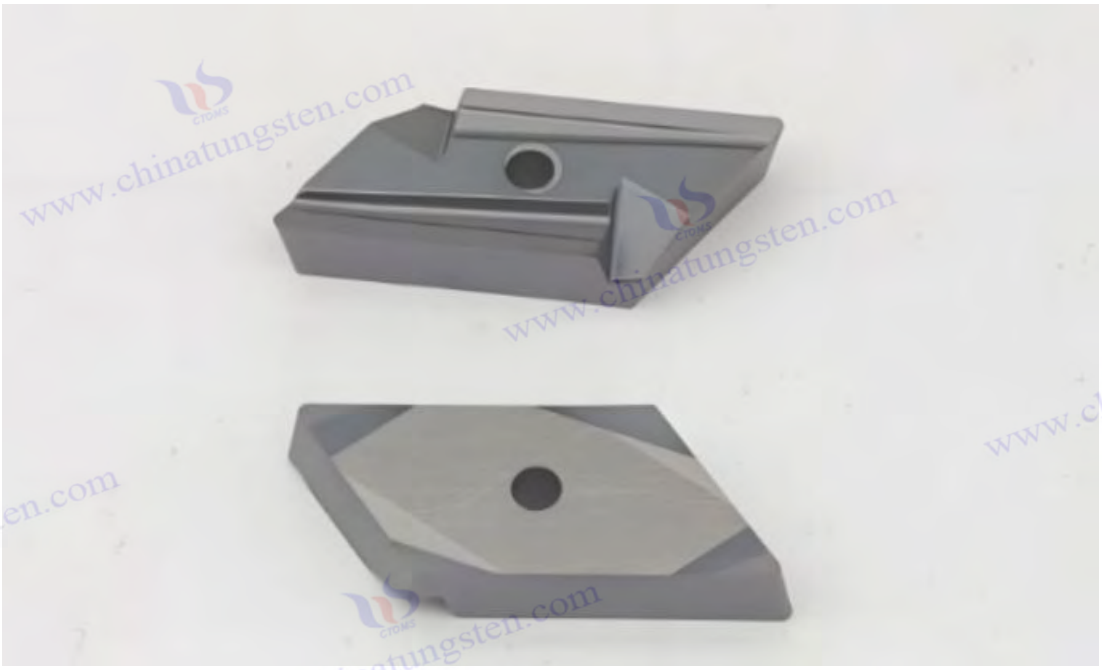
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ISO 13399-1:2006

Cutting tool data representation and exchange

— Part 1: Overview, basic principles and common information model

1. Scope

This international standard provides an overview, basic principles, and a common information model for the representation and exchange of cutting tool data for manufacturing processes such as turning, milling, drilling, and grinding. It establishes a standardized framework for describing cutting tools and their components, as well as related data (e.g., geometry, dimensions, materials), in a digital format that enables interoperability between computer-aided design (CAD), computer-aided manufacturing (CAM), manufacturing execution systems (MES), and other software platforms. This standard applies to cutting tools with defined cutting edges, including solid tools, indexable inserts, and tool assemblies, and forms a foundational part of the ISO 13399 series.

This standard focuses on:

A neutral data structure that defines cutting tool information.

Ensure consistency and compatibility across different systems and manufacturers.

Supports data exchange in formats such as XML or STEP (ISO 10303).

This standard does not cover:

Detailed performance characteristics (e.g. cutting forces, tool life).

The manufacturing process of tool production.

Non-cutting tools (e.g., fixtures, workholding devices).

2. Normative References

The following documents are referenced in ISO 13399-1:2006 and are indispensable for its application:

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ISO 10303-1:1994 : Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and basic principles.

ISO 10303-11:2004 : Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: EXPRESS language reference manual.

ISO 10303-21:2002 : Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Plain text encoding of exchange structures.

ISO 13584-1:2001 : Industrial automation systems and integration — Parts library — Part 1: Overview and basic principles.

3. Terms and Definitions

In this standard, the following terms apply:

Cutting Tool : A tool with a defined cutting edge used to remove material from a workpiece (e.g., drill, milling cutter, turning insert).

Tool Assembly : A complete cutting tool system including the tool body, insert, and clamping components.

Data representation : Structured description of cutting tool characteristics (e.g., geometry, material) in a digital format.

Data exchange : The process of transferring cutting tool data between systems (e.g., CAD, CAM) without loss of information.

Information model : A formal structure that defines the entities, attributes, and relationships of cutting tool data.

EXPRESS : A data modeling language for defining information models (ISO 10303-11).

STEP (Standard for the Exchange of Product Model Data) : A standardized format (ISO 10303) for exchanging product data, including cutting tool data.

Interoperability : The ability of different software systems to consistently exchange and utilize cutting tool data.

4. Basic Principles

This standard is based on the following principles to ensure efficient data representation and exchange:

Neutrality : The data model is independent of a specific software platform or vendor and uses a neutral format (e.g., EXPRESS, STEP).

Modularity : The model supports modular descriptions of tool components (e.g., inserts, handles) and assemblies for increased flexibility.

Extensibility : The model allows for future extensions to include new tool types or properties.

Consistency : Standardized definitions (e.g., according to ISO 13399-2, -3) ensure that data is uniform across systems.

Interoperability : The model enables seamless data exchange between CAD, CAM, MES and other systems.

Traceability : Data includes metadata (e.g., tool identification, manufacturer) to enable identification and lifecycle management.

4.1 Main Objectives

Provides a common language for cutting tool data.

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Reduce data exchange errors caused by proprietary formats.
Facilitates automation of tool selection, design, and manufacturing.

5. Common Information Model

The Common Information Model defines a structure for representing cutting tool data using the EXPRESS language (ISO 10303-11). It organizes data into entities, attributes, and relationships, ensuring a comprehensive and flexible framework.

5.1 Model Components

The information model includes:
Solids : Core objects such as cutting tools, tool assemblies, cutting items (for example, inserts), and tool items (for example, tool holders).
Attributes : Characteristics of an entity, such as size (for example, diameter, length), material, and tolerance.
Relationship : A connection between entities, such as a cutting item being part of a tool assembly.
Metadata : Additional data such as tool identification (according to ISO 1832:2004), manufacturer and catalog number.

5.2 Entity Hierarchy

The model adopts a hierarchical structure:
Cutting_tool : A top-level entity representing a complete tool or assembly.
Tool_item : Non-cutting component (e.g., shank, toolholder).
Cutting_item : Cutting component (e.g., blade, solid tool tip).
Assembly_relationship : Defines how components (e.g., blade, handle) are connected.
Property : Attributes such as geometry (e.g., inscribed circle diameter), material, or function parameters.

5.3 Example EXPRESS Mode (Simplified)

A simplified EXPRESS model of a cutting tool might include:

```
ENTITY cutting_tool;
identifier : STRING;
designation : STRING; -- For example, SPMN 120408 according to ISO 1832
tool_type : STRING; -- For example, turning, milling
material : STRING; -- For example, cemented carbide
SUBTYPE OF (product);
HAS cutting_item : LIST [0:?] OF cutting_item;
HAS tool_item : LIST [0:?] OF tool_item;
END_ENTITY;

ENTITY cutting_item;
```

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identifier : STRING;
geometry : geometry_specification;
material : STRING; -- For example, carbide, CBN
END_ENTITY;

ENTITY tool_item;
identifier : STRING;
geometry : geometry_specification;
clamping_method : STRING; -- e.g., screw, lever
END_ENTITY;

ENTITY geometry_specification;
diameter : REAL; -- For example, the diameter of the inscribed circle
length : REAL;
corner_radius : REAL;
END_ENTITY;
Note : This is a simplified representation; the complete schema includes many more entities and constraints.

5.4 Data Format

The model supports the following data exchange formats:
STEP (ISO 10303-21) : A machine-readable format for encoding geometry and metadata.
XML : Structured data exchange for metadata.
Other formats : Formats agreed upon by users, which must comply with the information model.

6. Data Exchange Agreement

This standard outlines a protocol for the exchange of cutting tool data:
STEP format : Uses ISO 10303-21 to encode data, ensuring compatibility with CAD/CAM systems.
XML Schema : Provides a structured format for metadata based on the EXPRESS model.
Validation : Data is verified for completeness (eg, all required attributes are present) and conformance to the ISO 13399 dictionary.
Interfaces : Data is exchanged via standardized interfaces that are compatible with software platforms (e.g. Siemens NX, Autodesk Inventor).

6.1 Example STEP File Structure

A simplified STEP file for a turning insert might include:
#10=PRODUCT('SPMN_120408','Turning insert',$,(#11));
#11=PRODUCT_DEFINITION('Design','',#12);
#12=PRODUCT_DEFINITION_FORMATION('1','',#10);
#20=PROPERTY_DEFINITION('Geometry','',#11);

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#21=PROPERTY_VALUE('diameter','9.52',#20);

#22=PROPERTY_VALUE('Thickness','4.76',#20);

#23=PROPERTY_VALUE('Corner radius','0.8',#20);

#30=PRODUCT('hard alloy','material',$,(#31));

NOTE : This is a text description; the actual STEP file is in a machine-readable format and contains the detailed data.

7. Integration with ISO 13399 series

The information model is integrated with other parts of the ISO 13399 series:

ISO 13399-2:2005 : Provides a reference dictionary for cutting items (e.g., inserts).

ISO 13399-3:2007 : Provides a reference dictionary for tool items (e.g., tool holders).

ISO/TS 13399-50:2013 : Defines reference systems and common concepts.

ISO/TS 13399-80:2017 : Specifies the creation and exchange of 3D models based on information models.

This integration ensures a unified framework for cutting tool data in design, manufacturing and lifecycle management.

8. Application Description

Tool selection : Standardized data supports automated tool selection in CAM and MES systems.

Design and Simulation : The model supports accurate CAD modeling and virtual machining simulation.

Data exchange : Neutral formats (STEP, XML) facilitate seamless data sharing between manufacturers, suppliers and users.

Interoperability : Ensure compatibility with diverse software and manufacturing systems.

Lifecycle management : Metadata supports tool identification, inventory tracking, and maintenance.

9. Appendix

Appendix A (Informative): Overview of the EXPRESS Language

Describes the EXPRESS language (ISO 10303-11) for defining information models, including syntax and examples.

Appendix B (Informative): Examples of Information Model Instances

Provides an example model instance of a turning tool assembly, including:

Entities: Cutting_tool, cutting_item (blade), tool_item (handle).

Attributes: Dimensions (e.g., 9.52 mm inscribed circle), Material (carbide).

Relationship: The assembly of blade and handle.

Appendix C (Informative): Implementation Guidelines

Outline the steps for implementing an information model in a software system, including:

Map EXPRESS to STEP or XML.

Verify data compliance.

Test interoperability.

10. References

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ISO 10303-1:1994, Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and basic principles.

ISO 10303-11:2004, Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: EXPRESS language reference manual.

ISO 10303-21:2002, Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Plain text encoding of the interchange fabric.

ISO 13584-1:2001, Industrial automation systems and integration — Parts library — Part 1: Overview and basic principles.

ISO 13399-2:2005, Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items.

ISO 13399-3:2007, Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange — Part 50: Reference dictionary of reference systems and common concepts.

ISO 1832:2004, Indexable inserts for cutting tools — Designation.

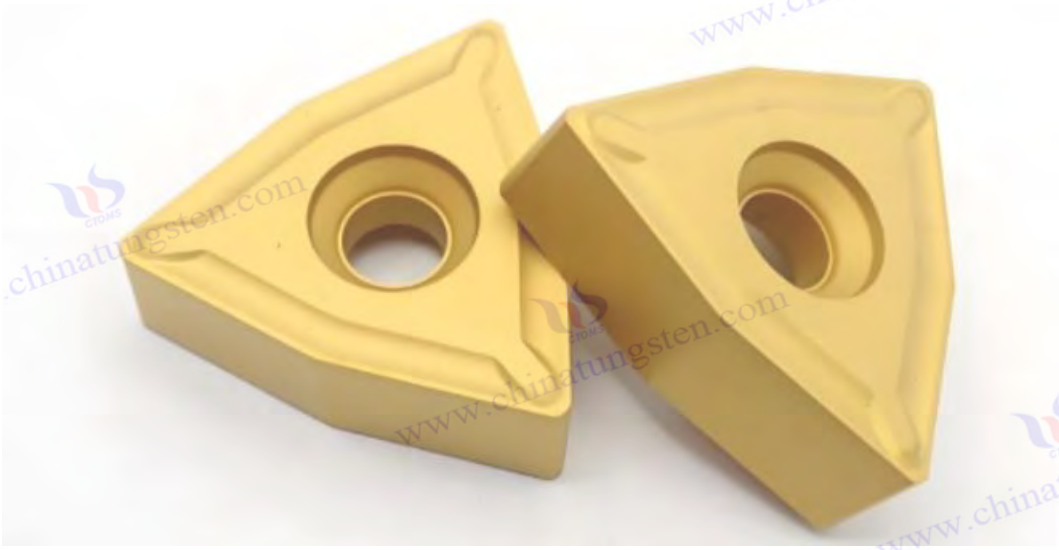
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ISO 13399-2:2005

Cutting tool data representation and exchange

— Part 2: Reference dictionary for cutting items

Cutting tool data representation and exchange

— Part 2: Reference dictionary for cutting items

1. Scope

This International Standard specifies a reference dictionary for cutting items, which are the components of cutting tools responsible for material removal (eg, indexable inserts, solid tool tips, edges of solid tools). It defines standardized terms, definitions, and properties for cutting items, enabling consistent data representation and exchange in digital formats across computer-aided design (CAD), computer-aided manufacturing (CAM), and manufacturing execution systems (MES). The standard is part of the ISO 13399 series and is cutting used in conjunction with ISO 13399-1:2006, which provides the general information model.

The reference dictionary covers:

Terminology and definitions for cutting items.

Properties such as geometry (eg, inscribed circle diameter, corner radius), material, and functional characteristics.

Data structures for integration with formats like STEP (ISO 10303) and XML.

It does not cover:

Non-cutting components (eg, tool holders, shanks), which are addressed in ISO 13399-3.

Performance characteristics (eg, cutting forces, tool life).

Manufacturing processes for producing cutting items.

2. Normative References

The following documents are referenced in ISO 13399-2:2005 and are indispensable for its application:

ISO 13399-1:2006 : Cutting tool data representation and exchange

— Part 1: Overview, fundamental principles and general information model.

ISO 10303-11:2004 : Industrial automation systems and integration

— Product data representation and exchange

— Part 11: Description methods: The EXPRESS language reference manual.

ISO 10303-21:2002 : Industrial automation systems and integration

— Product data representation and exchange

— Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 13584-1:2001 : Industrial automation systems and integration

— Parts library

— Part 1: Overview and fundamental principles.

ISO 13584-24:2003 : Industrial automation systems and integration

— Parts library

— Part 24: Logical resource: Logical model of supplier library.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Cutting item : A component of a cutting tool that directly removes material from a workpiece (eg, indexable insert,

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solid tool tip, cutting edge of a drill).

Reference dictionary : A structured collection of terms, definitions, and properties for cutting items, used for standardized data representation.

Property : A characteristic of a cutting item, such as its geometry (eg, diameter, thickness), material, or designation.

EXPRESS : A data modeling language (ISO 10303-11) used to define the reference dictionary.

STEP (Standard for the Exchange of Product model data) : A standardized format (ISO 10303) for exchanging cutting item data.

Interoperability : The ability of different software systems to exchange and utilize cutting item data consistently.

4. Reference Dictionary Structure

The reference dictionary is defined using the EXPRESS language (ISO 10303-11) and provides a structured framework for cutting item data. It organizes information into:

Classes : Categories of cutting items (eg, indexable insert, solid cutting tip).

Properties : Attributes of cutting items, such as geometric dimensions, material, and functional parameters.

Relationships : Links between classes and properties, ensuring data integrity and hierarchy.

4.1 Classes of Cutting Items

The dictionary includes classes such as:

Indexable_insert : A detachable cutting item (eg, turning insert, milling insert).

Solid_cutting_tip : A fixed cutting edge on a solid tool (eg, drill tip, end mill flutes).

Brazed_tip : A cutting edge brazed onto a tool body (eg, PCD or CBN tipped tools).

4.2 Properties of Cutting Items

Properties are categorized into:

Geometric properties : Dimensions such as inscribed circle diameter, thickness, corner radius, and cutting edge length.

Material properties : Material type (eg, carbide, CBN, PCD) and coating (eg, TiN, Al2O3).

Functional properties : Designation (per ISO 1832:2004), cutting edge condition (eg, sharp, honed), and chip breaker type.

Metadata : Manufacturer, catalog number, and standards compliance.

4.3 Example EXPRESS Schema (Simplified)

A simplified EXPRESS schema for an indexable insert might include:

```
ENTITY cutting_item;
identifier : STRING;
designation : STRING; -- eg, SPMN 120408 per ISO 1832
material : STRING; -- eg, carbide
SUBTYPE OF (product);
END_ENTITY;

ENTITY indexable_insert
SUBTYPE OF (cutting_item);
```

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geometry : insert_geometry;

chip_breaker : OPTIONAL STRING; -- eg, groove, step

coating: OPTIONAL STRING; -- eg, TiN

END_ENTITY;

ENTITY insert_geometry;

inscribed_circle_diameter : REAL; -- eg, 9.52 mm

thickness: REAL; --eg, 4.76 mm

corner_radius : REAL; -- eg, 0.8 mm

cutting_edge_length : REAL;

END_ENTITY;

Note : This is a simplified representation; the full schema includes additional properties and constraints.

5. Property Definitions

The reference dictionary defines properties with standardized names, units, and data types to ensure consistency. Below is a representative table of key properties for an indexable insert.

Table 1: Example Properties for Indexable Insert

Property Name	Description	Data Type	Unit	Example Value
inscribed_circle_diameter	Diameter of the inscribed circle	REAL	mm	9.52
thickness	Vertical height of the insert	REAL	mm	4.76
corner_radius	Radius of the corner	REAL	mm	0.8
cutting_edge_length	Length of the cutting edge	REAL	mm	12.0
material	Material of the cutting item	STRING	-	Carbide
coating	Coating type, if applicable	STRING	-	TiN
chip_breaker	Type of chip breaker, if present	STRING	-	Groove
designation	Standardized design (ISO 1832)	STRING	-	SPMN 120408
number_of_cutting_edges	Number of usable cutting edges	INTEGER	-	4

Notes :

Properties are mandatory or optional, depending on the cutting item class.

Units follow the SI system (eg, millimeters for lengths).

The dictionary references ISO 1832:2004 for designations.

6. Data Exchange

The reference dictionary supports data exchange in standardized formats:

STEP (ISO 10303-21) : Encodes cutting item data, including geometry and properties, for machine-readable exchange.

XML : Structures metadata and properties for integration with software systems.

Validation : Data must conform to the EXPRESS schema and include all mandatory properties.

Interfacing : Data is exchanged via interfaces compatible with CAD, CAM, and MES systems (eg, Siemens NX, Autodesk Inventor).

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6.1 Example STEP File Structure

A simplified STEP file for an indexable insert might include:

#10=PRODUCT('SPMN_120408','Indexable Insert',$,(#11));

#11=PRODUCT_DEFINITION('design','',#12);

#12=PRODUCT_DEFINITION_FORMATION('1','',#10);

#20=PROPERTY_DEFINITION('geometry','',#11);

#21=PROPERTY_VALUE('inscribed_circle_diameter','9.52',#20);

#22=PROPERTY_VALUE('thickness','4.76',#20);

#23=PROPERTY_VALUE('corner_radius','0.8',#20);

#24=PROPERTY_VALUE('material','Carbide',#20);

#25=PROPERTY_VALUE('designation','SPMN 120408',#20);

Note : This is a textual description; actual STEP files are machine-readable and include detailed data.

7. Integration with ISO 13399 Series

The reference dictionary integrates with other parts of the ISO 13399 series:

ISO 13399-1:2006 : Provides the general information model for cutting tool data.

ISO 13399-3:2007 : Defines a reference dictionary for tool items (eg, holders), complementing cutting items.

ISO/TS 13399-50:2013 : Specifies reference systems and common concepts for data consistency.

ISO/TS 13399-80:2017 : Uses the dictionary for 3D model creation and exchange.

This integration ensures a cohesive framework for representing and exchanging cutting tool data.

8. Application Notes

Data consistency : Standardized properties ensure uniform data across manufacturers and systems.

Tool selection : The dictionary supports automated tool selection in CAM and MES systems by providing precise cutting item data.

Interoperability : Enables seamless data exchange between CAD, CAM, and manufacturing systems.

Lifecycle management : Metadata (eg, designation, material) supports tool identification, inventory tracking, and maintenance.

Design and simulation : Provides data for accurate modeling and virtual machining simulations.

9. Annexes

Annex A (Normative): EXPRESS schema for cutting items

Provides the complete EXPRESS schema for the reference dictionary, including classes, properties, and relationships.

Annex B (Informative): Example dictionary instance

Describes a sample instance for an indexable insert, including:

Class: Indexable_insert.

Properties: Inscribed circle diameter (9.52 mm), thickness (4.76 mm), material (carbide), designation (SPMN 120408).

Relationships: Link to a tool assembly.

Annex C (Informative): Guidelines for implementation

Outlines steps for implementing the reference dictionary in software systems, including:

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Mapping EXPRESS to STEP or XML.

Validating data compliance.

Ensuring interoperability with other ISO 13399 parts.

10. Bibliography

ISO 13399-1:2006, Cutting tool data representation and exchange

— Part 1: Overview, fundamental principles and general information model.

ISO 10303-11:2004, Industrial automation systems and integration

— Product data representation and exchange

— Part 11: Description methods: The EXPRESS language reference manual.

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— Product data representation and exchange

— Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 13584-1:2001, Industrial automation systems and integration

— Parts library

— Part 1: Overview and fundamental principles.

ISO 13584-24:2003, Industrial automation systems and integration

— Parts library

— Part 24: Logical resource: Logical model of supplier library.

ISO 1832:2004, Indexable inserts for cutting tools

— Designation.

ISO 13399-3:2007, Cutting tool data representation and exchange

— Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange

— Part 50: Reference dictionary for reference systems and common concepts.

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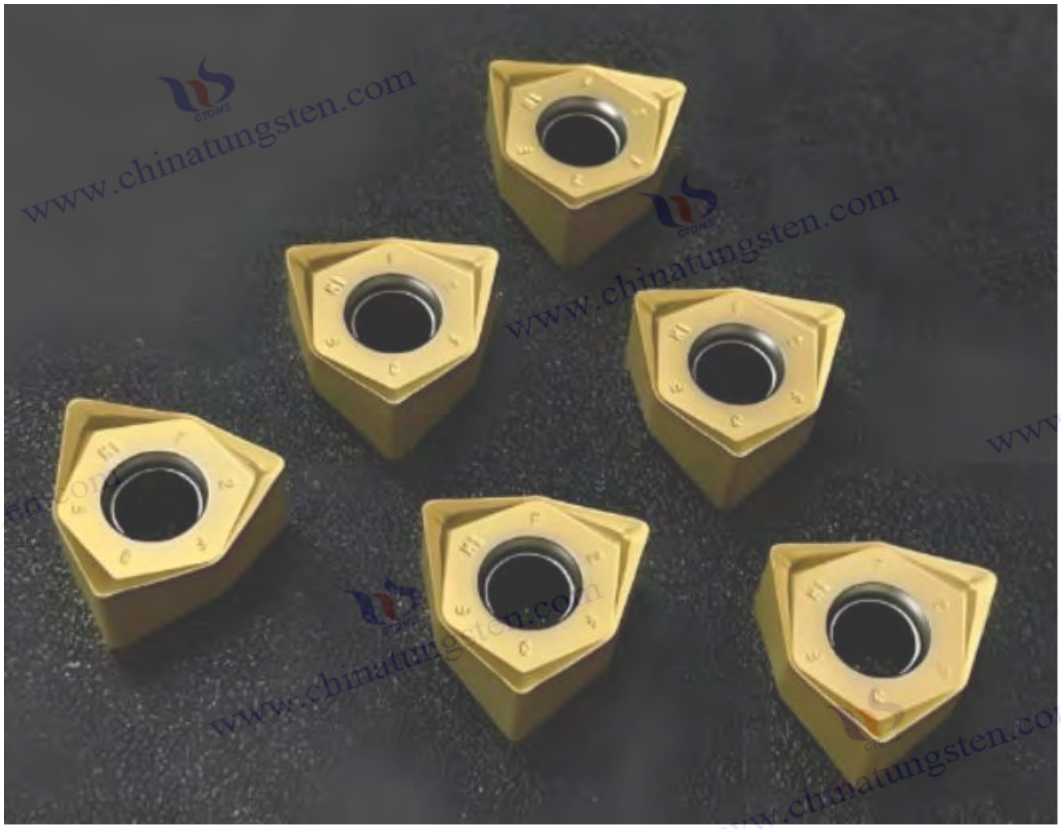
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ISO 13399-2:2005

Cutting tool data representation and exchange

— Part 2: Reference dictionary for cutting items

1. Scope

This International Standard specifies a reference dictionary for cutting items, which are cutting tool components responsible for material removal (e.g., indexable inserts, solid tool tips, cutting edges of solid tools). It defines standardized terms, definitions, and properties for cutting items to facilitate consistent data representation and exchange in digital formats within computer-aided design (CAD), computer-aided manufacturing (CAM), and manufacturing execution systems (MES). This standard is part of the ISO 13399 series and is intended to be used in conjunction with ISO 13399-1:2006, which provides a common information model.

The reference dictionary covers:

Terms and definitions for cutting items.

Attributes such as geometry (e.g., inscribed circle diameter, fillet radius), material, and functional properties.

Data structures that integrate with formats such as STEP (ISO 10303) and XML.

This standard does not cover:

Non-cutting components (e.g. tool holders, shanks) are dealt with by ISO 13399-3.

Performance characteristics (e.g., cutting forces, tool life).

The manufacturing process of cutting items.

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2. Normative References

The following documents are referenced in ISO 13399-2:2005 and are indispensable for its application:

ISO 13399-1:2006 : Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model.

ISO 10303-11:2004 : Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: EXPRESS language reference manual.

ISO 10303-21:2002 : Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Plain text encoding of exchange structures.

ISO 13584-1:2001 : Industrial automation systems and integration — Parts library — Part 1: Overview and basic principles.

ISO 13584-24:2003 : Industrial automation systems and integration — Parts libraries — Part 24: Logical resources: Logical model for supplier libraries.

3. Terms and Definitions

In this standard, the following terms apply:

Cutting Item : The component of a cutting tool that directly removes material from the workpiece (e.g., indexable insert, solid tool tip, cutting edge of a drill).

Reference dictionary : A structured collection of terms, definitions, and properties of cutting items for standardized data representation.

Attributes : Characteristics of a cutting item, such as geometry (e.g., diameter, thickness), material, or identification.

EXPRESS : A data modeling language for defining reference dictionaries (ISO 10303-11).

STEP (Standard for the Exchange of Model Data of Products) : A standardized format for exchanging cutting project data (ISO 10303).

Interoperability : The ability of different software systems to consistently exchange and utilize cutting project data.

4. Reference dictionary structure

The reference dictionary is defined in the EXPRESS language (ISO 10303-11) and provides a structured framework for cutting project data. It organizes the information into:

Class : The category of the cutting item (e.g., indexable insert, solid cutting tip).

Attributes : Characteristics of a cutting item, such as geometric dimensions, material, and functional parameters.

Relationships : Links between classes and attributes that ensure data integrity and hierarchy.

4.1 Cutting Projects

Dictionaries include the following classes:

Indexable_insert : Removable cutting items (e.g., turning inserts, milling inserts).

Solid_cutting_tip : A fixed cutting edge on a solid tool (e.g., drill tip, end mill flute).

Brazed_tip : A cutting edge brazed to the tool body (for example, PCD or CBN tipped tools).

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4.2 Cutting Project Properties

Attributes are divided into:

Geometric properties : Dimensions such as inscribed circle diameter, thickness, corner radius, and cutting edge length.

Material properties : Material type (e.g., carbide, CBN, PCD) and coating (e.g., TiN, Al2O3).

Functional attributes : Identification (according to ISO 1832:2004), cutting edge condition (e.g. sharp, blunt) and chipbreaker type.

Metadata : manufacturer, catalog number, and standards compliance.

4.3 Example EXPRESS mode (simplified)

A simplified EXPRESS model for indexable inserts may include:

ENTITY cutting_item;
identifier : STRING;
designation : STRING; -- For example, SPMN 120408 according to ISO 1832
material : STRING; -- For example, cemented carbide
SUBTYPE OF (product);
END_ENTITY;

ENTITY indexable_insert
SUBTYPE OF (cutting_item);
geometry : insert_geometry;
chip_breaker : OPTIONAL STRING; -- For example, slot type, step type
coating : OPTIONAL STRING; -- For example, TiN
END_ENTITY;

ENTITY insert_geometry;
inscribed_circle_diameter : REAL; -- for example, 9.52 mm
thickness : REAL; -- for example, 4.76 mm
corner_radius : REAL; -- for example, 0.8 mm
cutting_edge_length : REAL;
END_ENTITY;

Note : This is a simplified representation; the full schema includes many more properties and constraints.

5. Attribute Definition

Reference dictionaries define attributes with standardized names, units, and data types to ensure consistency. The following is a representative table of key attributes for indexable inserts.

Table 1: Example properties of indexable inserts

Attribute Name	describe	Data Type	unit	Example Value
inscribed_circle_diameter	Inscribed circle diameter	REAL	mm	9.52

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thickness	Blade vertical height	REAL	mm	4.76
corner_radius	Corner radius	REAL	mm	0.8
cutting_edge_length	Cutting edge length	REAL	mm	12.0
material	Cutting project materials	STRING	-	cemented carbide
coating	Coating type (if applicable)	STRING	-	TiN
chip_breaker	Chipbreaker type (if present)	STRING	-	Groove type
designation	Standardized symbols (ISO 1832)	STRING	-	SPMN 120408
number_of_cutting_edges	Number of available cutting edges	INTEGER	-	4

Note :

Attributes are classified as mandatory or optional depending on the cutting item type.

Units follow the SI system (for example, millimeters for length).

The dictionary refers to ISO 1832:2004 for identification.

6. Data Exchange

The reference dictionary supports data exchange in the following standardized formats:

STEP (ISO 10303-21) : Encodes cutting item data, including geometry and attributes, for machine-readable interchange.

XML : Structured metadata and attributes for easy integration with software systems.

Validation : The data must conform to the EXPRESS schema and contain all required attributes.

Interfaces : Exchange data via compatible interfaces with CAD, CAM and MES systems (eg Siemens NX, Autodesk Inventor).

6.1 Example STEP File Structure

A simplified STEP file for an indexable insert might include:

#10=PRODUCT('SPMN_120408','Indexable Insert',$,(#11));

#11=PRODUCT_DEFINITION('Design','',#12);

#12=PRODUCT_DEFINITION_FORMATION('1','',#10);

#20=PROPERTY_DEFINITION('Geometry','',#11);

#21=PROPERTY_VALUE('Inscribed circle diameter','9.52',#20);

#22=PROPERTY_VALUE('Thickness','4.76',#20);

#23=PROPERTY_VALUE('Corner radius','0.8',#20);

#24=PROPERTY_VALUE(' Material','Carbide',#20);

#25=PROPERTY_VALUE('ID','SPMN 120408',#20);

NOTE : This is a text description; the actual STEP file is in a machine-readable format and contains the detailed data.

7. Integration with ISO 13399 series

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The reference dictionary is integrated with other parts of the ISO 13399 series:

ISO 13399-1:2006 : Provides a common information model for cutting tool data.

ISO 13399-3:2007 : A reference dictionary defining tool items (e.g., tool holders), complementary to cutting items.

ISO/TS 13399-50:2013 : Specifies reference systems and common concepts to ensure data consistency.

ISO/TS 13399-80:2017 : Creation and exchange of 3D models using dictionaries.

This integration ensures a unified framework for representing and exchanging cutting tool data.

8. Application Description

Data consistency : Standardized attributes ensure data uniformity across manufacturers and systems.

Tool selection : The dictionary supports automated tool selection in CAM and MES systems by providing precise cutting project data.

Interoperability : Enable seamless data exchange between CAD, CAM, and manufacturing systems.

Lifecycle management : Metadata (e.g., identification, material) supports tool identification, inventory tracking, and maintenance.

Design and Simulation : Provide data for accurate modeling and virtual machining simulation.

9. Appendix

Appendix A (Normative): EXPRESS Mode for Cutting Projects

Provides the complete EXPRESS schema for the reference dictionary, including classes, attributes, and relations.

Appendix B (Informative): Dictionary Examples

Describes example instances of indexable inserts, including:

Class: Indexable_insert.

Attributes: Inscribed circle diameter (9.52 mm), thickness (4.76 mm), material (carbide), identification (SPMN 120408).

Relationship: Link to the tool assembly.

Appendix C (Informative): Implementation Guidelines

Outline the steps for implementing a reference dictionary in a software system, including:

Map EXPRESS to STEP or XML.

Verify data compliance.

Ensure interoperability with other parts of ISO 13399.

10. References

ISO 13399-1:2006, Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model.

ISO 10303-11:2004, Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: EXPRESS language reference manual.

ISO 10303-21:2002 , Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Plain text encoding of exchange structures.

ISO 13584-1:2001, Industrial automation systems and integration — Parts library — Part 1: Overview and basic

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principles.

ISO 13584-24:2003, Industrial automation systems and integration — Parts libraries — Part 24: Logical resources: Logical model for supplier libraries.

ISO 1832:2004, Indexable inserts for cutting tools — Designation.

ISO 13399-3:2007, Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange — Part 50: Reference dictionary of reference systems and common concepts.

Publication Information

Standard number : ISO 13399-2:2005

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Publisher : International Organization for Standardization (ISO), Geneva, Switzerland

Status : Current (as of April 26, 2025)



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ISO 13399-3:2014 Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items

Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items

1. Scope

This International Standard specifies a reference dictionary for tool items, which are the non-cutting components of cutting tools that support, position, or clamp items (eg, tool holders, shanks, adapters, clamping mechanisms). It defines standardized terms, definitions, and properties for tool items, enabling consistent data representation and exchange in digital formats across computer-aided design (CAD), computer-aided manufacturing (CAM), and manufacturing cutting execution systems (MES). The standard is part of the ISO 13399 series and complements ISO 13399-2:2005 (reference dictionary for cutting items) and ISO 13399-1:2006 (general information model).

The reference dictionary covers:

Terminology and definitions for tool items.

Properties such as geometry (eg, shank diameter, overall length), material, and functional characteristics.

Data structures for integration with formats like STEP (ISO 10303) and XML.

It does not cover:

Cutting items (eg, inserts, solid tool tips), which are addressed in ISO 13399-2.

Performance characteristics (eg, rigidity, vibration damping).

Manufacturing processes for producing tool items.

2. Normative References

The following documents are referenced in ISO 13399-3:2014 and are indispensable for its application:

ISO 13399-1:2006 : Cutting tool data representation and exchange — Part 1: Overview, fundamental principles and general information model.

ISO 13399-2:2005 : Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items.

ISO/TS 13399-50:2013 : Cutting tool data representation and exchange — Part 50: Reference dictionary for reference systems and common concepts.

ISO 10303-11:2004 : Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual.

ISO 10303-21:2016 : Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 13584-1:2001 : Industrial automation systems and integration — Parts library — Part 1: Overview and fundamental principles.

ISO 13584-24:2003 : Industrial automation systems and integration — Parts library — Part 24: Logical resource: Logical model of supplier library.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Tool item : A non-cutting component of a cutting tool that supports, positions, or clamps a cutting item (eg, tool holder, shank, adapter).

Reference dictionary : A structured collection of terms, definitions, and properties for tool items, used for standardized data representation.

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Property : A characteristic of a tool item, such as its geometry (eg, shank diameter, length), material, or clamping method.

EXPRESS : A data modeling language (ISO 10303-11) used to define the reference dictionary.

STEP (Standard for the Exchange of Product model data) : A standardized format (ISO 10303) for exchanging tool item data.

Interoperability : The ability of different software systems to exchange and utilize tool item data consistently.

4. Reference Dictionary Structure

The reference dictionary is defined using the EXPRESS language (ISO 10303-11) and provides a structured framework for tool item data. It organizes information into:

Classes : Categories of tool items (eg, tool holder, shank, adapter).

Properties : Attributes of tool items, such as geometric dimensions, material, and functional parameters.

Relationships : Links between classes and properties, ensuring data integrity and hierarchy.

4.1 Classes of Tool Items

The dictionary includes classes such as:

Tool_holder : A component that holds and positions a cutting item (eg, turning tool holder, milling arbor).

Shank : A component that connects the tool to the machine spindle (eg, cylindrical shank, HSK shank).

Adaptor : A component that interfaces between the tool and machine (eg, collet chuck, extension adapter).

Clamping_mechanism : A component for securing cutting items (eg, screw, lever).

4.2 Properties of Tool Items

Properties are categorized into:

Geometric properties : Dimensions such as shank diameter, overall length, body diameter, and clamping length.

Material properties : Material type (eg, steel, carbide) and surface treatment (eg, hardened, coated).

Functional properties : Clamping method (eg, screw, hydraulic), interface type (eg, ISO taper, HSK), and balance quality.

Metadata : Manufacturer, catalog number, and standards compliance (eg, ISO 5608 for tool holders).

4.3 Example EXPRESS Schema (Simplified)

A simplified EXPRESS schema for a tool holder might include:

```
ENTITY tool_item;
identifier : STRING;
designation : STRING; -- eg, ISO 5608 designation
material: STRING; -- eg, steel
SUBTYPE OF (product);
END_ENTITY;

ENTITY tool_holder
SUBTYPE OF (tool_item);
geometry : holder_geometry;
clamping_method : STRING; -- eg, screw, hydraulic
```

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interface_type : STRING; -- eg, HSK, ISO taper
END_ENTITY;

ENTITY holder_geometry;
shank_diameter : REAL; -- eg, 32 mm
overall_length : REAL; -- eg, 100 mm
body_diameter : REAL; -- eg, 50 mm
clamping_length : REAL; -- eg, 40 mm
END_ENTITY;

Note : This is a simplified representation; the full schema includes additional properties and constraints.

5. Property Definitions

The reference dictionary defines properties with standardized names, units, and data types to ensure consistency. Below is a representative table of key properties for a tool holder.

Table 1: Example Properties for Tool Holder

Property Name	Description	Data Type	Unit	Example Value
shank_diameter	Diameter of the shank	REAL	mm	32.0
overall_length	Total length of the holder	REAL	mm	100.0
body_diameter	Diameter of the holder body	REAL	mm	50.0
clamping_length	Length of the clamping area	REAL	mm	40.0
material	Material of the tool holder	STRING	-	Steel
surface_treatment	Surface treatment, if applicable	STRING	-	Hardened
clamping_method	Method of securing the cutting item	STRING	-	Screw
interface_type	Machine interface type	STRING	-	HSK-A63
designation	Standardized design (eg, ISO 5608)	STRING	-	SCLCR 2525M 09
balance_quality	Balance quality grade (eg, ISO 1940)	STRING	-	G2.5

Notes :

Properties are mandatory or optional, depending on the tool item class.

Units follow the SI system (eg, millimeters for lengths).

The dictionary references ISO 5608:1995 for tool holder designations.

6. Data Exchange

The reference dictionary supports data exchange in standardized formats:

STEP (ISO 10303-21) : Encodes tool item data, including geometry and properties, for machine-readable exchange.

XML : Structures metadata and properties for integration with software systems.

Validation : Data must conform to the EXPRESS schema and include all mandatory properties.

Interfacing : Data is exchanged via interfaces compatible with CAD, CAM, and MES systems (eg, Siemens NX, Autodesk Inventor).

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6.1 Example STEP File Structure

A simplified STEP file for a tool holder might include:

#10=PRODUCT('SCLCR_2525M_09','Tool Holder',$,(#11));

#11=PRODUCT_DEFINITION('design','',#12);

#12=PRODUCT_DEFINITION_FORMATION('1','',#10);

#20=PROPERTY_DEFINITION('geometry','',#11);

#21=PROPERTY_VALUE('shank_diameter','32.0',#20);

#22=PROPERTY_VALUE('overall_length','100.0',#20);

#23=PROPERTY_VALUE('body_diameter','50.0',#20);

#24=PROPERTY_VALUE('material','Steel',#20);

#25=PROPERTY_VALUE('designation','SCLCR 2525M 09',#20);

Note : This is a textual description; actual STEP files are machine-readable and include detailed data.

7. Integration with ISO 13399 Series

The reference dictionary integrates with other parts of the ISO 13399 series:

ISO 13399-1:2006 : Provides the general information model for cutting tool data.

ISO 13399-2:2005 : Defines a reference dictionary for cutting items, complementing tool items.

ISO/TS 13399-50:2013 : Specifies reference systems and common concepts for data consistency.

ISO/TS 13399-60:2014 : Defines connection codes for tool assemblies, linking tool items and cutting items.

ISO/TS 13399-80:2017 : Uses the dictionary for 3D model creation and exchange.

This integration ensures a cohesive framework for representing and exchanging cutting tool data.

8. Application Notes

Data consistency : Standardized properties ensure uniform data across manufacturers and systems.

Tool selection : The dictionary supports automated selection of tool holders in CAM and MES systems by providing precise tool item data.

Interoperability : Enables seamless data exchange between CAD, CAM, and manufacturing systems.

Lifecycle management : Metadata (eg, designation, material) supports tool holder identification, inventory tracking, and maintenance.

Design and simulation : Provides data for accurate modeling and virtual machining simulations.

9. Annexes

Annex A (Normative): EXPRESS schema for tool items

Provides the complete EXPRESS schema for the reference dictionary, including classes, properties, and relationships.

Annex B (Informative): Example dictionary instance

Describes a sample instance for a tool holder, including:

Class: Tool_holder.

Properties: Shank diameter (32.0 mm), overall length (100.0 mm), material (steel), designation (SCLCR 2525M 09).

Relationships: Link to a cutting item in a tool assembly.

Annex C (Informative): Guidelines for implementation

Outlines steps for implementing the reference dictionary in software systems, including:

Mapping EXPRESS to STEP or XML.

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Validating data compliance.

Ensuring interoperability with other ISO 13399 parts.

10. Bibliography

ISO 13399-1:2006, Cutting tool data representation and exchange — Part 1: Overview, fundamental principles and general information model.

ISO 13399-2:2005, Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange — Part 50: Reference dictionary for reference systems and common concepts.

ISO/TS 13399-60:2014, Cutting tool data representation and exchange — Part 60: Reference dictionary for connection systems.

ISO 10303-11:2004, Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual.

ISO 10303-21:2016, Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 13584-1:2001, Industrial automation systems and integration — Parts library — Part 1: Overview and fundamental principles.

ISO 13584-24:2003, Industrial automation systems and integration — Parts library — Part 24: Logical resource: Logical model of supplier library.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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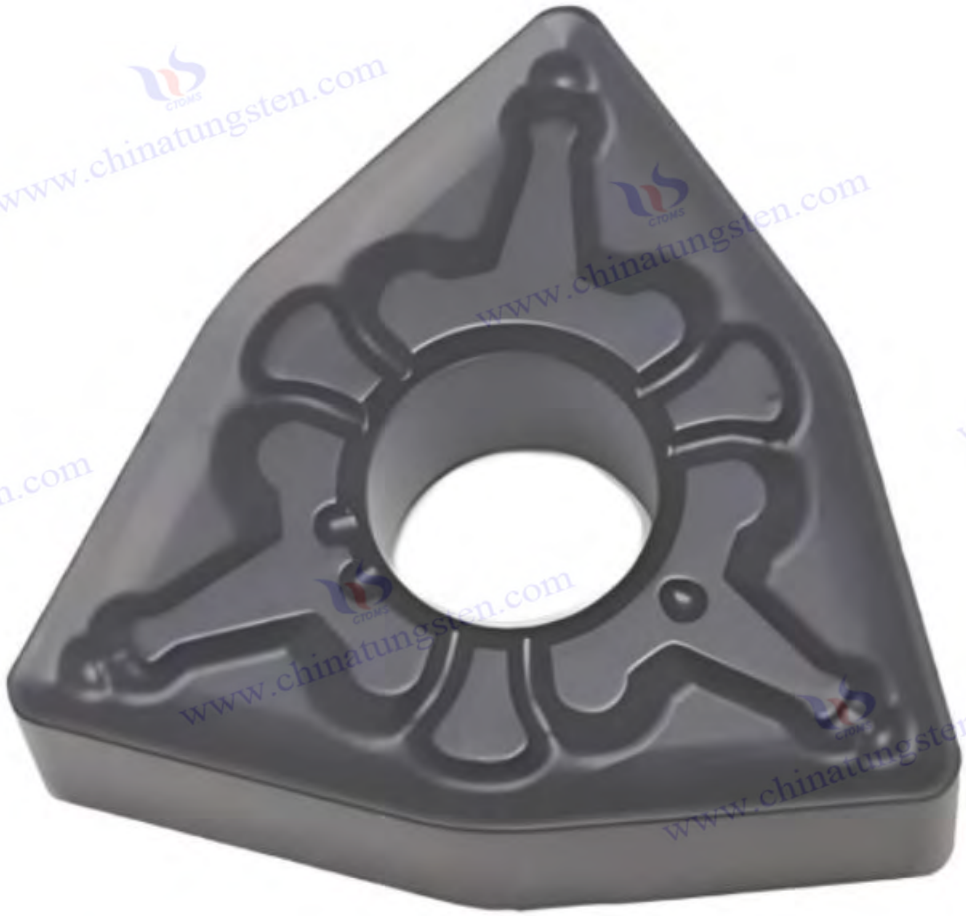
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ISO 13399-3:2014

Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items

1. Scope

This International Standard specifies a reference dictionary for tool items, which are non-cutting components of cutting tools used to support, locate, or clamp the cutting item (e.g., toolholders, shanks, adapters, clamping mechanisms). It defines standardized terms, definitions, and attributes for tool items to facilitate consistent data representation and exchange in digital formats within computer-aided design (CAD), computer-aided manufacturing (CAM), and manufacturing execution systems (MES). This standard is part of the ISO 13399 series and complements ISO 13399-2:2005 (Reference dictionary for cutting items) and ISO 13399-1:2006 (Common information model).

The reference dictionary covers:

Terms and definitions for the Tools project.

Attributes such as geometry (e.g., shank diameter, overall length), material, and functional properties.

Data structures that integrate with formats such as STEP (ISO 10303) and XML.

This standard does not cover:

Cutting items (e.g., inserts, solid tool tips), are dealt with by ISO 13399-2.

Performance characteristics (e.g., stiffness, vibration damping).

Manufacturing process of tool items.

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2. Normative References

The following documents are referenced in ISO 13399-3:2014 and are indispensable for its application:

ISO 13399-1:2006 : Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model.

ISO 13399-2:2005 : Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items.

ISO/TS 13399-50:2013 : Cutting tool data representation and exchange — Part 50: Reference dictionary of reference systems and common concepts.

ISO 10303-11:2004 : Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: EXPRESS language reference manual.

ISO 10303-21:2016 : Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Plain text encoding of exchange structures.

ISO 13584-1:2001 : Industrial automation systems and integration — Parts library — Part 1: Overview and basic principles.

ISO 13584-24:2003 : Industrial automation systems and integration — Parts libraries — Part 24: Logical resources: Logical model for supplier libraries.

3. Terms and Definitions

In this standard, the following terms apply:

Tool Item : A non-cutting component of a cutting tool used to support, locate, or clamp the cutting item (e.g., holder, shank, adapter).

Reference dictionary : A structured collection of terms, definitions, and properties for tool items used to standardize data representation.

Attributes : Characteristics of a tool item, such as geometry (e.g., shank diameter, length), material, or clamping method.

EXPRESS : A data modeling language for defining reference dictionaries (ISO 10303-11).

STEP (Standard for the Exchange of Product Model Data) : A standardized format for exchanging tool project data (ISO 10303).

Interoperability : The ability of different software systems to consistently exchange and utilize tool project data.

4. Reference dictionary structure

The reference dictionary is defined using the EXPRESS language (ISO 10303-11) and provides a structured framework for tool project data. It organizes the information into:

Class : The category of the tool item (for example, handle, shank, adapter).

Attributes : Characteristics of a tool item, such as geometric dimensions, materials, and functional parameters.

Relationships : Links between classes and attributes that ensure data integrity and hierarchy.

4.1 Tool Project Class

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Dictionaries include the following classes:

Tool_holder : A component used to hold and position a cutting item (e.g., turning tool holder, milling tool holder).

Shank : The component that connects the tool to the machine tool spindle (e.g., cylindrical shank, HSK shank).

Adapter : The interface component between the tool and the machine tool (e.g., chuck, extension adapter).

Clamping_mechanism : The component used to secure the cutting item (e.g., screw, lever).

4.2 Tool Project Properties

Attributes are divided into:

Geometric properties : Dimensions such as shank diameter, overall length, body diameter, and clamping length.

Material properties : Material type (e.g., steel, carbide) and surface treatment (e.g., hardened, coated).

Functional properties : Clamping method (e.g. screw, hydraulic), connection type (e.g. ISO taper, HSK), and balancing quality.

Metadata : Manufacturer, catalog number, and standards compliance (e.g., ISO 5608 standard for tool holders).

4.3 Example EXPRESS mode (simplified)

A simplified EXPRESS model of a toolholder may include:

```
ENTITY tool_item;
identifier : STRING;
designation : STRING; -- For example, ISO 5608 designation
material : STRING; -- For example, steel
SUBTYPE OF (product);
END_ENTITY;

ENTITY tool_holder
SUBTYPE OF (tool_item);
geometry : holder_geometry;
clamping_method : STRING; -- e.g., screw, hydraulic
interface_type : STRING; -- For example, HSK, ISO taper
END_ENTITY;

ENTITY holder_geometry;
shank_diameter : REAL; -- For example, 32 mm
overall_length : REAL; -- for example, 100 mm
body_diameter : REAL; -- For example, 50 mm
clamping_length : REAL; -- For example, 40 mm
END_ENTITY;
```

Note : This is a simplified representation; the full schema includes many more properties and constraints.

5. Attribute Definition

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The reference dictionary defines properties with standardized names, units, and data types to ensure consistency. The following is a representative table of key properties for toolholders.

Table 1: Example properties of tool holders

Attribute Name	describe	Data Type	unit	Example Value
shank_diameter	Shank diameter	REAL	mm	32.0
overall_length	Total length of handle	REAL	mm	100.0
body_diameter	Shank body diameter	REAL	mm	50.0
clamping_length	Clamping area length	REAL	mm	40.0
material	Handle material	STRING	-	steel
surface_treatment	Surface treatment (if applicable)	STRING	-	hardening
clamping_method	Method for fixing cutting items	STRING	-	screws
interface_type	Machine tool interface type	STRING	-	HSK-A63
designation	Standardized designations (e.g., ISO 5608)	STRING	-	SCLCR 2525M 09
balance_quality	Balance quality class (e.g., ISO 1940)	STRING	-	G2.5

Note :

Attributes are classified as required or optional based on the tool item class.

Units follow the SI system (for example, millimeters for length).

The dictionary refers to ISO 5608:1995 for tool holder identification.

6. Data Exchange

The reference dictionary supports data exchange in the following standardized formats:

STEP (ISO 10303-21) : Encodes tool project data, including geometry and attributes, for machine-readable interchange.

XML : Structured metadata and attributes for easy integration with software systems.

Validation : The data must conform to the EXPRESS schema and contain all required attributes.

Interfaces : Exchange data via compatible interfaces with CAD, CAM and MES systems (eg Siemens NX, Autodesk Inventor).

6.1 Example STEP File Structure

A simplified STEP file for a tool holder might include:

#10=PRODUCT('SCLCR_2525M_09','Handle',$,(#11));

#11=PRODUCT_DEFINITION(' Design','',#12);

#12=PRODUCT_DEFINITION_FORMATION('1','',#10);

#20=PROPERTY_DEFINITION('Geometry','',#11);

#21=PROPERTY_VALUE('Handle diameter','32.0',#20);

#22=PROPERTY_VALUE('Total length','100.0',#20);

#23=PROPERTY_VALUE('body diameter','50.0',#20);

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#24=PROPERTY_VALUE('Material','Steel',#20);

#25=PROPERTY_VALUE('Logo','SCLCR 2525M 09',#20);

NOTE : This is a text description; the actual STEP file is in a machine-readable format and contains the detailed data.

7. Integration with ISO 13399 series

The reference dictionary is integrated with other parts of the ISO 13399 series:

ISO 13399-1:2006 : Provides a common information model for cutting tool data.

ISO 13399-2:2005 : Reference dictionary for defining cutting items, complementary to tool items.

ISO/TS 13399-50:2013 : Specifies reference systems and common concepts to ensure data consistency.

ISO/TS 13399-60:2014 : Defines connection codes for tool assemblies, linking tool items and cutting items.

ISO/TS 13399-80:2017 : Creation and exchange of 3D models using dictionaries.

This integration ensures a unified framework for representing and exchanging cutting tool data.

8. Application Description

Data consistency : Standardized attributes ensure data uniformity across manufacturers and systems.

Tool Selection : The dictionary supports automated toolholder selection in CAM and MES systems by providing precise tool item data.

Interoperability : Enable seamless data exchange between CAD, CAM, and manufacturing systems.

Lifecycle management : Metadata (e.g., identification, material) supports toolholder identification, inventory tracking, and maintenance.

Design and Simulation : Provide data for accurate modeling and virtual machining simulation.

9. Appendix

Appendix A (Normative): EXPRESS Mode for Tool Projects

Provides the complete EXPRESS schema for the reference dictionary, including classes, attributes, and relations.

Appendix B (Informative): Dictionary Examples

Example instances describing tool holders include:

Class: Tool_holder.

Attributes: Shank diameter (32.0 mm), overall length (100.0 mm), material (steel), identification (SCLCR 2525M 09).

Relationship: Link to the cutting item in the tool assembly.

Appendix C (Informative): Implementation Guidelines

Outline the steps for implementing a reference dictionary in a software system, including:

Map EXPRESS to STEP or XML.

Verify data compliance.

Ensure interoperability with other parts of ISO 13399.

10. References

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ISO 13399-1:2006, Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model.

ISO 13399-2:2005, Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items.

ISO/TS 13399-50:2013, Cutting tool data representation and exchange — Part 50: Reference dictionary of reference systems and common concepts.

ISO/TS 13399-60:2014, Cutting tool data representation and exchange — Part 60: Reference dictionary for connection systems.

ISO 10303-11:2004, Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: EXPRESS language reference manual.

ISO 10303-21:2016, Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Plain text encoding of exchange structures.

ISO 13584-1:2001, Industrial automation systems and integration — Parts library — Part 1: Overview and basic principles.

ISO 13584-24:2003, Industrial automation systems and integration — Parts libraries — Part 24: Logical resources: Logical model for supplier libraries.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 1832:2017

Indexable inserts for cutting tools — Designation

Indexable inserts for cutting tools - identification.

1. Scope

This International Standard specifies a designation system for indexable inserts used in cutting tools for machining processes such as turning, milling, drilling, and boring. The designation system provides a standardized code to identify the shape, dimensions, tolerances, and other characteristics of indexable inserts, facilitating their identification, cataloging, and data exchange in manufacturing, design, and procurement. or uncoated, and with or without chip breakers.

The standard covers:

A structured code comprising symbols for insert shape, clearance angle, tolerance class, and other features.

Rules for constructing and interpreting designations.

Application to inserts for both rotating and non-rotating tools.

It does not cover:

Performance characteristics (eg, cutting forces, tool life).

Manufacturing processes for producing inserts.

Non-indexable inserts or tools without detachable inserts.

2. Normative References

The following documents are referenced in ISO 1832:2017 and are indispensable for its application:

ISO 513:2011 : Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation of the main groups and groups of application.

ISO 13399 (all parts) : Cutting tool data representation and exchange.

3. Terms and Definitions

For the purposes of this standard, the following terms apply:

Indexable insert : A detachable cutting component with one or more cutting edges, designed to be clamped onto a tool body and rotated or replaced when worn.

Designation : A standardized code consisting of letters and numbers that identify the characteristics of an indexable insert.

Cutting edge : The portion of the insert that removes material from the workpiece.

Chip breaker : A feature on the insert's rake face designed to control chip formation and removal.

Clearance angle : The angle between the insert's flank and the machined surface, influencing cutting efficiency and tool life.

Tolerance class : A classification defining the dimensional accuracy of the insert's seating surfaces and cutting edges.

4. Designation System

The designation system for indexable inserts consists of a code with up to 10 symbols (letters and numbers), each representing a specific characteristic of the insert. The code is structured in a fixed sequence, with mandatory and optional symbols. The system is designed to be concise, unambiguous, and compatible with digital data exchange

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(eg, ISO 13399).

4.1 Structure of the Designation Code

The designation code is divided into the following positions:

Position	Symbol	Description	Mandatory/Optional
1	Letter	Insert shape (eg, S for square, T for triangular)	Mandatory
2	Letter	Clearance angle (eg, N for 0°, C for 7°)	Mandatory
3	Letter	Tolerance class (eg, M, G)	Mandatory
4	Letter	Fixing and/or chip breaker type (eg, A, M)	Mandatory
5–6	Number	Inscribed circle diameter or characteristic dimension (mm or code)	Mandatory
7–8	Number	Thickness (mm or code)	Mandatory
9–10	Number	Corner radius (mm or code)	Mandatory
11	Letter	Cutting edge condition (eg, F for sharp, T for honed)	Optional
12	Letter	Hand of cutting (eg, R for right, L for left)	Optional

Note : Positions 11 and 12 are used only when necessary to specify additional features.

4.2 Symbol Definitions

4.2.1 Position 1: Insert Shape

The shape of the insert's top view, identified by a single letter:

A : Parallelogram (85°)

C : Rhomboid (80°)

D : Diamond (55°)

H : Hexagonal

S : Square

T : Triangular

V : Rhomboid (35°)

W : Trigon

Others : Additional shapes (eg, R for round, O for octagonal).

4.2.2 Position 2: Clearance Angle

The clearance angle of the insert's flank, identified by a single letter:

A : 5°

B : 6°

C : 7°

N : 0°

P : 11°

Others : Additional angles as defined by manufacturers.

4.2.3 Position 3: Tolerance Class

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The dimensional tolerance of the insert's seating surfaces and cutting edges:

A : ±0.005 mm (high precision)

F : ±0.013 mm

G : ±0.025 mm

M : ±0.05–0.13 mm (general purpose)

U : ±0.08–0.25 mm (roughing).

4.2.4 Position 4: Fixing and/or Chip Breaker Type

The method of fixing the insert and/or presence of a chip breaker:

A : Hole, no chip breaker

G : Hole with chip breaker

M : Hole with chip breaker on one side

N : No hole, no chip breaker

T : Hole with chip breaker on both sides.

4.2.5 Positions 5–6: Inscribed Circle Diameter or Characteristic Dimension

The diameter of the inscribed circle (for shapes like S, T) or a characteristic dimension (eg, side length for R), expressed in millimeters or as a code:

Examples :

06 : 6.35 mm

12 : 12.70 mm

25 : 25.40 mm

For round inserts (R), the actual diameter is used (eg, 12 for 12 mm).

4.2.6 Positions 7–8: Thickness

The thickness of the insert, measured from the seating surface to the top, expressed in millimeters or as a code:

Examples :

02 : 2.38 mm

04 : 4.76 mm

06 : 6.35 mm

4.2.7 Positions 9–10: Corner Radius

The radius of the insert's corner, expressed in millimeters or as a code:

Examples :

04 : 0.4 mm

08 : 0.8 mm

16 : 1.6 mm

4.2.8 Position 11: Cutting Edge Condition (Optional)

The condition of the cutting edge:

F : Sharp

T : Honed

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E : Chamfered

S : Chamfered and honed.

4.2.9 Position 12: Hand of Cutting (Optional)

The cutting hand for asymmetrical inserts:

R : Right-hand

L : Left-hand

N : Neutral (symmetrical).

4.3 Example Designations

SPMN 120408 :

S: Square shape

P: 11° clearance angle

M: General-purpose tolerance (±0.05–0.13 mm)

N: No hole, no chip breaker

12: 12.70 mm inscribed circle diameter

04: 4.76 mm thickness

08: 0.8 mm corner radius

CCMT 09T304-F :

C: Rhomboid (80°)

C: 7° clearance angle

M: General-purpose tolerance

T: Hole with chip breaker on both sides

09: 9.52 mm inscribed circle diameter

T3: 3.97 mm thickness

04: 0.4 mm corner radius

F: Sharp cutting edge

5. Rules for Designation

Sequence : Symbols must follow the specified order (positions 1–12).

Mandatory symbols : Positions 1–10 are required unless the insert is round (position 5–6 may represent actual diameter).

Optional symbols : Positions 11–12 are included only when relevant (eg, for specific edge conditions or handedness).

Coding : Numerical values use codes (eg, 12 for 12.70 mm) for consistency with international practice, but actual dimensions may be used for round inserts.

Compatibility : Designations align with ISO 13399 for data exchange and ISO 513 for material classification.

6. Application Notes

Identification : The designation uniquely identifies an insert for ordering, inventory, and tool selection.

Data exchange : The standardized code integrates with ISO 13399 for CAD, CAM, and MES systems.

Manufacturing : Ensures compatibility between inserts and tool holders (eg, per ISO 5608).

Interoperability : Facilitates communication among manufacturers, suppliers, and users.

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Traceability : Supports lifecycle management by linking inserts to material and application data (eg, ISO 513).

7. Annexes

Annex A (Normative): Symbol tables

Provides detailed tables for each position in the designation code, including:

Insert shapes (eg, S, T, C) with corresponding letters.

Clearance angles (eg, N: 0°, C: 7°) and their codes.

Tolerance classes (eg, A, M, U) with dimensional ranges.

Fixing/chip breaker types, dimensions, and optional symbols.

Annex B (Informative): Examples of designations

Lists sample designations with explanations:

TNMG 160408 : Triangular, 0° clearance, general-purpose tolerance, hole with chip breaker, 16.5 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius.

VCGT 160404-F : Rhomboid (35°), 7° clearance, general-purpose tolerance, hole with chip breaker, 16.5 mm inscribed circle, 4.76 mm thickness, 0.4 mm corner radius, sharp edge.

Annex C (Informative): Relationship with other standards

Describes integration with:

ISO 13399 (data exchange).

ISO 513 (material classification).

ISO 5608 (tool holder designations).

8. Bibliography

ISO 513:2011, Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation of the main groups and groups of application.

ISO 13399 (all parts), Cutting tool data representation and exchange.

ISO 5608:1995, Turning and copying tool holders and cartridges for indexable inserts — Designation.

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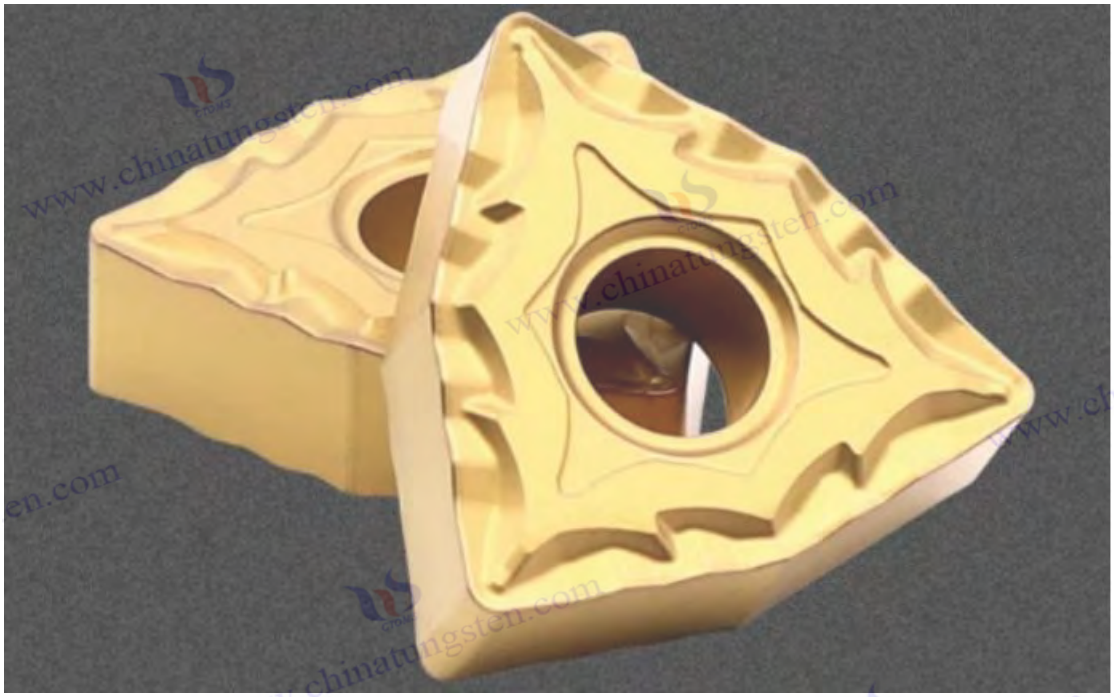
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ISO 1832:2017

Indexable inserts for cutting tools — Marking

1. Scope

This International Standard specifies a marking system for indexable inserts used in cutting tools for machining processes such as turning, milling, drilling, and boring. The marking system provides a standardized code for identifying the shape, dimensions, tolerances, and other characteristics of indexable inserts, facilitating identification, cataloging, and data exchange in manufacturing, design, and procurement. This standard applies to indexable inserts made of hard materials (e.g., carbide, ceramics, CBN, PCD) with defined cutting edges, whether or not coated, and with or without chipbreakers.

This standard covers:

A structured code containing features such as insert shape, clearance angle, tolerance grade, etc.

Rules for constructing and interpreting logos.

Inserts for rotating and non-rotating tools.

This standard does not cover:

Performance characteristics (e.g., cutting forces, tool life).

The manufacturing process of the blade.

Tools without indexable inserts or detachable inserts.

2. Normative References

The following documents are referenced in ISO 1832:2017 and are indispensable for its application:

ISO 513:2011 : Classification and use of hard cutting materials for metal cutting — Designation of principal classes and application classes.

ISO 13399 (all parts) : Cutting tool data representation and exchange.

3. Terms and Definitions

In this standard, the following terms apply:

Indexable Insert : A removable cutting component with one or more cutting edges designed to be clamped to a tool body and rotated or replaced when worn.

Identification : A standardized code consisting of letters and numbers that identifies the characteristics of an indexable insert.

Cutting Edge : The portion of the insert that removes material from the workpiece.

Chipbreaker : A feature on the rake face of an insert designed to control chip formation and removal.

Back angle : The angle between the side of the insert and the machined surface, which affects cutting efficiency and tool life.

Tolerance Grade : A classification that defines the dimensional accuracy of the insert seat and cutting edge.

4. Identification system

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The identification system for indexable inserts consists of a code consisting of up to 10 characters (alphanumeric), each representing a specific characteristic of the insert. The code is structured in a fixed sequence and contains both mandatory and optional characters. The system is designed to be concise, unambiguous, and compatible with digital data exchange (e.g., ISO 13399).

4.1 Identification code structure

The identification codes are divided into the following positions:

Location	symbol	describe	Required/Optional
1	letter	Blade shape (e.g., S for square, T for triangle)	Required
2	letter	Clearance angle (e.g., N for 0°, C for 7°)	Required
3	letter	Tolerance grade (e.g., M, G)	Required
4	letter	Fixing method and/or chipbreaker type (e.g., A, M)	Required
5–6	number	Inscribed circle diameter or characteristic size (mm or code)	Required
7–8	number	Thickness (mm or code)	Required
9–10	number	Corner radius (mm or code)	Required
11	letter	Cutting edge condition (e.g., F for sharp, T for dull)	Optional
12	letter	Cutting direction (for example, R for right, L for left)	Optional

NOTE : Positions 11 and 12 are only used when additional features need to be specified.

4.2 Symbol Definition

4.2.1 Position 1: Blade shape

The blade's top view shape, identified by a single letter:

A : Parallelogram (85°)

C : Diamond (80°)

D : Diamond (55°)

H ： Hexagon

S ： Square

T : triangle

V : Diamond (35°)

W : tricuspid

Other : Additional shapes (for example, R for circle, O for octagon).

4.2.2 Position 2: Back Corner

The clearance angle on the side of the blade, identified by a single letter:

A : 5°

B : 6°

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C : 7°

N : 0°

P : 11°

Other : Additional angles defined by the manufacturer.

4.2.3 Position 3: Tolerance Grade

Dimensional tolerances of insert seat and cutting edge:

A : ±0.005 mm (high precision)

F : ±0.013 mm

G : ±0.025 mm

M : ±0.05–0.13 mm (universal)

U : ±0.08–0.25 mm (roughing).

4.2.4 Position 4: Fixing method and/or chipbreaker type

Insert mounting method and/or presence of chipbreakers:

A : With hole, no chip breaker

G : With hole and chip breaker

M : with hole, single-sided chip breaker

N : No hole, no chip breaker

T : With hole, double-sided chip breaker.

4.2.5 Positions 5–6: Inscribed Circle Diameter or Characteristic Dimension

Inscribed circle diameter (for shapes like S, T, etc.) or characteristic dimension (e.g., side length of R), expressed in millimeters or code:

Example :

06 : 6.35 mm

12 : 12.70 mm

25 : 25.40 mm

For round inserts (R), use the actual diameter (eg 12 for 12 mm).

4.2.6 Positions 7–8: Thickness

Thickness of the insert from the seat to the top, expressed in millimeters or code:

Example :

02 : 2.38 mm

04 : 4.76 mm

06 : 6.35 mm

4.2.7 Positions 9–10: Corner Radius

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Radius of the insert corner, expressed in mm or code:

Example :

04 : 0.4 mm

08 : 0.8 mm

16 : 1.6 mm

4.2.8 Position 11: Cutting Edge Status (Optional)

Cutting edge condition:

F ： Sharp

T : passivation

E ： Chamfer

S : Chamfered and passivated.

4.2.9 Position 12: Cutting direction (optional)

Cutting direction of asymmetric inserts:

R ： Right

L ： Left

N : Neutral (symmetrical).

4.3 Example Logo

SPMN 120408 :

S: Square

P: 11° back angle

M: General tolerance (±0.05–0.13 mm)

N: No hole, no chip breaker

12: 12.70 mm inscribed circle diameter

04: 4.76 mm thickness

08: 0.8 mm corner radius

CCMT 09T304-F :

C: Diamond (80°)

C: 7° relief angle

M: General tolerance

T: with hole, double-sided chip breaker

09: 9.52 mm inscribed circle diameter

T3: 3.97 mm thickness

04: 0.4 mm corner radius

F: Sharp cutting edge

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5. Identification Rules

Order : Symbols must follow a specified order (positions 1–12).

Required Symbol : Positions 1–10 are required unless the insert is round (positions 5–6 may indicate actual diameter).

Optional symbols : Positions 11–12 are included only when relevant (e.g., to specify a particular edge condition or orientation).

Coding : Values are coded (e.g. 12 for 12.70 mm) to conform to international conventions, but circular inserts may use the actual size.

Compatibility : Identification is aligned with ISO 13399 (data exchange) and ISO 513 (material classification).

6. Application Description

Identification : The marking uniquely identifies the insert for ordering, inventory, and tool selection purposes.

Data exchange : Standardized codes integrated with ISO 13399 for CAD, CAM and MES systems.

Manufacturing : Ensure insert-holder compatibility (e.g. according to ISO 5608).

Interoperability : Facilitates communication between manufacturers, suppliers, and users.

Traceability : Supports lifecycle management by linking inserts with material and application data (e.g., ISO 513).

7. Appendix

Appendix A (Normative): Symbol Table

Provide a detailed table identifying each location of the code, including:

The blade shape (e.g., S, T, C) and its corresponding letter.

Relief angle (e.g., N: 0°, C: 7°) and its code.

Tolerance grades (e.g. A, M, U) and their size ranges.

Fixed/chipbreaker type, size and optional symbols.

Appendix B (Informative): Labeling Examples

List example identifiers and their explanations:

TNMG 160408 : Triangular, 0° relief angle, general tolerance, hole with chip breaker, 16.5 mm inscribed circle, 4.76 mm thickness, 0.8 mm corner radius.

VCGT 160404-F : Diamond (35°), 7° relief angle, general tolerance, hole with chip breaker, 16.5 mm inscribed circle, 4.76 mm thickness, 0.4 mm corner radius, sharp edge.

Appendix C (Informative): Relationship with other standards

Describes integration with the following standards:

ISO 13399 (data exchange).

ISO 513 (material classification).

ISO 5608 (tool handle marking).

8. References

ISO 513:2011, Classification and use of hard cutting materials for metal cutting — Designation of principal classes

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and application classes.

ISO 13399 (all parts), Cutting tool data representation and exchange.

ISO 5608:1995, Turning and profiling toolholders and indexable insert holders — Designation.

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ISO 3369:2006

Density determination of cemented carbide

1. Scope

This international standard specifies a general method for determining the density of cemented carbides. It is applicable to sintered materials composed mainly of tungsten carbide (WC) (>85% ± 1%) and a metallic binder phase (e.g., Co, 6% to 15% ± 1%). The density range is typically 14.0 to 15.5 g/cm³ ± 0.1 g/ cm³ . This standard applies to:

Industrial products: such as cutting tools (lifespan > 1000 h ± 100 h), mining drill bits (impact resistance > 2 GPa ± 0.1 GPa) and wear-resistant parts (wear rate < 0.05 mm³ / N · m ± 0.01 mm³ / N · m).

Laboratory samples: such as recycled powder (particle size 15 μm ± 0.1 μm) or new cemented carbide (such as high entropy alloy, hardness HV> 2000 ± 30).

This method uses the Archimedean principle (buoyancy method) and has an accuracy of ±0.01 g/cm³ . It is applicable to uncoated cemented carbides or those with coatings less than 10 μm ± 1 μm thick. It is not suitable for porous materials (porosity > 0.1% ± 0.01%) or non-sintered powders.

Background:

Density is a key quality indicator for cemented carbide (14.5-15.0 g/cm³ ± 0.1 g/cm³) , reflecting sintering densification (>99.9% ± 0.1%) and compositional uniformity (Co deviation <0.5% ± 0.1%). For example, aerospace cutting tools require a density of 14.8 g/cm³ ± 0.1 g/ cm³ to ensure a hardness of HV 1650 ± 30 and a toughness of $K_{11}c$ > 10 MPa·m^{1} / ^{2} ± 0.5 . Deviations may indicate porosity (>0.01% ± 0.001%) or inclusions (>0.1% ± 0.01%), affecting cutting performance (speeds >200 m/min ± 10 m/min).

2. Terms and Definitions

For the purposes of this standard, the following terms and definitions apply:

Cemented Carbide: A composite material formed by sintering WC as the matrix (>85%±1%) and bonding phases such as Co and Ni (6%15%±1%), with a hardness of HV 16002000±30.

Density: Mass per unit volume, expressed in g/cm³ , with an accuracy of ±0.01 g/cm³ , and expressed as ρ.

Archimedes' Principle: The buoyant force on an object in a liquid is equal to the weight of the liquid it displaces, which is used to calculate density.

Dry mass: The mass of the sample after drying in air (m_dry, ±0.0001 g).

Immersed Mass: The mass of a sample when completely immersed in a liquid (usually water) (m_wet, ±0.0001 g).

Porosity: The volume fraction of pores inside a material (<0.01%±0.001%), which affects density determination.

English explanation:

" Density" reflects the density of the cemented carbide. For example, the theoretical density of WC10Co is approximately 14.8 g/cm³ ± 0.1 g/cm³ . Deviations may be due to insufficient sintering (densification <99.9% ± 0.1%). Archimedes' principle accurately measures volume (± 0.001 cm³) using buoyancy (> 0.0001 g) .

3. Principle

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This method is based on the Archimedean principle. The density is determined by measuring the dry weight of the cemented carbide sample in air (m_dry) and the weight of the sample immersed in liquid (distilled water, density 1.000 g/cm³ ± 0.001 g/cm³) (m_wet). The volume of the displaced liquid is calculated. The formula is as follows:

$$\rho = \frac{m_{\text{dry}}}{\frac{m_{\text{dry}} - m_{\text{wet}}}{\rho_{\text{water}}}}$$

in:

- m_{dry}：干重（g，±0.0001 g）。
- m_{wet}：浸重（g，±0.0001 g）。
- ρ_{water}：水密度（g/cm³，20°C时为1.000 g/cm³±0.001 g/cm³）。
- ρ：样品密度（g/cm³，±0.01 g/cm³）。

Mechanism Analysis:

The high density of cemented carbide (>14.0 g/cm³ ± 0.1 g/cm³) stems from the composite composition of WC (density 15.6 g/cm³ ± 0.1 g/cm³) and Co (density 8.9 g/cm³ ± 0.1 g/cm³) . The buoyancy method eliminates the influence of porosity (<0.01% ± 0.001%) through volume measurement (accuracy ±0.001 cm³) , ensuring reliable results. For example, a tool manufacturer measured the density of WC6Co at 14.9 g/cm³ ± 0.01 g/cm³ , verifying the sintering quality (porosity <0.005% ± 0.001%).

4. Apparatus and Materials

4.1 Equipment

Analytical Balance:

Accuracy ±0.0001 g, range >50 g, with windshield (wind speed <0.1 m/s ±0.01 m/s).

Application: Measure dry and submerged weights with an error of <0.0001 g.

Density Measurement Kit:

Includes a suspension device (wire diameter <0.1 mm ± 0.01 mm), a liquid container (volume >100 cm³ ± 1 cm³) , and a sample holder (diameter >10 mm ± 1 mm).

Purpose: Ensure that the sample is completely immersed and free of bubbles (<0.1 mm ± 0.01 mm).

Thermostatic Water Bath:

Temperature controlled at 20°C ± 0.1°C, accuracy ± 0.05°C.

Purpose: Maintains a stable water density (1.000 g/cm³ ± 0.001 g/cm³) .

Vacuum Drying Oven:

Temperature 100°C±1°C, Pressure <10 Pa±1 Pa.

Purpose: Remove moisture from samples (<0.001%±0.0001%).

Ultrasonic Cleaner:

Frequency 40 kHz ± 1 kHz, Power > 100 W ± 10 W.

Application: Removes surface oil (< 0.001 g ± 0.0001 g).

4.2 Materials

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Distilled Water:

Conforms to ISO 3696:1987 standard for primary water, with a conductivity of <1 μS/cm ± 0.1 μS/cm and a density of 1.000 g/cm³ ± 0.001 g/cm³ at 20°C.

Use: As an immersion liquid to eliminate the effects of impurities (<0.001% ± 0.0001%).

Ethanol:

Purity >99.5% ± 0.1%, used for cleaning samples.

Application: Removal of grease (<0.001 g ± 0.0001 g).

Lint-Free Cloth:

Fiber residue <0.0001 g ± 0.00001 g.

Purpose: Wipe samples to avoid contamination.

Application:

A factory used an analytical balance (accuracy ±0.0001 g) and a constant temperature water bath (20°C ±0.1°C) to measure the density of WC8Co cutting tools and obtained a value of 14.7 g/cm³ ± 0.01 g /cm³ . This confirmed the absence of porosity (<0.01% ± 0.001%) and met aviation standards (14.5-15.0 g/cm³ ± 0.1 g/cm³) .

5. Sample Preparation

5.1 Sample Requirements

Dimensions: Mass >1 g ± 0.1 g, surface area >1 cm² ± 0.1 cm² , to avoid errors (>0.01 g/cm³) caused by tiny samples (volume <0.1 cm³ ± 0.01 cm³) .

Surface: free of cracks (<0.01 mm ± 0.001 mm), pores (<0.01% ± 0.001%), or coatings (thickness <10 μm ± 1 μm).

Quantity: At least 3 samples, representing the same batch (sintering condition deviation <1%±0.1%).

5.2 Cleaning

The samples were ultrasonically cleaned in ethanol (40 kHz ± 1 kHz, 5 min ± 0.1 min) to remove oil contaminants (<0.001 g ± 0.0001 g).

Rinse with distilled water (flow rate >1 L/min±0.1 L/min, 10 s±1 s) to remove residual ethanol (<0.0001 g±0.00001 g).

Wipe with a dust-free cloth and check that there is no residue on the surface (visible to the naked eye <0.01 mm ± 0.001 mm).

5.3 Drying

Place in a vacuum drying oven (100°C±1°C, <10 Pa±1 Pa) and dry for 30 min±1 min.

Cool to 20°C ± 1°C (constant temperature chamber, humidity < 60% ± 5%), ensuring that the moisture content is < 0.001% ± 0.0001%.

The dry weight (m_dry, ±0.0001 g) was measured three times with a deviation of <0.0001 g.

Example:

A laboratory cleans a WC10Co sample (mass 5 g ± 0.1 g) and ultrasonically cleans it for 5 min ± 0.1 min. The dry

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weight after drying is 5.1234 g ± 0.0001 g, with a deviation of < 0.00005 g, which meets the test requirements.

6. Test Procedure

6.1 Environmental conditions

Temperature: 20°C ± 1°C, avoid thermal expansion (<0.001 cm^3 ± 0.0001 cm^3) .

Humidity: 40%60%±5%, prevent moisture absorption (<0.0001 g±0.00001 g).

Airflow: Wind speed <0.1 m/s±0.01 m/s, dust cover protects the balance.

6.2 Equipment Calibration

Balance calibration: Use standard weights (1 g ± 0.00001 g, 10 g ± 0.00001 g), with an error of < 0.0001 g.

Water temperature calibration: Confirm 20°C ± 0.1°C with a high-precision thermometer (± 0.05°C), water density 1.000 g/cm^3 ± 0.001 g/ cm^3 .

Suspension device: Check the wire (mass <0.0001 g ± 0.00001 g) and ensure there is no buoyancy effect (<0.00001 g).

6.3 Dry weight measurement

Place the sample on a balance and record the dry weight (m_dry, ±0.0001 g).

Repeat 3 times and take the average value with a deviation of <0.0001 g.

Verify that the sample is free of moisture (<0.001% ± 0.0001%) or dust (<0.0001 g ± 0.00001 g).

6.4 Immersion weight measurement

Fill the container with liquid (distilled water, >100 cm^3 ± 1 cm^3) , removing air bubbles (<0.1 mm±0.01 mm).

The sample was suspended (wire diameter <0.1 mm ± 0.01 mm) and completely immersed in water (depth >10 mm ± 1 mm).

Wait for stabilization (>10 s ± 1 s) and record the immersion weight (m_wet, ± 0.0001 g).

Repeat 3 times and take the average value with a deviation of <0.0001 g.

Check that there are no bubbles attached (<0.1 mm ± 0.01 mm). If not, remove them with a fine needle (diameter <0.5 mm ± 0.1 mm).

6.5 Temperature Recording

Record the water temperature (20°C ± 0.1°C). If the deviation is > 0.1°C, correct the water density (see Appendix A).

Example:

A factory measures a WC6Co sample with a dry weight of 10.2345 g ± 0.0001 g, an immersion weight of 9.5678 g ± 0.0001 g, and a water temperature of 20.1°C ± 0.1°C. The calculated density is 14.85 g/cm^3 ± 0.01 g/ cm^3 .

7. Calculation

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7.1 Density Calculation

Calculate the density using the following formula:

$$\rho = \frac{m_{dry}}{\frac{m_{dry} - m_{wet}}{\rho_{water}}}$$

- m_{dry}：干重平均值（g，±0.0001 g）。
- m_{wet}：浸重平均值（g，±0.0001 g）。
- ρ_{water}：20°C时为1.000 g/cm³±0.001 g/cm³，若温度偏差，参考附录A。
- ρ：保留2位小数（±0.01 g/cm³）。

7.2 Error Analysis

Measurement error: balance (±0.0001 g), water density (±0.001 g/cm³) .

Total error: density error <±0.01 g/cm³ , repeatability deviation <0.005 g/ cm³ .

Outliers: If the density deviation is >0.02 g/cm³ , check for air bubbles (>0.1 mm ± 0.01 mm) or sample defects (porosity >0.01% ± 0.001%).

Example:

Sample dry weight is 5.1234 g ± 0.0001 g, immersed weight is 4.7890 g ± 0.0001 g, water density is 1.000 g/cm³ ± 0.001 g/ cm³ , calculation:

$$\rho = \frac{5.1234}{\frac{5.1234 - 4.7890}{1.000}} = 14.82\,g/cm^3 \pm 0.01\,g/cm^3$$

Repeated 3 times, the deviation is <0.005 g/cm³ , which meets the standard.

8. Test Report

The test report should include the following:

Standard number: ISO 3369:2006.

Sample information: batch, size (±0.1 mm), mass (±0.1 g), composition (e.g. WC10Co).

Test conditions: temperature (20°C ± 0.1°C), humidity (40% - 60% ± 5%), water density (1.000 g/cm³ ± 0.001 g/cm³) .

Equipment information: balance model (accuracy ±0.0001 g), water bath model (±0.05°C).

Measurement data: dry weight (m_dry, ±0.0001 g), wet weight (m_wet, ±0.0001 g), number of repetitions (≥3).

Results: Density (g/cm³ , ±0.01 g/cm³) , mean value and standard deviation (<0.005 g/cm³) .

Note: Abnormal conditions (such as bubbles, cracks) or reasons for deviation (such as porosity > 0.01% ± 0.001%).

Tester: Name, Date (Format: YYYYMMDD).

Laboratory: name, address, accreditation (e.g. ISO 17025).

Example:

A tool manufacturer reports: WC8Co sample (5 g ± 0.1 g), dry weight 5.2345 g ± 0.0001 g, immersed weight 4.8765 g ± 0.0001 g, water temperature 20.0°C ± 0.1°C, density 14.79 g/cm³ ± 0.01 g/cm³ , deviation 0.003 g/cm³ , in line with aviation standards (14.515.0 g/cm³ ± 0.1 g/cm³) .

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9. Precision and Uncertainty

9.1 Repeatability

For the same operator, equipment, and sample, the deviation of three measurements is <0.005 g/cm³ . Example : WC10Co sample measured 14.82, 14.83, 14.82 g/cm³ ± 0.01 g/cm³ , with a deviation of 0.002 g/ cm³ .

9.2 Reproducibility

The deviation between different laboratories and operators is <0.01 g/cm³ . Example : Two laboratories measured WC6Co, and the results were 14.85±0.01 g/cm³ and 14.86±0.01 g/cm³ respectively , with a deviation of 0.006 g/ cm³ .

9.3 Uncertainty

Balance: ±0.0001 g, contribution <0.002 g/ cm³ .
Water density: ±0.001 g/cm³ , contribution <0.003 g/ cm³ .
Temperature: ±0.1°C, contribution <0.001 g/ cm³ .
Total uncertainty: ±0.01 g/cm³ (95% confidence level).
Significance: High precision (±0.01 g/ cm³) ensures reliable density, excluding porosity (>0.01%±0.001%) or composition deviations (Co>0.5%±0.1%).

10. Annexes

Annex A (Normative) Water density and temperature correction
Water density changes with temperature, refer to the following data:
19.0°C: 1.001 g/cm³ ± 0.001 g/ cm³
19.5°C: 1.0005 g/cm³ ± 0.001 g/ cm³
20.0°C: 1.000 g/cm³ ± 0.001 g/ cm³
20.5°C: 0.9995 g/cm³ ± 0.001 g/ cm³
21.0°C: 0.999 g/cm³ ± 0.001 g/ cm³
Formula: If the water temperature is not 20°C, correct the density:

$$\rho_{\text{corrected}} = \rho \cdot \frac{1.000}{\rho_{\text{water}}}$$

Example: Water temperature is 20.5°C, density is measured to be 14.80 g/cm³ ± 0.01 g/ cm³ , correction:

$$\rho_{\text{corrected}} = 14.80 \cdot \frac{1.000}{0.9995} = 14.81\,\text{g/cm}^3 \pm 0.01\,\text{g/cm}^3$$

Annex B (Informative) Typical carbide density
WC6Co: 14.9 g/cm³ ± 0.1 g/cm³ , tool (cutting speed 200 m/min±10 m/min).

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WC10Co: 14.7 g/cm³ ± 0.1 g/ cm³ , mining drill bits (impact resistance >2 GPa±0.1 GPa).

WC15Co: 14.4 g/cm³ ± 0.1 g/ cm³ , wear-resistant parts (wear rate <0.05 mm³ / N · m ± 0.01 mm³ /N · m).

Annex C (Informative) Common Problems and Solutions

Air bubble adhesion: Check the sample surface (<0.1 mm ± 0.01 mm), remove it with a fine needle, and repeat the measurement.

Sample crack: Replace the sample (crack <0.01 mm ± 0.001 mm) to avoid volume error (>0.001 cm³) .

Water temperature deviation: controlled at 20°C ± 0.1°C, or corrected using Appendix A.

Balance drift: Calibrated (weight ±0.00001 g), ensuring error <0.0001 g.

11. Application and Significance

This standard provides a unified method for determining the density of cemented carbide (accuracy ±0.01 g/cm³) , ensuring consistent performance (hardness HV>1600±30). Main applications include:

Quality control: Verify sintering quality (densification >99.9%±0.1%), e.g. density 14.8 g/cm³ ± 0.1 g/cm³ for aviation tools , service life > 1000 h±100 h.

Recycling Verification: Confirms recycled powder density (14.515.0 g/cm³ ± 0.1 g/cm³) , supporting a circular economy (recycling rate >95% ± 2%).

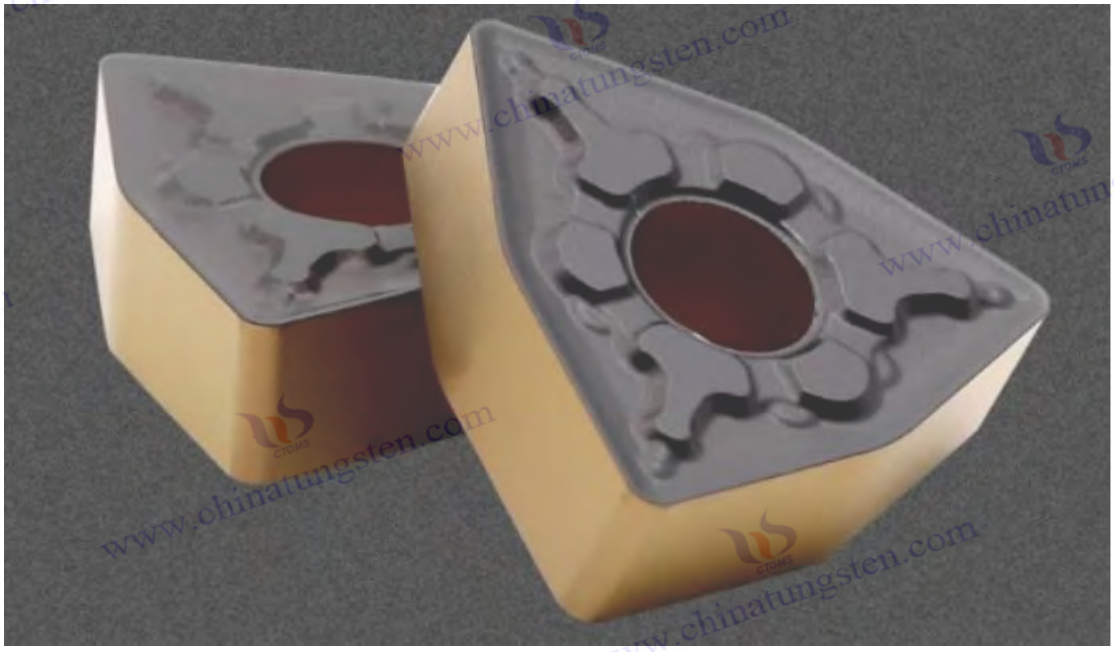
Research and Development: Evaluate new cemented carbides (e.g. TiB_2 based , density >14.0 g/cm³ ± 0.1 g/cm³) and drive innovation (hardness HV >2000±30).

Example:

A mining equipment manufacturer measured the density of a WC10Co drill bit to be 14.7 g/cm³ ± 0.01 g/cm³ , confirming it was free of porosity (<0.005%±0.001%), with an impact resistance of >2.5 GPa±0.1 GPa and a service life of >2000 h±100 h.

Sustainability:

High-precision density measurement reduces scrap (>10% ± 2%) and energy consumption (<400 kWh/t ± 50 kWh/t), meeting green manufacturing targets (CO_2 < 0.5 t CO_2 / t ± 0.1 t CO_2 / t).



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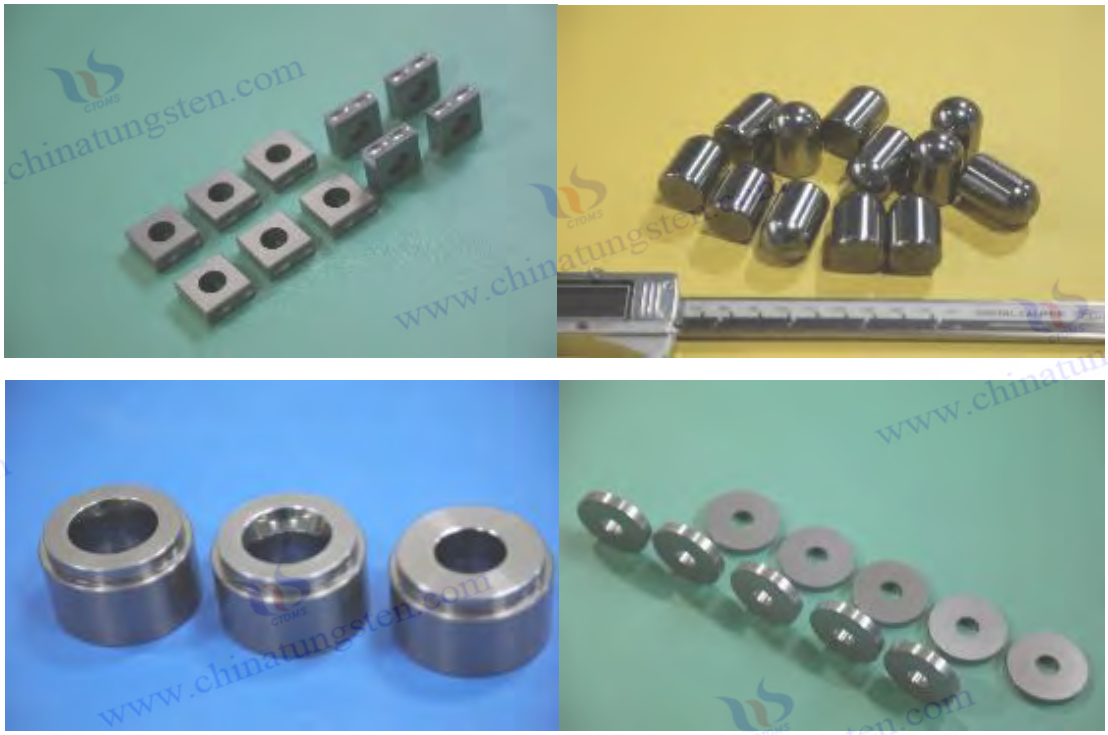
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ISO 3327:2009

Hardmetals—Determination of transverse rupture strength

Cemented carbide — Determination of transverse rupture strength

1. Scope

This international standard specifies a general method for determining the transverse rupture strength (TRS) of cemented carbides. It is applicable to sintered materials composed primarily of tungsten carbide (WC) (>85% ± 1%) and a metallic binder phase (e.g., Co, 6% to 15% ± 1%). The TRS range is typically 1.5-4.0 GPa ± 0.1 GPa. This standard uses a three-point bend test and is applicable to:

Industrial products: cutting tools (cutting speed > 200 m/min ± 10 m/min, life > 1000 h ± 100 h), mining drill bits (impact resistance > 2 GPa ± 0.1 GPa), wear-resistant parts (wear rate < 0.05 mm^3 / N · m ± 0.01 mm^3 / N · m).

Laboratory samples: recycled powder (particle size 15 μm ± 0.1 μm), new cemented carbide (such as high entropy alloy, hardness HV> 2000 ± 30).

This method is applicable to cemented carbides without significant plastic deformation (plastic strain <0.1% ± 0.01%). If the sample undergoes significant plastic deformation before fracture (>0.1% ± 0.01%), the result is for comparison only and not an absolute strength value. This standard is not applicable to unsintered powders, materials with a porosity >0.1% ± 0.01%, or micromechanical testing (sample size <5 mm ± 0.1 mm). The test error is <2% ± 0.2%.

Background:

Transverse rupture strength (TRS) is a critical mechanical property of cemented carbide (>2 GPa ± 0.1 GPa), reflecting the material's resistance to flexural fracture and closely related to toughness (K_{1c} > 10 $MPa \cdot m^{1/2}$ ± 0.5) and impact resistance (>2 GPa ± 0.1 GPa). For example, mining drill bits require a TRS > 2.5 GPa ± 0.1 GPa to withstand high-frequency impacts (> 10 Hz ± 1 Hz) and a lifespan > 2000 h ± 100 h. TRS deviations can result from grain heterogeneity (> 1 μm ± 0.1 μm), porosity (> 0.01% ± 0.001%), or fluctuations in Co content (> 0.5% ± 0.1%), impacting performance (reducing lifespan by > 20% ± 5%).

Application scenario:

A mining equipment manufacturer tested a WC10Co drill bit with a TRS of 2.8 GPa ± 0.1 GPa, meeting impact resistance requirements (> 2.5 GPa ± 0.1 GPa) and ensuring drilling efficiency (> 1 m/h ± 0.1 m/h).

2. Terms and Definitions

For the purposes of this standard, the following terms and definitions apply:

Cemented Carbide: A composite material with WC as the matrix (>85%±1%) and sintered through bonding phases such as Co and Ni (6%15%±1%), with a hardness of HV 16002000±30.

Transverse Rupture Strength (TRS): The maximum stress per unit area when the sample breaks in a three-point bending test, measured in GPa (or MPa), with an error of <2%±0.2%.

Three-point bending test: The breaking strength is determined by applying a force (±0.01 kN) through two support points (span >20 mm±0.1 mm) and one loading point.

Fracture Load: The maximum force at which the sample breaks (kN, ±0.01 kN).

Porosity: The volume fraction of pores inside the material (<0.01%±0.001%), which affects TRS determination.

Plastic deformation: Irreversible deformation before fracture (strain > 0.1% ± 0.01%), which may reduce the

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reliability of TRS results.

English explanation:

" Transverse rupture strength" is the ability of a material to withstand fracture, measured in three-point bending (e.g., TRS 2.5 GPa ± 0.1 GPa). The high TRS of cemented carbide is due to the synergistic effect of the WC grains (<1 μm ± 0.1 μm) and the Co binder phase (bonding strength >1 J/m² ± 0.1 J /m²) .

3. Principle

This method is based on the principle of a three-point bending test. A rectangular carbide specimen (dimensions 40 × 5 × 5 mm ± 0.1 mm) is placed between two supports (span 30 mm ± 0.1 mm). A constant force (0.5 mm/min ± 0.01 mm/min) is applied through the central loading point until the specimen breaks (strain < 0.1% ± 0.01%). The fracture load is recorded (± 0.01 kN), and the transverse rupture strength is calculated according to the following formula:

$$\sigma = \frac{3FL}{2bh^2}$$

in:

σσ: transverse rupture strength (GPa or MPa, error <2%±0.2%).

FF: breaking load (N, ±10 N).

LL: support point span (mm, 30 mm ± 0.1 mm).

bb: sample width (mm, 5 mm ± 0.01 mm).

hh: sample thickness (mm, 5 mm ± 0.01 mm).

Mechanistic Analysis:

The high TRS (>2 GPa ± 0.1 GPa) of cemented carbide is attributed to the high compressive strength of WC (>10 GPa ± 0.1 GPa) and the plastic buffering of Co (strain >0.1% ± 0.01%). Fracture typically occurs along grain boundaries (<1 μm ± 0.1 μm) or pores (<0.01% ± 0.001%). The TRS reflects grain uniformity (deviation <0.05% ± 0.01%) and sintering quality (densification >99.9% ± 0.1%). For example, a WC8Co sample has a TRS of 2.7 GPa ± 0.1 GPa and a fracture load of 1.5 kN ± 0.01 kN, indicating excellent impact resistance (>2 GPa ± 0.1 GPa).

Application:

A tool manufacturer tested WC6Co inserts, achieving a TRS of 3.0 GPa ± 0.1 GPa and a fracture load of 1.6 kN ± 0.01 kN. The toughness, K_{IC}, was confirmed to be > 11 $MPa \cdot m^{1/2}$ ± 0.5 , making it suitable for aerospace machining (cutting speed 250 m/min ± 10 m/min).

4. Apparatus and Materials

4.1 Equipment

Universal Testing Machine:

Load range: 0.10 kN ± 0.01 kN, accuracy ± 0.1%.

Loading rate: 0.5 mm/min±0.01 mm/min.

Purpose: To apply breaking load (>1 kN±0.01 kN).

ThreePoint Bending Fixture:

Support roller diameter: 5 mm ± 0.1 mm, span 30 mm ± 0.1 mm.

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Loading roller diameter: 5 mm ± 0.1 mm, hardness HRC> 60 ± 1.

Purpose: To ensure uniform loading with an error of <0.1 mm.

Micrometer:

Accuracy ±0.001 mm, measuring range >50 mm.

Application: To measure sample size (±0.01 mm).

Polishing Machine:

Rotation speed: 100500 rpm ± 10 rpm, diamond abrasive (particle size: 1 μm ± 0.1 μm).

Application: To prepare sample surface (Ra<0.1 μm±0.01 μm).

Thermostatic Chamber :

Temperature 20°C±1°C, humidity 40%60%±5%.

Purpose: To maintain a stable test environment and avoid thermal expansion (<0.001 mm ± 0.0001 mm).

4.2 Materials

Polishing Agent:

Diamond suspension, particle size 1 μm±0.1 μm, purity >99.9%±0.1%.

Application: Polishing samples (Ra<0.1 μm±0.01 μm).

Ethanol:

Purity>99.5%±0.1%, used for cleaning samples.

Application: Removal of oil stains (<0.001 g ± 0.0001 g).

Lint-Free Cloth:

Fiber residue <0.0001 g ± 0.00001 g.

Purpose: To wipe samples to avoid contamination.

Application:

A drill bit manufacturer used a universal testing machine (accuracy ±0.1%) and a three-point bend fixture (span 30 mm ±0.1 mm) to test WC10Co. The results showed a TRS of 2.8 GPa ±0.1 GPa and a breaking load of 1.55 kN ±0.01 kN, meeting mining standards (TRS > 2.5 GPa ±0.1 GPa).

5. Sample Preparation

5.1 Sample Requirements

Dimensions: Rectangular specimen, recommended 40×5×5 mm±0.1 mm, length>35 mm±0.1 mm, width and thickness deviation<0.01 mm.

Surface: free of cracks (<0.01 mm ± 0.001 mm), pores (<0.01% ± 0.001%), or coatings (thickness <10 μm ± 1 μm).

Quantity: At least 5 samples, representing the same batch (sintering condition deviation <1%±0.1%).

Edge: Chamfer radius 0.10.2 mm ± 0.01 mm, avoid stress concentration (> 0.1 GPa ± 0.01 GPa).

5.2 Polishing

Use a polishing machine (rotation speed 300 rpm ± 10 rpm) and diamond abrasive (1 μm ± 0.1 μm) to polish the tensile surface (Ra < 0.1 μm ± 0.01 μm).

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Check the surface (magnifying glass, 10× ± 1×) to ensure there are no scratches (<0.01 mm ± 0.001 mm) or residues (<0.001 g ± 0.0001 g).

5.3 Cleaning

Immerse in ethanol (>99.5%±0.1%) and ultrasonically clean (40 kHz±1 kHz, 5 min±0.1 min) to remove oil stains (<0.001 g±0.0001 g).

Wipe with a dust-free cloth and check that there is no residue on the surface (visible to the naked eye <0.01 mm ± 0.001 mm).

5.4 Dimensional measurement

The width (b) and thickness (h) of the sample were measured using a micrometer (±0.001 mm), and 3 points were measured for each dimension, and the average value was taken (deviation <0.01 mm).

Record the length (>35 mm ± 0.1 mm) and ensure the span is 30 mm ± 0.1 mm.

Example:

A laboratory prepares a WC8Co sample (40×5.02×5.01 mm±0.01 mm), with polished Ra<0.1 μm±0.01 μm, no cracks after cleaning (<0.01 mm±0.001 mm), and dimensional deviation<0.005 mm, meeting the test requirements.

6. Test Procedure

6.1 Environmental conditions

Temperature: 20°C ± 1°C, avoid thermal expansion (<0.001 mm ± 0.0001 mm).

Humidity: 40%60%±5%, prevent moisture absorption (<0.0001 g±0.00001 g).

Vibration: Acceleration <0.01 m/ s² ± 0.001 m/ s² , ensuring fixture stability (<0.1 mm±0.01 mm).

6.2 Equipment Calibration

Testing machine calibration: Use a standard force sensor (±0.01 kN), with an error of <0.1%.

Fixture calibration: Check the support roller and loading roller (diameter 5 mm ± 0.1 mm), span 30 mm ± 0.1 mm, parallelism < 0.01 mm.

Loading rate: set to 0.5 mm/min±0.01 mm/min, verification deviation <0.01 mm/min.

6.3 Sample Installation

Place the sample in the fixture with the polished surface (Ra < 0.1 μm ± 0.01 μm) facing down and centered (deviation < 0.1 mm).

Ensure that the support rollers are in even contact (force <0.01 N ± 0.001 N) and the loading rollers are aligned to the center (<0.1 mm ± 0.01 mm).

6.4 Loading

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Load was applied at 0.5 mm/min ± 0.01 mm/min, and the force (± 0.01 kN) and displacement (± 0.01 mm) were recorded.

Continue loading until the sample breaks (<0.1 s ± 0.01 s) and record the breaking load (F, ± 0.01 kN).

Inspect the fracture surface (magnifying glass, 10× ± 1×) to confirm that there are no abnormalities (e.g., porosity > 0.01% ± 0.001%).

6.5 Repeated testing

For each batch, five specimens were tested and the fracture load (±0.01 kN) and fracture characteristics (brittle or slightly ductile, <0.1% ± 0.01%) were recorded.

Example:

A factory tests a WC10Co sample (40×5×5 mm±0.01 mm), with a breaking load of 1.55 kN±0.01 kN and a span of 30 mm±0.1 mm. The calculated TRS is 2.79 GPa±0.1 GPa, repeated 5 times, with a deviation of <0.05 GPa.

7. Calculation

7.1 Transverse rupture strength

Calculate TRS using the following formula:

$$\sigma = \frac{3FL}{2bh^2}$$

σσ: TRS (GPa or MPa, retain 2 decimal places, ±0.1 GPa).

FF: breaking load (N, ±10 N).

LL: span (mm, 30 mm ± 0.1 mm).

bb: width (mm, ±0.01 mm).

hh: thickness (mm, ±0.01 mm).

7.2 Mean and Deviation

Calculate the TRS of the five samples in a unified unit (GPa or MPa).

The mean value (±0.1 GPa) was taken and the standard deviation (<0.05 GPa) was calculated.

If any TRS deviation is >0.2 GPa, check for sample defects (porosity >0.01% ± 0.001%) or fixture deflection (>0.1 mm ± 0.01 mm).

Example:

Sample size 40×5.02×5.01 mm±0.01 mm, breaking load 1550 N±10 N, span 30 mm±0.1 mm, calculation:

$$\sigma = \frac{3 \cdot 1550 \cdot 30}{2 \cdot 5.02 \cdot 5.01^2} = 2790\,\text{MPa} = 2.79\,\text{GPa} \pm 0.1\,\text{GPa}$$

5 tests: 2.78, 2.79, 2.80, 2.77, 2.81 GPa, average 2.79 GPa±0.1 GPa, standard deviation 0.015 GPa, which meets the standard.

8. Test Report

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The test report should include the following:

Standard number: ISO 3327:2009.

Sample information: batch, size (±0.01 mm), composition (e.g. WC10Co), quantity (≥5).

Test conditions: temperature (20°C±1°C), humidity (40%60%±5%), loading rate (0.5 mm/min±0.01 mm/min).

Equipment information: testing machine model (accuracy ±0.1%), fixture span (30 mm ±0.1 mm).

Measurement data: breaking load (±0.01 kN), sample size (±0.01 mm), TRS (±0.1 GPa).

Results: Mean TRS (GPa or MPa, ±0.1 GPa), standard deviation (<0.05 GPa).

Note: Abnormal conditions (such as plastic deformation>0.1%±0.01%, porosity>0.01%±0.001%).

Tester: Name, Date (Format: YYYYMMDD).

Laboratory: name, address, accreditation (e.g. ISO 17025).

Example:

A drill bit factory reports: WC8Co samples (40×5×5 mm±0.01 mm, 5 pieces), breaking load 1.501.60 kN±0.01 kN, temperature 20.1°C±1°C, TRS 2.752.85 GPa, average 2.80 GPa±0.1 GPa, deviation 0.02 GPa, meeting mining standards (TRS>2.5 GPa±0.1 GPa).

9. Precision and Uncertainty

9.1 Repeatability

For the same operator, equipment, and batch, the deviation of 5 tests is <0.05 GPa.

Example: WC10Co sample, TRS 2.782.81 GPa, deviation 0.015 GPa.

9.2 Reproducibility

The deviation between different laboratories and operators is <0.1 GPa.

Example: Two laboratories measured WC6Co, and the results were 2.80±0.1 GPa and 2.85±0.1 GPa respectively, with a deviation of 0.05 GPa.

9.3 Uncertainty

Load: ±10 N, contribution <0.02 GPa.

Dimensions: ±0.01 mm, contribution <0.03 GPa.

Span: ±0.1 mm, contribution <0.01 GPa.

Total uncertainty: ±0.1 GPa (95% confidence level).

Significance: High accuracy (±0.1 GPa) ensures reliable TRS, excluding the influence of porosity (>0.01%±0.001%) or grain deviation (>0.05%±0.01%).

10. Annexes

Annex A (Normative) Sample size and fixture requirements

Standard size: 40×5×5 mm±0.1 mm, span 30 mm±0.1 mm.

Non-standard size: Length > 25 mm ± 0.1 mm, the span is adjusted to 0.75 ± 0.01 of the length, the formula remains

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unchanged.

Fixture: Support roller and loading roller hardness HRC>60±1, surface roughness Ra<0.1 μm±0.01 μm.

Annex B (Informative) Typical carbide TRS

WC6Co: 3.0 GPa ± 0.1 GPa, tool (cutting speed 250 m/min ± 10 m/min).

WC10Co: 2.7 GPa±0.1 GPa, mining drill bits (impact resistance>2.5 GPa±0.1 GPa).

WC15Co: 2.2 GPa ± 0.1 GPa, wear-resistant parts (wear rate < 0.05 mm^3 / N · m ± 0.01 mm^3 / N · m).

Annex C (Informative) Common Problems and Solutions

Plastic deformation: If the strain is >0.1%±0.01%, mark the result as a comparative value and check the Co content (>15%±1%).

Sample crack: Replace the sample (crack <0.01 mm ± 0.001 mm) to avoid premature fracture (>0.1 GPa ± 0.01 GPa).

Fixture offset: Calibrate span (30 mm ± 0.1 mm) to ensure parallelism < 0.01 mm.

Porosity effect: If the TRS deviation is >0.2 GPa, check the porosity (SEM, <0.01% ± 0.001%).

11. Application and Significance

This standard provides a unified method for determining TRS of cemented carbide (error <2% ± 0.2%), ensuring consistency of mechanical properties (> 2 GPa ± 0.1 GPa). Main applications include:

Quality control: Verify sintering quality (densification >99.9%±0.1%), e.g. mining drill bits TRS>2.5 GPa±0.1 GPa, life>2000 h±100 h.

Recycling Verification: Confirm the TRS of recycled materials (>2 GPa±0.1 GPa) and support the circular economy (recycling rate>95%±2%).

R&D: Evaluate new cemented carbides (e.g. Fe-based, TRS>2.5 GPa±0.1 GPa) and drive innovation (toughness K_{IC} > 12 MPa·$m^{1/2}$ ± 0.5).

Example:

A tool factory tested a WC6Co insert and found it had a TRS of 3.0 GPa±0.1 GPa, confirming that its impact resistance was >2 GPa±0.1 GPa, which was sufficient for aviation processing (titanium alloy, cutting speed 150 m/min±10 m/min).

Sustainability:

High-precision TRS measurement reduces scrap rates (>10%±2%) and energy consumption (<400 kWh/t±50 kWh/t), meeting green manufacturing targets (CO_2 < 0.5 t CO_2 / t±0.1 t CO_2 / t).

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ISO 28079:2009 Wear and life testing of cemented carbide cutting tools

Hardmetals — Palmqvist toughness test

1. Scope

This International Standard specifies a general method for measuring the Palmqvist toughness of cemented carbides using Vickers hardness indentation cracking at room temperature. It is applicable to sintered materials composed primarily of tungsten carbide (WC) (>85% ± 1%) and a metallic binder (e.g., Co, 6% to 15% ± 1%), as well as cermets (e.g., TiC-based). This method uses a Vickers hardness tester to apply a load (recommended 30 kg ± 0.1 kg), measures the crack length at the four corners of the indentation (<1 mm ± 0.01 mm), and calculates the Palmqvist toughness (W, in N/mm).

This standard applies to:

Industrial products: cutting tools (cutting speed > 200 m/min ± 10 m/min, life > 1000 h ± 100 h), mining drill bits (impact resistance > 2 GPa ± 0.1 GPa), wear-resistant parts (wear rate < 0.05 mm^3 / N · m ± 0.01 mm^3 / N · m).

Laboratory samples: recycled powder (particle size 15 μm ± 0.1 μm), new cemented carbide (such as high entropy alloy, hardness HV> 2000 ± 30).

This method is applicable to uncoated cemented carbides or those with coatings less than 10 μm ± 1 μm thick, with a test error of <5% ± 0.5%. It is not applicable to unsintered powders, materials with porosity greater than 0.1% ± 0.01%, or microtoughness tests (loads less than 10 kg). If the sample exhibits unusual crack morphology (e.g., branching cracks greater than 0.1 mm ± 0.01 mm), the results should be used for comparison only.

Background:

Palmqvist toughness reflects the ability of cemented carbide to resist crack growth (K_{1C} > 10 $MPa \cdot m^{1/2}$ ± 0.5) and is correlated with transverse rupture strength (TRS > 2 GPa ± 0.1 GPa) and impact resistance (> 2 GPa ± 0.1 GPa). For example, mining drill bits require a toughness W > 100 N/mm ± 5 N/mm to withstand high-frequency impacts (> 10 Hz ± 1 Hz) and a lifespan > 2000 h ± 100 h. Toughness variations can result from grain heterogeneity (> 1 μm ± 0.1 μm), porosity (> 0.01% ± 0.001%), or fluctuations in Co content (> 0.5% ± 0.1%), impacting performance (reducing lifespan by > 20% ± 5%).

Application scenario:

A mining equipment manufacturer tested WC10Co drill bits with a Palmqvist toughness of 120 N/mm ± 5 N/mm, meeting impact resistance requirements (>2.5 GPa ± 0.1 GPa) and ensuring drilling efficiency (>1 m/h ± 0.1 m/h).

2. Terms and Definitions

For the purposes of this standard, the following terms and definitions apply:

Cemented Carbide: A composite material with WC as the matrix (>85%±1%) and sintered through bonding phases such as Co and Ni (6%15%±1%), with a hardness of HV 16002000±30.

Cermet: A composite material with TiC or Ti(C,N) as the matrix (>50%±1%) and a metal binder phase (such as Ni), with a hardness of HV 15001800±30.

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Palmqvist Toughness (W): The resistance to crack growth calculated based on Vickers indentation crack length (<1 mm ± 0.01 mm) and load (30 kg ± 0.1 kg), unit: N/mm, with an error of <5% ± 0.5%.

Vickers Indentation: A square indentation (diagonal > 0.1 mm ± 0.01 mm) formed by a diamond quadrangular pyramid indenter (vertex angle 136° ± 0.5°), accompanied by cracks in the four corners (< 1 mm ± 0.01 mm).

Crack Length: The single-side length of the crack at the four corners of the indentation (l, mm, ±0.01 mm), from the edge of the indentation (±0.001 mm) to the crack tip (±0.001 mm).

Porosity: The volume fraction of pores inside the material (<0.01%±0.001%), which affects the toughness determination.

Chinese explanation:

"Palmqvist toughness" quantifies crack resistance (e.g. W 100 N/mm ± 5 N/mm) by indentation crack length (<1 mm ± 0.01 mm). The high toughness of cemented carbide comes from the plastic buffering of WC grains (<1 μm ± 0.1 μm) and Co phase (strain > 0.1% ± 0.01%).

3. Principle

This method is based on the Palmqvist toughness test principle. Using a Vickers hardness tester, a diamond pyramid indenter (apex angle 136° ± 0.5°) is pressed into a cemented carbide surface (Ra < 0.1 μm ± 0.01 μm) at a constant load (30 kg ± 0.1 kg, approximately 294 N ± 1 N). This creates a square indentation (diagonal > 0.1 mm ± 0.01 mm) and a square crack (< 1 mm ± 0.01 mm). The indentation diagonal (d, ± 0.001 mm) and crack length (l, ± 0.01 mm) are measured using an optical microscope (magnification > 400× ± 10×). The Palmqvist toughness is calculated as follows:

$$W = \frac{F}{L}$$

in:

WWW: Palmqvist toughness (N/mm, error <5%±0.5%).

FFF: load (N, 294 N ± 1 N).

LLL: Total length of the four corner cracks (mm, ±0.01 mm), i.e., L=l1+l2+l3+l4 L = l_1 + l_2 + l_3 + l_4 L=l1 + l2 + l3 + l4 , each crack from the indentation edge to the tip.

Mechanism Analysis:

The high toughness of cemented carbide (W > 100 N/mm ± 5 N/mm) stems from the high compressive strength of WC (> 10 GPa ± 0.1 GPa) and the plasticity of Co (strain > 0.1% ± 0.01%). Cracks propagate along grain boundaries (< 1 μm ± 0.1 μm) or pores (< 0.01% ± 0.001%), and their length (< 1 mm ± 0.01 mm) reflects grain uniformity (deviation < 0.05% ± 0.01%) and sintering quality (densification > 99.9% ± 0.1%). For example, a WC8Co sample with a W of 110 N/mm ± 5 N/mm exhibited a total crack length of 2.67 mm ± 0.01 mm, indicating excellent crack resistance ($K_{1}c$ > 11 MPa·m¹ / ² ± 0.5).

Application:

A tool manufacturer tested a WC6Co insert, achieving a W of 130 N/mm ± 5 N/mm and a crack length of 2.26 mm ± 0.01 mm. The toughness, $K_{1}c$, was confirmed to be > 12 MPa·m¹ / ² ± 0.5 , making it suitable for aerospace machining (cutting speed 250 m/min ± 10 m/min).

4. Apparatus and Materials

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4.1 Equipment

Vickers Hardness Tester:

Load range: 1050 kg ± 0.1 kg, recommended 30 kg ± 0.1 kg (294 N ± 1 N).

Accuracy: load error <0.5%±0.1%, indentation measurement error <0.001 mm.

Purpose: To form indentations (diagonal > 0.1 mm ± 0.01 mm) and cracks (< 1 mm ± 0.01 mm).

Diamond Indenter:

Quadrangular pyramid, vertex angle 136°±0.5°, edge straightness <0.001 mm.

Application: To produce standard indentations and cracks (<1 mm ± 0.01 mm).

Optical Microscope:

Magnification: 400×1000×±10×, resolution: <0.001 mm.

Application: To measure the indentation diagonal (±0.001 mm) and crack length (±0.01 mm).

Polishing Machine:

Rotation speed: 100500 rpm ± 10 rpm, diamond abrasive (particle size: 1 μm ± 0.1 μm).

Application: To prepare sample surface (Ra<0.1 μm±0.01 μm).

Thermostatic Chamber:

Temperature 20°C±1°C, humidity 40%60%±5%.

Purpose: To maintain a stable test environment and avoid thermal expansion (<0.001 mm ± 0.0001 mm).

4.2 Materials

Polishing Agent:

Diamond suspension, particle size 1 μm±0.1 μm, purity >99.9%±0.1%.

Application: Polishing samples (Ra<0.1 μm±0.01 μm).

Ethanol:

Purity>99.5%±0.1%, used for cleaning samples.

Application: Removal of oil stains (<0.001 g ± 0.0001 g).

Lint-Free Cloth:

Fiber residue <0.0001 g ± 0.00001 g.

Purpose: To wipe samples to avoid contamination.

Application:

A drill bit factory used a Vickers hardness tester (load 30 kg ± 0.1 kg) and a 400× microscope (resolution < 0.001 mm) to test WC10Co. The W was 115 N/mm ± 5 N/mm, and the crack was clear (total length 2.55 mm ± 0.01 mm), meeting mining standards (W> 100 N/mm ± 5 N/mm).

5. Sample Preparation

5.1 Sample Requirements

Dimensions: Surface area >10 mm^2 ± 1 mm^2 , thickness >1 mm±0.1 mm, ensure indentations and cracks are complete (diagonal >0.1 mm±0.01 mm, cracks <1 mm±0.01 mm).

Surface: free of cracks (<0.01 mm ± 0.001 mm), pores (<0.01% ± 0.001%), or coatings (thickness <10 μm ± 1 μm).

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Quantity: At least 3 samples, representing the same batch (sintering condition deviation <1%±0.1%).

5.2 Polishing

Use a polishing machine (rotation speed 300 rpm ± 10 rpm) and diamond abrasive (1 μm ± 0.1 μm) to polish to a surface roughness Ra < 0.1 μm ± 0.01 μm.
Check the surface (magnifying glass, 10× ± 1×) to ensure there are no scratches (<0.01 mm ± 0.001 mm) or residues (<0.001 g ± 0.0001 g).

5.3 Cleaning

Immerse in ethanol (>99.5%±0.1%) and ultrasonically clean (40 kHz±1 kHz, 5 min±0.1 min) to remove oil stains (<0.001 g±0.0001 g).
Wipe with a dust-free cloth and check that there is no residue on the surface (visible to the naked eye <0.01 mm ± 0.001 mm).

5.4 Drying

Place in a constant temperature box (20°C±1°C, humidity <60%±5%) and dry for 10 min±1 min.
Verify that there is no moisture (<0.001%±0.0001%) or dust (<0.0001 g±0.00001 g).
Example:
A laboratory prepares a WC8Co sample (10×10×5 mm±0.1 mm), which is polished to Ra<0.08 μm±0.01 μm and has no scratches after cleaning (<0.01 mm±0.001 mm), meeting the test requirements.

6. Test Procedure

6.1 Environmental conditions

Temperature: 20°C ± 1°C, avoid thermal expansion (<0.001 mm ± 0.0001 mm).
Humidity: 40%60%±5%, prevent moisture absorption (<0.0001 g±0.00001 g).
Lighting: Uniform lighting (>500 lx±50 lx) to ensure that cracks are visible (<0.01 mm±0.001 mm).

6.2 Equipment Calibration

Hardness tester calibration: Use a standard hardness block (HV 1600±30, error <10 HV), confirm the load (30 kg±0.1 kg) and indenter (vertex angle 136°±0.5°).
Microscope calibration: using a standard reticle (±0.001 mm), the error is <0.001 mm.
Load time: Set the holding time to 15 s±1 s, and verify that the deviation is <0.1 s.

6.3 Indentation test

Place the sample on the hardness tester platform with the polished surface (Ra < 0.1 μm ± 0.01 μm) facing up and

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fix it (deviation < 0.1 mm).

Apply a load (30 kg ± 0.1 kg, 294 N ± 1 N) and hold for 15 s ± 1 s.

Unloading (<5 s±1 s) forms indentations (diagonal >0.1 mm±0.01 mm) and cracks (<1 mm±0.01 mm).

At least three indentations were made for each sample, with a spacing >2.5 times the diagonal (>0.25 mm ± 0.01 mm) and away from the edge (>1 mm ± 0.1 mm).

6.4 Crack Measurement

Using an optical microscope (400×±10×), the two diagonals of the indentation were measured (d_1, d_2, ±0.001 mm), and the average value (d, ±0.001 mm) was taken.

The crack lengths at the four corners (l_1, l_2, l_3, l_4, ±0.01 mm) were measured from the indentation edge (± 0.001 mm) to the crack tip (±0.001 mm).

Calculate the total crack length L=l1+l2+l3+l4 L = l_1 + l_2 + l_3 + l_4 L=l1 + l2 + l3 + l4 (±0.01 mm).

Check the crack morphology and ensure that there is no branching (>0.1 mm ± 0.01 mm) or deviation (>0.05 mm ± 0.01 mm). Otherwise, mark it as invalid.

6.5 Repeated testing

For each batch, three samples were tested, and three indentations were made on each sample. The diagonal (±0.001 mm) and crack length (±0.01 mm) were recorded.

Example:

A factory tests WC10Co samples with a load of 30 kg ± 0.1 kg, an indentation diagonal of 0.124 mm ± 0.001 mm, a crack length of 0.630.65 mm ± 0.01 mm, a total length of 2.55 mm ± 0.01 mm, and a W of 115 N/mm ± 5 N/mm.

7. Calculation

7.1 Palmqvist toughness

Palmqvist toughness is calculated using the following formula:

$$W = \frac{F}{L}$$

WWW: Toughness (N/mm, keep 1 decimal place, ±5 N/mm).

FFF: load (N, 294 N ± 1 N).

LLL: total length of four-corner cracks (mm, ±0.01 mm).

7.2 Hardness verification

To ensure that the indentation is valid, calculate the Vickers hardness (refer to ISO 65071):

$$HV = \frac{1.8544 \cdot F}{d^2}$$

HV HV HV: Vickers hardness (tolerance <10 HV).

FFF: load (kg, 30 kg ± 0.1 kg).

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ddd: average value of the indentation diagonal (mm, ±0.001 mm).

If the HV deviation is >50 HV, check the sample for homogeneity (grains >1 μm ± 0.1 μm) or porosity (>0.01% ± 0.001%).

7.3 Mean and Deviation

Calculate W for 3 indentations of each sample in N/mm.

Take the average W of 3 samples (±5 N/mm) and calculate the standard deviation (<3 N/mm).

If any W deviation is >10 N/mm, check for abnormal cracks (branching >0.1 mm ± 0.01 mm) or indenter defects (edge <0.001 mm).

Example:

Sample load 294 N ± 1 N, crack lengths 0.64, 0.63, 0.65, 0.64 mm ± 0.01 mm, total length 2.56 mm ± 0.01 mm, calculation:

$$W = \frac{294}{2.56} = 114.8\,\mathrm{N/mm} \approx 115\,\mathrm{N/mm} \pm 5\,\mathrm{N/mm}$$

Hardness: diagonal 0.124 mm ± 0.001 mm, HV 1650 ± 10. 3 samples: 115, 116, 114 N/mm, average 115 N/mm ± 5 N/mm, deviation 0.8 N/mm, in line with the standard.

8. Test Report

The test report should include the following:

Standard number: ISO 28079:2009.

Sample information: batch, size (±0.1 mm), composition (e.g. WC10Co), quantity (≥3).

Test conditions: temperature (20°C ± 1°C), humidity (40% 60% ± 5%), load (30 kg ± 0.1 kg), hold time (15 s ± 1 s).

Equipment information: hardness tester model (accuracy ±0.1%), microscope model (resolution <0.001 mm).

Measurement data: indentation diagonal (±0.001 mm), crack length (±0.01 mm), HV (±10 HV), W (±5 N/mm).

Results: Mean W (N/mm, ±5 N/mm), standard deviation (<3 N/mm).

Note: Abnormal conditions (such as branch cracks > 0.1 mm ± 0.01 mm, porosity > 0.01% ± 0.001%).

Tester: Name, Date (Format: YYYYMMDD).

Laboratory: name, address, accreditation (e.g. ISO 17025).

Example:

A tool manufacturer's report: WC8Co samples (10×10×5 mm±0.1 mm, 3 pieces), load 30 kg±0.1 kg, temperature 20.2°C±1°C, diagonal 0.1230.125 mm±0.001 mm, total crack length 2.242.28 mm±0.01 mm, HV 16501660±10, W 128131 N/mm, average 130 N/mm±5 N/mm, deviation 1.5 N/mm, meeting aviation standards (W>120 N/mm±5 N/mm).

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9. Precision and Uncertainty

9.1 Repeatability

For the same operator, equipment, and batch, the deviation of three indentations is <3 N/mm.

Example: WC10Co sample, W 115, 116, 114 N/mm, the deviation is 0.8 N/mm.

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9.2 Reproducibility

The deviation between different laboratories and operators is less than 5 N/mm.

Example: Two laboratories measured WC6Co and the results were 130±5 N/mm and 132±5 N/mm respectively, with a deviation of 2 N/mm.

9.3 Uncertainty

Load: ±1 N, contribution <1 N/mm.

Crack length: ±0.01 mm, contribution <3 N/mm.

Microscope: ±0.001 mm, contribution <0.5 N/mm.

Total uncertainty: ±5 N/mm (95% confidence level).

Significance: High precision (±5 N/mm) ensures reliable toughness, eliminating the influence of porosity (>0.01%±0.001%) or grain deviation (>0.05%±0.01%).

10. Annexes

Annex A (Normative) Crack Measurement Requirements

Effective crack: extends from the indentation edge (±0.001 mm) along a straight line (deviation <0.05 mm±0.01 mm), with a length of 0.11 mm±0.01 mm.

Invalid cracks: branching (>0.1 mm±0.01 mm), deflection (>45°±5°) or interruption (>0.05 mm±0.01 mm).

Measurement: Each crack was measured twice, with a deviation of <0.01 mm.

Annex B (Informative) Typical Carbide Palmqvist Toughness

WC6Co: 130 N/mm ± 5 N/mm, tool (cutting speed 250 m/min ± 10 m/min).

WC10Co: 110 N/mm±5 N/mm, mining drill bits (impact resistance >2.5 GPa±0.1 GPa).

WC15Co: 90 N/mm ± 5 N/mm, wear-resistant parts (wear rate <0.05 mm^3 / N · m ± 0.01 mm^3 /N · m).

TiCNi cermet: 80 N/mm±5 N/mm, finishing tool (surface roughness Ra<0.4 μm±0.1 μm).

Annex C (Informative) Common Problems and Solutions

Cracks are unclear: Increase magnification (>1000×±10×) and adjust lighting (>500 lx±50 lx).

Branching cracks: Marking is invalid, increase indentations (>3), and check for porosity (SEM, <0.01% ± 0.001%).

Indenter wear: Replace the indenter (edge < 0.001 mm) and calibrate the hardness (HV 1600 ± 30).

Sample inhomogeneity: If the W deviation is >10 N/mm, analyze the grain size (>1 μm ± 0.1 μm) or the Co distribution (>0.5% ± 0.1%).

11. Application and Significance

This standard provides a unified method for determining the Palmqvist toughness of cemented carbide (error <5% ± 0.5%), ensuring consistency in crack resistance (W> 100 N/mm ± 5 N/mm). Main applications include:

Quality control: Verify sintering quality (densification >99.9% ± 0.1%), e.g. mining drill bits W >110 N/mm ± 5 N/mm, life >2000 h ± 100 h.

Recycling verification: Confirm the toughness of recycled materials (W>90 N/mm±5 N/mm) and support the circular economy (recycling rate>95%±2%).

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R&D: Evaluate new cemented carbides (e.g. Fe-based, W>100 N/mm±5 N/mm) and drive innovation ($K_{1}c$ > 12 MPa·m^{1} / ² ± 0.5).

Example:

A tool manufacturer tested a WC6Co insert with a W of 130 N/mm ± 5 N/mm and confirmed that its crack resistance $K_{1}c$ > 12 MPa·m^{1} / ² ± 0.5 , which meets the requirements for aviation machining (titanium alloy, cutting speed 150 m/min ± 10 m/min).

Sustainability:

High-precision toughness measurement reduces scrap (>10% ± 2%) and energy consumption (<400 kWh/t ± 50 kWh/t), meeting green manufacturing targets (CO_2 < 0.5 t CO_2 / t ± 0.1 t CO_2 / t).

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American Society for Testing and Materials (ASTM) standards

ASTM B40696(2015) Test Method for Transverse Rupture Strength of Cemented Carbide

ASTM B40696 (2015) Test Method for Transverse Fracture Strength of Tungsten Cemented Carbide

1. Scope

1.1 This test method specifies the transverse rupture strength (TRS) of cemented carbide using a three-point bend test. This method is applicable to cemented carbide (also called hard metal), which consists primarily of tungsten carbide (WC) with a metallic binder (usually cobalt, Co) and is used for cutting tools, wear-resistant parts, and structural components.

1.2 This test method is applicable to specimens having a rectangular cross-section and is tested under controlled conditions to ensure consistent results. Transverse rupture strength is expressed in pounds per square inch (psi) or megapascals (MPa) and typically ranges from 200,000 to 600,000 psi (1380 to 4140 MPa ± 70 MPa).

1.3 This method is not suitable for materials that undergo significant plastic deformation before fracture (strain > 0.2% ± 0.02%) because the results may not reflect the true brittle strength. This method is also not suitable for unsintered powders or materials with porosity > 0.5% ± 0.05%.

1.4 The values stated in inch-pound units are to be regarded as standard. The metric unit values given in parentheses are obtained by mathematical conversion and are for reference only.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations.

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1. Reference Documents

2.1 ASTM Standards:

B243 Standard Terminology of Powder Metallurgy: Provides definitions of terms related to powder metallurgy, including terms for cemented carbide and transverse rupture strength.

E4 Standard Practices for Force Verification of Testing Machines: Specifies the method for force calibration of testing machines to ensure load accuracy (±0.5% ± 0.1%).

E7 Standard Terminology Relating to Metallography: defines terms related to metallographic analysis and used to describe the specimen surface and porosity (<0.5% ± 0.05%).

E18 Standard Test Methods for Rockwell Hardness of Metallic Materials: Provides a hardness test reference for verifying grip roller hardness (HRC >60 ± 1).

E29 Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications: Guides the effective digital processing of test data to ensure TRS result accuracy (±10,000 psi, ±70 MPa).

3. Terminology

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3.1 Definitions:

3.1.1 Cemented Carbide: A composite material made by sintering tungsten carbide (WC, content >85% ± 1%) and a metal binder (such as cobalt, 6%15% ± 1%), with high hardness (HV 16002000 ± 30).

3.1.2 Transverse Rupture Strength (TRS): The maximum stress per unit area at which a specimen breaks in a three-point bending test, expressed in psi or MPa with an error of <5% ± 0.5%.

3.1.3 Three-Point Bending Test: Determine the breaking strength by applying a force (±0.01 kN) at two support points (span 1.2 inches ± 0.01 inches) and a central loading point.

3.1.4 Fracture Load: The maximum force at which the specimen fractures, expressed in pounds-force (lbf) or Newtons (N), with an accuracy of ±10 N.

3.1.5 Porosity: The volume fraction of pores inside the specimen (<0.5% ± 0.05%), which affects the strength determination.

4. Significance and Use

4.1 Transverse rupture strength is an important mechanical property of cemented carbide, used to evaluate its ability to resist bending fracture. The test results can be used for:

4.1.1 Compare the strengths of different cemented carbide grades (e.g., WC6Co and WC10Co, TRS 200,000600,000 psi ± 10,000 psi).

4.1.2 Quality control to ensure that the sintered specimens meet the requirements (densification >99.5% ± 0.05%).

4.1.3 Material selection guides the application of cutting tools and wear-resistant parts.

4.2 This method provides standardized test conditions (span 1.2 in. ± 0.01 in.) to ensure repeatable results (variation < 5% ± 0.5%).

5. Equipment

5.1 Universal Testing Machine:

Load range: 05000 lbf ± 1 lbf (022 kN ± 0.01 kN).

Accuracy: Load error <0.5% ± 0.1%.

Loading rate: 0.02 in./min ± 0.001 in./min (0.5 mm/min ± 0.01 mm/min).

5.2 Three-point bending fixture

Support roller diameter: 0.25 in. ± 0.005 in. (6.35 mm ± 0.13 mm).

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Load roller diameter: 0.25 in. ± 0.005 in. (6.35 mm ± 0.13 mm).

Span: 1.2 in. ± 0.01 in. (30.48 mm ± 0.25 mm).

Roller hardness: HRC >60 ± 1.

5.3 Micrometer

Accuracy: ±0.0001 in. (±0.0025 mm).

Measuring range: >2 inches (>50 mm).

5.4 Polishing Equipment:

Speed: 100500 rpm ± 10 rpm.

Abrasive: Diamond, particle size 1 μm ± 0.1 μm.

5.5 Cleaning equipment:

Ultrasonic cleaner, frequency 40 kHz ± 1 kHz, power >100 W ± 10 W.

6. Specimens

6.1 Specimen type:

Shape: rectangular rod.

Dimensions: Length 1.5 inches ± 0.01 inches (38.1 mm ± 0.25 mm), width 0.25 inches ± 0.005 inches (6.35 mm ± 0.13 mm), thickness 0.2 inches ± 0.005 inches (5.08 mm ± 0.13 mm).

6.2 Surface requirements:

The tensile surface is polished to a surface roughness of Ra <4 μin ± 0.4 μin (0.1 μm ± 0.01 μm).

No visible cracks (<0.001 in. ± 0.0001 in., <0.025 mm ± 0.0025 mm) or porosity (<0.5% ± 0.05%).

6.3 Edge processing:

Chamfer radius: 0.0050.010 inch ± 0.001 inch (0.130.25 mm ± 0.025 mm).

6.4 Quantity:

Each batch shall consist of at least 5 specimens representing the same sintering conditions (temperature deviation <10°C ± 1°C).

7. Sample Preparation

7.1 Polishing :

7.1.1 Use a polishing machine (300 rpm ± 10 rpm) and diamond abrasive (1 μm ± 0.1 μm) to polish the tensile surface to Ra < 4 μin ± 0.4 μin (0.1 μm ± 0.01 μm).

7.1.2 Inspect the surface (magnifying glass, 10× ± 1×) to ensure that there are no scratches (<0.001 in. ± 0.0001 in., <0.025 mm ± 0.0025 mm).

7.2 Cleaning:

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7.2.1 Place the specimen in ethanol (purity >99.5% ± 0.1%) and clean it ultrasonically (40 kHz ± 1 kHz, 5 min ± 0.1 min).

7.2.2 Wipe with a dust-free cloth to ensure there is no oil or dirt (<0.0001 g ± 0.00001 g).

7.3 Dimensional Measurement:

7.3.1 Use a micrometer (±0.0001 in., ±0.0025 mm) to measure the width (b) and thickness (h). Measure three points for each dimension and take the average value (deviation <0.0005 in., <0.013 mm).

7.3.2 Record Length (>1.4 in. ± 0.01 in., >35.56 mm ± 0.25 mm).

8. Experimental Procedure

8.1 Environmental conditions :

Temperature: 73°F ± 3.6°F (23°C ± 2°C).

Humidity: 30%70% ± 5%.

Vibration: acceleration <0.01 m/ s^2 ± 0.001 m/ s^2 .

8.2 Equipment Calibration:

8.2.1 Calibrate the testing machine using a standard force transducer (±1 lbf, ±4.45 N) with an accuracy of <0.5% ± 0.1%.

8.2.2 Inspect the fixture to ensure that the support and load rollers have the correct diameters (0.25 in. ± 0.005 in., 6.35 mm ± 0.13 mm), spans (1.2 in. ± 0.01 in., 30.48 mm ± 0.25 mm), and parallelism < 0.001 in. (< 0.025 mm).

8.3 Specimen installation:

8.3.1 Place the specimen in the fixture with the polished surface (Ra <4 μin ± 0.4 μin, 0.1 μm ± 0.01 μm) facing down and centered (deviation <0.01 in., <0.25 mm).

8.3.2 Ensure that the support rollers have even contact (force <0.1 lbf ± 0.01 lbf, <0.445 N ± 0.0445 N) and that the load rollers are aligned on center (<0.01 in., <0.25 mm).

8.4 Loading:

8.4.1 Load at 0.02 in./min ± 0.001 in./min (0.5 mm/min ± 0.01 mm/min) and record the force (±1 lbf, ±4.45 N).

8.4.2 Continue loading until the specimen breaks (<0.1 s ± 0.01 s) and record the breaking load (F, ±1 lbf, ±4.45 N).

8.4.3 Inspect the fracture surface (magnifying glass, 10× ± 1×) to confirm that there are no abnormalities (such as porosity > 0.5% ± 0.05%).

8.5 Repeat the test:

8.5.1 Test five specimens from each batch and record the fracture load (±1 lbf, ±4.45 N) and fracture characteristics (brittle, plastic strain <0.2% ± 0.02%).

9. Calculation

9.1 Transverse rupture strength:

9.1.1 Calculate TRS using the following formula:

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$$\sigma = \frac{3FL}{2bh^2}$$

σ: TRS (psi or MPa, retain 3 significant figures, ±10,000 psi, ±70 MPa).

F: Breaking load (lbf or N, ±1 lbf, ±4.45 N).

L: Span (inches or mm, 1.2 inches ± 0.01 inches, 30.48 mm ± 0.25 mm).

b: Width (inches or mm, ±0.0005 inches, ±0.013 mm).

h: thickness (inches or mm, ±0.0005 inches, ±0.013 mm).

9.1.2 Imperial units (psi):

$$\sigma(\text{psi}) = \frac{3FL}{2bh^2}$$

F: lbf, ±1 lbf.

L, b, h: inches, ±0.0005 inches.

9.1.3 Metric units (MPa):

$$\sigma(\text{MPa}) = \frac{3FL}{2bh^2} \times 6.89476$$

F: N, ±4.45 N.

L, b, h: mm, ±0.013 mm.

6.89476: The factor used to convert psi to MPa.

9.2 Mean and Deviation:

9.2.1 Calculate the TRS of the five specimens and take the average value (±10,000 psi, ±70 MPa).

9.2.2 Calculate the standard deviation (<10,000 psi, <70 MPa).

9.2.3 If any TRS deviation is >30,000 psi (>200 MPa), check for specimen defects (eg, porosity >0.5% ± 0.05%) or fixture deflection (>0.01 in., >0.25 mm).

10. Report

10.1 The report should include the following:

10.1.1 This standard is numbered: ASTM B40696(2015).

10.1.2 Test specimen description: batch, composition (e.g., WC10Co), dimensions (± 0.0005 in., ± 0.013 mm), and quantity (≥ 5).

10.1.3 Test conditions: Temperature (73°F ± 3.6°F, 23°C ± 2°C), humidity (30% 70% ± 5%), loading rate (0.02 in./min ± 0.001 in./min, 0.5 mm/min ± 0.01 mm/min).

10.1.4 Equipment information: Testing machine model (accuracy ± 0.5% ± 0.1%), fixture span (1.2 inches ± 0.01 inches, 30.48 mm ± 0.25 mm).

10.1.5 Test Data: Breaking load (±1 lbf, ±4.45 N), specimen dimensions (±0.0005 in., ±0.013 mm), TRS (±10,000 psi, ±70 MPa).

10.1.6 Results: Mean TRS (psi and MPa, ±10,000 psi, ±70 MPa), standard deviation (<10,000 psi, <70 MPa).

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10.1.7 Notes: Abnormal conditions (e.g. plastic deformation > 0.2% ± 0.02%, porosity > 0.5% ± 0.05%).

11. Precision and Bias

11.1 Repeatability:

11.1.1 For the same operator, equipment, and batch, the deviation of 5 tests is < 10,000 psi (< 70 MPa).

11.2 Reproducibility:

11.2.1 The deviation between different laboratories and operators is <20,000 psi (<140 MPa).

11.3 Sources of Deviation:

Load measurement: ±1 lbf (±4.45 N), contributing <5,000 psi (<35 MPa).

Dimensional measurements: ±0.0005 in. (±0.013 mm), contributing <5,000 psi (<35 MPa).

Fixture alignment: ±0.01 in. (±0.25 mm), contributing <2,000 psi (<14 MPa).

12. Keywords

12.1 Cemented carbide; transverse rupture strength; three-point bend; tungsten carbide; breaking load.

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ASTM B61113 Standard Test Method for Determining the High Stress Abrasion Resistance of Hard Materials
ASTM B61113 Test Method for Abrasive Wear of Cemented Carbide

1. Scope

1.1 This test method specifies the determination of the resistance of cemented carbide and other hard materials to high-stress abrasive wear using a rotating steel wheel and wet sand abrasive. This method is particularly applicable to cemented carbide (also called hard metal), which consists primarily of tungsten carbide (WC) with a metallic binder (e.g., cobalt, Co), used in mining tools, cutting tools, and wear-resistant components.

cm³ or in³) of a specimen under specified abrasive (aluminum oxide grit), load, and number of revolutions . Typical volume loss ranges from 0.01 to 0.1 cm³ . ± 0.005 cm³ (0.0006 to 0.006 in³) ± 0.0003 in³) .

1.3 This method is not suitable for coated materials (thickness > 0.1 mm ± 0.01 mm), materials with a porosity > 1% ± 0.1%, or soft materials (hardness < HV 1000 ± 30). The results may be affected by the surface condition of the specimen (Ra > 0.8 μm ± 0.08 μm).

1.4 The values stated in metric units are to be regarded as standard. The values stated in parentheses for imperial units are obtained by mathematical conversion and are for reference only.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations.

2. Reference Documents

2.1 ASTM Standards:

B243 Standard Terminology of Powder Metallurgy: Provides terms related to powder metallurgy, including definitions of cemented carbide and wear resistance.
E11 Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves: Specifies the standard sieve for abrasive sieving to ensure the abrasive particle size (0.61.0 mm ± 0.05 mm).
E177 Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods defines the terms precision and bias for use in evaluating test results (error <5% ± 0.5%).
E691 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method: Guides interlaboratory studies to ensure repeatability and reproducibility (bias <5% ± 0.5%).
G40 Standard Terminology Relating to Wear and Erosion: Defines wear-related terms, including high-stress abrasive wear.

3. Terminology

3.1 Definitions:

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3.1.1 Cemented Carbide: A composite material made by sintering tungsten carbide (WC, content >85% ± 1%) and a metal binder (such as cobalt, 6%15% ± 1%), with a hardness of HV 10002000 ± 30.

3.1.2 High Stress Abrasion: Surface loss caused by the interaction of a material with a hard abrasive (such as aluminum oxide) under high contact stress (>1 MPa ± 0.1 MPa).

3.1.3 Volume Loss: The volume of material lost by the specimen after the wear test, expressed in cm^3 or in^3 , with an accuracy of ±0.005 cm^3 (±0.0003 in^3) .

3.1.4 Abrasion Resistance: The ability of a material to resist abrasive wear, expressed as the inverse of the volume loss of the specimen (1/volume loss , cm^{-3} or in^{-3}) .

3.1.5 Wet Sand/Steel Wheel Test: An abrasion test using a rotating steel wheel (9 in. ± 0.1 in. diameter) and wet aluminum oxide abrasive (0.61.0 mm ± 0.05 mm).

4. Significance and Use

4.1 This test method is used to evaluate the performance of cemented carbide under high-stress abrasive wear conditions and is suitable for the following applications:

4.1.1 Comparison of wear resistance of different cemented carbide grades (e.g. WC6Co and WC10Co, volume loss 0.010.1 cm^3 ± 0.005 cm^3) .

4.1.2 Quality control to ensure that the material meets the wear resistance requirements (volume loss <0.1 cm^3 ± 0.005 cm^3) .

4.1.3 Material selection guides mining tools and wear parts.

4.2 This method simulates a high-stress wear environment (e.g., mining, abrasive flow rate >1 kg/min ± 0.1 kg/min) and provides standardized test conditions (load 45 lbf ± 1 lbf) to ensure repeatable results (deviation <5% ± 0.5%).

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5. Equipment

5.1 Abrasion Test Machine:

Steel wheel: diameter 9 inches ± 0.1 inches (228.6 mm ± 2.54 mm), width 0.5 inches ± 0.01 inches (12.7 mm ± 0.25 mm), hardness HRC 5862 ± 1.

Rotation speed: 200 rpm ± 5 rpm.

Load: 45 lbf ± 1 lbf (200 N ± 4.45 N).

Abrasive supply system: flow rate 1.5 kg/min ± 0.1 kg/min.

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5.2 Specimen grips:

The specimen was positioned so that the contact surface was parallel to the steel wheel (deviation < 0.01 in, < 0.25 mm).

Adjust the device to maintain a constant load (45 lbf ± 1 lbf, 200 N ± 4.45 N).

5.3 Balance

Accuracy: ±0.0001 g.

Capacity: >100 g.

5.4 Screening equipment:

Standard sieves: Conforms to ASTM E11, apertures 0.6 mm and 1.0 mm ± 0.05 mm.

5.5 Drying Oven:

Temperature: 100°C ± 5°C.

Application: Drying abrasives and specimens (moisture content <0.1% ± 0.01%).

5.6 Cleaning Equipment:

Ultrasonic cleaner, frequency 40 kHz ± 1 kHz, power >100 W ± 10 W.

6. Specimens

6.1 Specimen type:

Shape: rectangular or cylindrical.

Dimensions: Length 2 inches ± 0.05 inches (50.8 mm ± 1.27 mm), width or diameter 0.5 inches ± 0.01 inches (12.7 mm ± 0.25 mm), thickness >0.2 inches ± 0.01 inches (>5.08 mm ± 0.25 mm).

6.2 Surface requirements:

The test surface was polished to a surface roughness of Ra <32 μin ± 3.2 μin (0.8 μm ± 0.08 μm).

No visible cracks (<0.001 in. ± 0.0001 in., <0.025 mm ± 0.0025 mm) or porosity (<1% ± 0.1%).

6.3 Quantity:

Each batch shall consist of at least three specimens representing the same sintering conditions (temperature deviation <10°C ± 1°C).

7. Sample Preparation

7.1 Polishing:

7.1.1 Polish the test surface to Ra < 32 μin ± 3.2 μin (0.8 μm ± 0.08 μm) using a polishing machine (300 rpm ± 10 rpm) and diamond abrasive (1 μm ± 0.1 μm).

7.1.2 Inspect the surface (magnifying glass, 10× ± 1×) to ensure that there are no scratches (<0.001 in. ± 0.0001 in., <0.025 mm ± 0.0025 mm).

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7.2 Cleaning:

7.2.1 Place the sample in ethanol (purity >99.5% ± 0.1%) and ultrasonically clean it (40 kHz ± 1 kHz, 5 min ± 0.1 min).

7.2.2 Wipe with a dust-free cloth to ensure there is no oil or dirt (<0.0001 g ± 0.00001 g).

7.3 Drying:

7.3.1 Place in a drying oven (100°C ± 5°C) and dry for 30 min ± 1 min.

7.3.2 Cool to room temperature (23°C ± 2°C) and ensure that the moisture content is <0.1% ± 0.01%.

7.4 Weighing:

7.4.1 Weigh the initial mass of the sample (m_1, ±0.0001 g) using a balance (± 0.0001 g) and repeat three times with a deviation of <0.0001 g.

8. Abrasive

8.1 Type: Alumina sand (Al_2O_3 , purity > 99 % ± 0.1%).

8.2 Granularity:

Range: 0.61.0 mm ± 0.05 mm.

Sieving: Use 0.6 mm and 1.0 mm standard sieves conforming to ASTM E11.

8.3 Preparation:

8.3.1 Place the abrasive in a drying oven (100°C ± 5°C) and dry for 1 h ± 0.1 h.

8.3.2 Cool to room temperature (23°C ± 2°C) and ensure that the moisture content is <0.1% ± 0.01%.

8.4 Mixing:

8.4.1 Mix the abrasive and water in a mass ratio of 3:1 ± 0.1 to form a homogeneous slurry (viscosity 100200 cP ± 10 cP).

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9. Experimental Procedure

9.1 Environmental conditions:

Temperature: 73°F ± 3.6°F (23°C ± 2°C).

Humidity: 30%70% ± 5%.

9.2 Equipment Calibration:

9.2.1 Calibrate the testing machine to verify the drum speed (200 rpm ± 5 rpm) and load (45 lbf ± 1 lbf, 200 N ± 4.45 N).

9.2.2 Check the surface of the steel wheel (Ra <32 μin ± 3.2 μin, <0.8 μm ± 0.08 μm) and check for wear (<0.01 inch, <0.25 mm).

9.2.3 Calibrate the balance (±0.0001 g), with an error of <0.0001 g.

9.3 Specimen installation:

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9.3.1 Secure the specimen in the fixture with the test surface (Ra <32 μin ± 3.2 μin, <0.8 μm ± 0.08 μm) in contact with the steel wheel and parallelism <0.01 inch (<0.25 mm).

9.3.2 Adjust the clamp to ensure uniform load (45 lbf ± 1 lbf, 200 N ± 4.45 N).

9.4 Test operation:

9.4.1 Start the steel wheel (200 rpm ± 5 rpm) and supply abrasive slurry (flow rate 1.5 kg/min ± 0.1 kg/min).

9.4.2 Apply a load (45 lbf ± 1 lbf, 200 N ± 4.45 N) and run for 1000 revolutions ± 10 revolutions (approximately 5 min ± 0.1 min).

9.4.3 Stop the test and remove the specimen.

9.5 Sample processing:

9.5.1 Ultrasonic clean the specimen with ethanol (5 min ± 0.1 min) to remove any abrasive residue (<0.0001 g ± 0.00001 g).

9.5.2 Dry in a drying oven (100°C ± 5°C) for 30 min ± 1 min and cool to room temperature (23°C ± 2°C).

9.5.3 Weigh the final mass of the sample (m_2 , ±0.0001 g), repeat three times, and the deviation is <0.0001 g.

9.6 Replicate Tests:

9.6.1 Test three specimens from each batch and record the initial and final masses (± 0.0001 g).

10. Calculation

10.1 Quality Loss:

10.1.1 Calculate the mass loss of the specimen (Δm):

$$\Delta m = m_1 - m_2$$

ΔmΔm: mass loss (g, ±0.0001 g).

m_1 : initial mass (g, ±0.0001 g).

m_2 : Final mass (g, ±0.0001 g).

10.2 Volume loss:

10.2.1 Calculation of volume loss (V):

$$V = \frac{\Delta m}{\rho}$$

V: Volume loss (cm^3 or in^3 , ±0.005 cm^3 , ±0.0003 in^3) .

Δm: mass loss (g, ±0.0001 g).

ρ: density of the specimen (g/cm^3 , ±0.1 g/cm^3) , provided by the specimen manufacturer or measured separately.

10.2.2 Imperial units (in^3) :

$$V(\text{in}^3) = \frac{\Delta m}{\rho \times 16.387}$$

ρ: g/ cm^3 , ±0.1 g/ cm^3 .

16.387: Factor used to convert cm^3 to in^3 .

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10.3 Wear resistance:

10.3.1 Calculation of wear resistance (R):

$$R = \frac{1}{V}$$

R: wear resistance (cm^{-3} or in^{-3}, ±5% ± 0.5%).

V: Volume loss (cm^3 or in^3, ±0.005 cm^3, ±0.0003 in^3) .

10.4 Mean and Deviation:

10.4.1 Calculate the volume loss (V) and wear resistance (R) of the three specimens and take the average value (± 0.005 cm^3, ± 0.0003 in^3) .

10.4.2 Calculate the standard deviation (<0.005 cm^3, <0.0003 in^3) .

10.4.3 If any V deviation is > 0.01 cm^3 (> 0.0006 in^3) , check the specimen for defects (e.g., porosity > 1% ± 0.1%) or abrasive grit size (> 1.0 mm ± 0.05 mm).

11. Report

11.1 The report should include the following:

11.1.1 This standard is numbered: ASTM B61113.

11.1.2 Test specimen description: batch, composition (e.g., WC10Co), dimensions (±0.01 in., ±0.25 mm), density (±0.1 g/cm^3) , and number (≥3).

11.1.3 Test conditions: Temperature (73°F ± 3.6°F, 23°C ± 2°C), humidity (30% to 70% ± 5%), load (45 lbf ± 1 lbf, 200 N ± 4.45 N), rotation speed (200 rpm ± 5 rpm), number of revolutions (1000 rpm ± 10 rpm).

11.1.4 Abrasive information: type (aluminum oxide), grit size (0.61.0 mm ± 0.05 mm), flow rate (1.5 kg/min ± 0.1 kg/min).

11.1.5 Equipment information: Steel wheel diameter (9 inches ± 0.1 inches, 228.6 mm ± 2.54 mm), clamp model.

11.1.6 Test data: Initial mass (±0.0001 g), final mass (±0.0001 g), volume loss (±0.005 cm^3, ±0.0003 in^3) , wear resistance (±5% ± 0.5%).

11.1.7 Results: Average volume loss (cm^3 and in^3, ±0.005 cm^3, ±0.0003 in^3), average wear resistance (cm^{-3} and in^{-3}, ± 5% ± 0.5%), standard deviation (<0.005 cm^3, <0.0003 in^3)

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11.1.8 Notes: Abnormal conditions (e.g. porosity > 1% ± 0.1%, abrasive contamination > 0.1% ± 0.01%).

12. Precision and Bias

12.1 Repeatability:

12.1.1 For the same operator, equipment, and batch, the volume loss deviation between three tests shall be < 0.005 cm^3 (< 0.0003 in^3) .

12.2 Reproducibility:

cm^3 (<0.0006 in^3) between different laboratories and operators .

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12.3 Sources of Deviation:

Mass measurement: ±0.0001 g, contribution <0.002 cm^3 (<0.0001 in^3) .

Density measurement: ±0.1 g/ cm^3 , contribution <0.003 cm^3 (<0.0002 in^3) .

Abrasive grit size: ±0.05 mm, contributing <0.002 cm^3 (<0.0001 in^3) .

Load Control: ±1 lbf (±4.45 N), Contribution <0.001 cm^3 (<0.00006 in^3) .

13. Keywords

13.1 Carbide; abrasive wear; high-stress wear; volume loss; wear resistance; wet sand/steel wheels.



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ASTM E40707(2015)

Standard Practice for Microetching Metals and Alloys

ASTM E40707(2015)

Standard practice for microetching of metals and alloys

1. scope

1.1 This practice provides a method for microetching metals and alloys (including cemented carbides) for characterizing their microstructures using an optical microscope. This practice is applicable to cemented carbides (primarily composed of tungsten carbide, WC, with a metallic binder such as cobalt, Co) and other metals and alloys for laboratory analysis and quality control.

1.2 This practice lists various etchant formulations and their application conditions for revealing grain boundaries (<1 μm ± 0.1 μm), phase distribution (e.g., WC and Co phases), inclusions, and other microstructural features. Etching methods include chemical etching, electrolytic etching, and thermal etching.

1.3 This practice does not specify quantitative microstructural analysis methods; it only provides etching procedures and recommended etchants. The resolution of microstructural observation depends on the microscope magnification (50× to 1000× ± 10×) and the specimen surface quality (Ra < 0.1 μm ± 0.01 μm).

1.4 The values stated in metric units are to be regarded as standard. The values stated in parentheses for imperial units are obtained by mathematical conversion and are for reference only.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and comply with regulatory requirements.

2. Reference Documents

2.1 ASTM Standards:

E3 Standard Guide for Preparation of Metallographic Specimens: Provides guidance on the preparation of metallographic specimens, including cutting, mounting, and polishing of cemented carbides.

E7 Standard Terminology Relating to Metallography: Defines metallographic analysis terms such as grain boundaries, phase distribution, and inclusions.

E112 Standard Test Methods for Determining Average Grain Size: Provides a reference method for grain size measurement, suitable for observation after etching.

E340 Standard Practice for Macroetching Metals and Alloys: Provides macroetching methods to complement microetching.

E883 Standard Guide for Reflected Light Photomicrography: Guide for optical photography of microstructures, suitable for post-etch documentation.

3. Terminology

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3.1 Definitions:

3.1.1 Cemented Carbide: A composite material made by sintering tungsten carbide (WC, content >85% ± 1%) and a metal binder (such as cobalt, 6%15% ± 1%), with a hardness of HV 16002000 ± 30.

3.1.2 Microetching: Selectively etching the sample surface by chemical, electrolytic, or thermal methods to reveal microstructural features (e.g., grain boundaries <1 μm ± 0.1 μm).

3.1.3 Grain Boundary: The interface between grains, revealed by etching, with a width of <0.1 μm ± 0.01 μm.

3.1.4 Phase Distribution: The spatial distribution of different phases (such as WC and Co) in the material, distinguished by etching.

3.1.5 Etchant: A chemical solution or electrolyte used to corrode a specimen, such as Murakami's reagent.

4. Significance and Use

4.1 Microetching is used to reveal the microstructural characteristics of cemented carbides and other metals to support the following applications:

4.1.1 Quality control, verifying the grain size (<1 μm ± 0.1 μm) and phase distribution uniformity (deviation <5% ± 0.5%) of the cemented carbide.
4.1.2 Material analysis to identify inclusions (<0.1 μm ± 0.01 μm), porosity (<0.5% ± 0.05%), or other defects.
4.1.3 Process optimization, evaluate the effect of sintering conditions on microstructure (e.g., temperature deviation <10°C ± 1°C).

4.2 This procedure provides a standardized etching method that ensures visualization of microstructural features (magnification 50×1000× ± 10×) and consistency (etching depth <1 μm ± 0.1 μm).

5. Equipment

5.1 Metallographic Microscope:
Magnification: 50× to 1000× ± 10×.
Resolution: <0.1 μm ± 0.01 μm.
Lighting: Reflected light, brightness >500 lx ± 50 lx.
5.2 Metallographic specimen preparation equipment:
Cutting machine: speed 10003000 rpm ± 100 rpm, coolant flow rate >1 L/min ± 0.1 L/min.
Mounting machine: temperature 150°C ± 5°C, pressure 2000 psi ± 100 psi (13.8 MPa ± 0.7 MPa).
Polishing machine: speed 100500 rpm ± 10 rpm, abrasive particle size 19 μm ± 0.1 μm.

5.3 Etching equipment:
Chemically etched containers: Acid-resistant glass or plastic, capacity >100 mL ± 10 mL.

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Electrolytic etching device: DC power supply, voltage 0.50 V ± 0.1 V, current 0.5 A ± 0.01 A.

Fume hood: air velocity > 0.5 m/s ± 0.05 m/s.

5.4 Cleaning equipment:

Ultrasonic cleaner: frequency 40 kHz ± 1 kHz, power >100 W ± 10 W.

5.5 Safety equipment:

Protective gloves: chemical resistant, thickness >0.5 mm ± 0.05 mm.

Protective eyewear: Conforms to ANSI Z87.1.

6. Specimens

6.1 Specimen type:

Materials: carbide (such as WCC), steel, aluminum alloy, etc.

Dimensions: Diameter or side length 0.51.5 inches ± 0.01 inches (12.738.1 mm ± 0.25 mm), thickness >0.1 inches ± 0.01 inches (>2.54 mm ± 0.25 mm).

6.2 Surface requirements:

Polished to a mirror finish with a surface roughness of Ra <4 μin ± 0.4 μin (0.1 μm ± 0.01 μm).

No scratches (<0.001 in. ± 0.0001 in., <0.025 mm ± 0.0025 mm) or porosity (<0.5% ± 0.05%).

6.3 Quantity:

Each batch shall contain at least one specimen representing the same material condition (sintering temperature deviation <10°C ± 1°C).

7. Sample Preparation

7.1 Cutting:

7.1.1 Use a diamond or aluminum oxide cutting wheel (speed 2000 rpm ± 100 rpm) with a coolant flow rate >1 L/min ± 0.1 L/min.

7.1.2 Ensure that the cut surface is flat (deviation < 0.01 inch, < 0.25 mm) and has no heat-affected zone (< 0.001 inch, < 0.025 mm).

7.2 Mounting:

7.2.1 Use hot mounting resin (150°C ± 5°C, 2000 psi ± 100 psi, 13.8 MPa ± 0.7 MPa) and cool to room temperature (23°C ± 2°C).

7.2.2 Verify that the specimen is secure and free of air bubbles (<0.01 in., <0.25 mm).

7.3 Polishing:

7.3.1 Use silicon carbide sandpaper (grit size 2401200, increasing), a rotation speed of 200 rpm ± 10 rpm, and a water flow rate >0.5 L/min ± 0.1 L/min.

7.3.2 Polish for 12 min ± 0.1 min per level, rotating the specimen 90° ± 5° to ensure that there are no scratches

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(<0.001 inch, <0.025 mm).

7.4 Polishing:

7.4.1 Use a polishing machine (300 rpm ± 10 rpm) and diamond abrasive (9 μm to 1 μm ± 0.1 μm).

7.4.2 Polish to Ra < 4 μin ± 0.4 μin (0.1 μm ± 0.01 μm). Inspect the surface (magnifying glass, 10× ± 1×).

7.5 Cleaning:

7.5.1 Place the sample in ethanol (purity >99.5% ± 0.1%) and ultrasonically clean (40 kHz ± 1 kHz, 5 min ± 0.1 min).

7.5.2 Wipe with a dust-free cloth to confirm that no residue remains (<0.0001 g ± 0.00001 g).

8. Safety Precautions

8.1 Chemical Handling:

8.1.1 Prepare and use etchants (e.g., Murakami's reagent) in a fume hood (air velocity > 0.5 m/s ± 0.05 m/s).

8.1.2 Wear protective gloves (thickness > 0.5 mm ± 0.05 mm) and safety glasses (ANSI Z87.1).

8.2 Electrolytic Etching:

8.2.1 Ensure the power supply is insulated (resistance > 1 MΩ ± 0.1 MΩ) and avoid short circuits (current < 0.01 A ± 0.001 A).

8.2.2 Use low voltage (< 50 V ± 0.1 V) to prevent electric shock.

8.3 Waste Liquid Disposal:

8.3.1 Collect and dispose of etching waste liquid in accordance with local regulations (e.g. acid pH <2 ± 0.1) and avoid environmental pollution (<0.001% ± 0.0001%).

9. Etching step

9.1 Selecting an etchant:

9.1.1 Select an etchant based on the material (see Appendix A). For cemented carbide, Murakami's reagent (10 g $K_3Fe(CN)_6$ + 10 g KOH + 100 mL H_2O) is recommended .

9.2 Prepare the etchant:

9.2.1 Prepare in a fume hood, ensuring chemical purity (>99% ± 0.1%) and measuring accuracy (±1 mL, ±0.1 g).

9.2.2 Mix thoroughly and maintain at 2025°C ± 1°C.

9.3 Chemical Etching:

9.3.1 Immerse the specimen in the etchant (depth > 0.1 in., > 2.54 mm) for 560 s ± 1 s with gentle agitation (frequency 1 Hz ± 0.1 Hz).

9.3.2 Remove the specimen and immediately rinse it with running water (> 1 L/min ± 0.1 L/min) for 10 s ± 1 s.

9.4 Electrolytic etching (if applicable):

9.4.1 Use the sample as the anode, stainless steel as the cathode, and electrolyte (e.g., 10% NaOH).

9.4.2 Set the voltage (612 ± 0.1 V) and current density (0.11 A/cm²). ± 0.01A/cm²) , time 530 s ± 1 s.

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9.4.3 Rinse the specimen (running water, 10 s ± 1 s).

9.5 Drying:

9.5.1 Dry with hot air (50°C ± 5°C) for 10 s ± 1 s, ensuring that no water marks remain (<0.001 in., <0.025 mm).

9.6 Observation:

9.6.1 Use a metallographic microscope (50×1000× ± 10×) and adjust the illumination (>500 lx ± 50 lx).

9.6.2 Inspect grain boundaries (<1 μm ± 0.1 μm), phase distribution, and defects (<0.1 μm ± 0.01 μm).

9.6.3 If etching is insufficient (features are unclear, <0.1 μm ± 0.01 μm), repeat etching (increase the etching time by 5 s ± 1 s).

10. Report

10.1 The report should include the following:

10.1.1 Standard Number: ASTM E40707(2015).

10.1.2 Specimen Description: Material (e.g., WC10Co), Dimensions (±0.01 in., ±0.25 mm), Quantity (≥1).

10.1.3 Preparation Conditions: Cutting, Mounting, Grinding, and Polishing (Ra <4 μin ± 0.4 μin, <0.1 μm ± 0.01 μm).

10.1.4 Etching Conditions: Etching Agent (e.g., Murakami's Reagent), Formula (±1 mL, ±0.1 g), Time (±1 s), Method (Chemical or Electrolytic).

10.1.5 Observation Equipment: Microscope Model, Magnification (50×1000× ± 10×).

10.1.6 Results: Description of Microstructural Characteristics (e.g., Grain Size <1 μm ± 0.1 μm, Phase Distribution Uniformity <5% ± 0.5%).

10.1.7 Notes: Abnormal conditions (e.g., overetching > 1 μm ± 0.1 μm, defects > 0.1 μm ± 0.01 μm).

11. Precision and Bias

11.1 Repeatability:

11.1.1 The microstructural characteristics of multiple etchings performed by the same operator, equipment, and specimens should be consistent (deviation < 5% ± 0.5%).

11.2 Reproducibility:

11.2.1 The deviation of microstructural characteristics between different laboratories and operators is <10% ± 1%.

11.3 Sources of Deviation:

Polishing quality: Ra >4 μin (>0.1 μm ± 0.01 μm), contribution <5% ± 0.5%.

Etching time: ±1 s, contribution <3% ± 0.3%.

Etchant concentration: ±1 mL, ±0.1 g, contribution <2% ± 0.2%.

12. Appendix A Etching Agent Formula

A1 Recommended etchant for cemented carbide: Murakami's Reagent:

Recipe: 10 g $K_3Fe(CN)_6$ ± 0.1 g, 10 g KOH ± 0.1 g, 100 mL H_2O ± 1 mL.

Method: Chemical etching, immersion 560 s ± 1 s, temperature 2025°C ± 1°C.

Purpose: Reveal WC grain boundaries (<1 μm ± 0.1 μm) and Co phase.

Electrolytic etching (optional): Electrolyte: 10% NaOH (10 g NaOH ± 0.1 g + 100 mL H_2O ± 1 mL).

Conditions: Voltage 612 V ± 0.1 V, Current density 0.10.5 A/ cm^2 ± 0.01 A/cm^2 , time 520 s ± 1 s.

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Purpose: Enhance WCCo relative contrast (<0.1 μm ± 0.01 μm).

A2 Other materials (example):

2 mL HNO_3 ± 0.1 mL + 98 mL ethanol ± 1 mL), immersion time 1030 s ± 1 s.

Aluminum alloy: Keller reagent (1 mL HF ± 0.1 mL + 1.5 mL HCl ± 0.1 mL + 2.5 mL HNO_3 ± 0.1 mL + 95 mL H_2O ± 1 mL), immersion time 1020 s ± 1 s.

13. Keywords

13.1 Cemented carbide; microetching; microstructure; grain boundary; phase distribution; Murakami's reagent.

ASTM G6516

Test Method for Measuring Abrasive Wear Using a Dry Sand/Rubber Wheel Device

Test method for measuring abrasive wear using a dry sand/rubber wheel apparatus

1. Scope

1.1 This test method specifies the resistance of cemented carbide and other materials to abrasive wear using a dry sand/rubber wheel apparatus. This method is applicable to cemented carbide (consisting primarily of tungsten carbide, WC, with a metallic binder such as cobalt, Co) used in mining tools, cutting tools, and wear-resistant components.

1.2 This method evaluates the resistance to wear by measuring the volume loss (mm^3 or in^3) of a specimen under specified abrasive (silica sand), load, and number of revolutions . Typical volume loss ranges from 1 to 100 mm^3 . ± 0.5 mm^3 (0.00006 to 0.006 in^3) ± 0.00003 in^3) .

1.3 This method provides five test procedures (A to E) suitable for low-stress or high-stress wear conditions, depending on the load (50130 N ± 1 N), number of revolutions (1006000 revolutions ± 10 revolutions), and abrasive flow rate (200400 g/min ± 10 g/min).

1.4 This method is not suitable for coated materials (thickness > 0.1 mm ± 0.01 mm), materials with a porosity > 1% ± 0.1%, or soft materials (hardness < HV 200 ± 10). The results may be affected by the surface condition of the specimen (Ra > 3.2 μm ± 0.3 μm).

1.5 The values stated in metric units are to be regarded as standard. The values stated in parentheses for imperial units are obtained by mathematical conversion and are for reference only.

1.6 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations.

2. Reference Documents

2.1 ASTM Standards:

E11 Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves: Specifies standard sieves for abrasive sieving to ensure abrasive grit size (0.2120.3 mm ± 0.01 mm).

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E177 Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods: Defines the terms precision and bias for use in evaluating test results (error <5% ± 0.5%).

E691 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method: Guides interlaboratory studies to ensure repeatability and reproducibility (bias <5% ± 0.5%).

G40 Standard Terminology Relating to Wear and Erosion: Defines wear-related terms, including abrasive wear and volume loss.

3. Terminology

3.1 Definitions:

3.1.1 Cemented Carbide: A composite material made by sintering tungsten carbide (WC, content >85% ± 1%) and a metal binder (such as cobalt, 6%15% ± 1%), with a hardness of HV 10002000 ± 30.

3.1.2 Abrasive Wear: Material loss caused by contact and relative motion between the material surface and hard abrasives (such as silica sand).

3.1.3 Volume Loss: The volume of material lost by the specimen after the wear test, expressed in mm^3 or in^3 , with an accuracy of ±0.5 mm^3 (±0.00003 in^3) .

3.1.4 Abrasion Resistance: The ability of a material to resist abrasive wear, expressed as the inverse of the volume loss of the specimen (1/volume loss , mm^{-3} or in^{-3}) .

3.1.5 Dry Sand/Rubber Wheel Test: An abrasion test performed using a rotating rubber wheel (hardness Shore A 60 ± 2) and dry silica abrasive (0.2120.3 mm ± 0.01 mm).

4. Significance and Use

4.1 This test method is used to evaluate the performance of cemented carbide and other materials under abrasive wear conditions and is suitable for the following applications:

4.1.1 Comparison of wear resistance of different material grades (e.g. WC6Co and WC10Co, volume loss 1100 mm^3 ± 0.5 mm^3) .

4.1.2 Quality control to ensure that the material meets the wear resistance requirements (volume loss <100 mm^3 ± 0.5 mm^3) .

4.1.3 Material selection, guidance for wear-resistant components (e.g. mining tools).

4.2 This method simulates low-stress or high-stress wear environments (e.g., sand-stone contact, abrasive flow rate 200-400 g/min ± 10 g/min) and provides standardized test conditions (load 50-130 N ± 1 N) to ensure repeatable results (deviation <5% ± 0.5%).

5. Equipment

5.1 Wear tester (Dry Sand/Rubber Wheel Apparatus):

Rubber wheel: diameter 9 inches ± 0.1 inches (228.6 mm ± 2.54 mm), width 0.5 inches ± 0.01 inches (12.7 mm ± 0.25 mm), hardness Shore A 60 ± 2.

Rotation speed: 200 rpm ± 5 rpm.

Load: 50 N ± 1 N or 130 N ± 1 N (11.24 lbf ± 0.22 lbf or 29.22 lbf ± 0.22 lbf).

Abrasive supply system: flow rate 200400 g/min ± 10 g/min.

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5.2 Specimen grips:

Secure the specimen so that the contact surface is parallel to the rubber wheel (deviation <0.01 in, <0.25 mm).

Adjustment device: Maintain a constant load (50130 N ± 1 N).

5.3 Balance

Accuracy: ±0.0001 g.

Capacity: >100 g.

5.4 Screening equipment:

Standard sieve: Conforms to ASTM E11, apertures 0.212 mm and 0.3 mm ± 0.01 mm.

5.5 Drying Oven:

Temperature: 100°C ± 5°C.

Application: Drying abrasives (moisture content <0.1% ± 0.01%).

5.6 Cleaning Equipment:

Ultrasonic cleaner, frequency 40 kHz ± 1 kHz, power >100 W ± 10 W.

6. Specimens

6.1 Specimen type:

Shape: rectangular or round.

Dimensions: Length 3 inches ± 0.05 inches (76.2 mm ± 1.27 mm), width or diameter 1 inch ± 0.01 inches (25.4 mm ± 0.25 mm), thickness 0.250.5 inches ± 0.01 inches (6.3512.7 mm ± 0.25 mm).

6.2 Surface requirements:

The test surface is flat, with a surface roughness of Ra <125 μin ± 12.5 μin (3.2 μm ± 0.3 μm).

No visible cracks (<0.001 in. ± 0.0001 in., <0.025 mm ± 0.0025 mm) or porosity (<1% ± 0.1%).

6.3 Quantity:

Each batch shall consist of at least 3 specimens representing the same material conditions (sintering temperature deviation <10°C ± 1°C).

7. Sample Preparation

7.1 Surface Preparation:

7.1.1 Using sandpaper (grit 240600) or a grinding device, prepare the test surface to an Ra of <125 μin ± 12.5 μin (3.2 μm ± 0.3 μm).

7.1.2 Inspect the surface (magnifying glass, 10× ± 1×) to ensure that there are no scratches (<0.001 in. ± 0.0001 in., <0.025 mm ± 0.0025 mm).

7.2 Cleaning:

7.2.1 Place the specimen in ethanol (purity >99.5% ± 0.1%) and ultrasonically clean (40 kHz ± 1 kHz, 5 min ± 0.1

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min).

7.2.2 Wipe with a dust-free cloth to ensure there is no oil contamination (<0.0001 g ± 0.00001 g).

7.3 Drying:

7.3.1 Place in a drying oven (100°C ± 5°C) for 30 min ± 1 min.

7.3.2 Cool to room temperature (23°C ± 2°C) to ensure that the moisture content is <0.1% ± 0.01%.

7.4 Weighing:

7.4.1 Weigh the initial mass of the sample (m_1, ±0.0001 g) using a balance (± 0.0001 g) and repeat three times with a deviation of <0.0001 g.

8. Abrasive

8.1 Type

Silica sand (SiO_2 , purity >99% ± 0.1%), round or semi-angular particles.

8.2 Granularity:

Range: 0.2120.3 mm ± 0.01 mm (5070 mesh).

Sieving: Use 0.212 mm and 0.3 mm standard sieves conforming to ASTM E11.

8.3 Preparation:

8.3.1 Place the abrasive in a drying oven (100°C ± 5°C) and dry for 1 h ± 0.1 h.

8.3.2 Cool to room temperature (23°C ± 2°C) and ensure that the moisture content is < 0.1% ± 0.01%.

8.4 Storage:

8.4.1 Store in sealed containers to prevent contamination (<0.1% ± 0.01%).

9. Experimental Procedure

9.1 Environmental conditions:

Temperature: 73°F ± 3.6°F (23°C ± 2°C).

Humidity: 30%70% ± 5%.

9.2 Equipment Calibration:

9.2.1 Calibrate the testing machine, confirming the rubber wheel speed (200 rpm ± 5 rpm) and load (50130 N ± 1 N).

9.2.2 Inspect the rubber wheel surface (Shore A 60 ± 2) for wear (<0.01 in., <0.25 mm).

9.2.3 Calibrate the balance (±0.0001 g), with an error of <0.0001 g.

9.3 Test procedure:

9.3.1 Select the test procedure (A to E, see Table 1):

Procedure A: 130 N ± 1 N, 6000 rpm ± 10 rpm, flow rate 300400 g/min ± 10 g/min, high stress, long-term wear.

Procedure B: 130 N ± 1 N, 2000 rpm ± 10 rpm, flow rate 300-400 g/min ± 10 g/min, high stress, short-term wear.

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Procedure C: 130 N ± 1 N, 100 rpm ± 10 rpm, flow rate 300–400 g/min ± 10 g/min, initial wear.

Procedure D: 50 N ± 1 N, 2000 rpm ± 10 rpm, flow rate 200300 g/min ± 10 g/min, low stress wear.

Procedure E: 130 N ± 1 N, 1000 rpm ± 10 rpm, flow rate 300-400 g/min ± 10 g/min, moderate abrasion.

Table 1: Test procedure parameters

program	Load (N)	Revolutions	Flow rate (g/min)	use
A	130 ± 1	6000 ± 10	300400 ± 10	High stress, long term
B	130 ± 1	2000 ± 10	300400 ± 10	High stress, short term
C	130 ± 1	100 ± 10	300400 ± 10	Initial wear
D	50 ± 1	2000 ± 10	200300 ± 10	Low stress
E	130 ± 1	1000 ± 10	300400 ± 10	Moderate wear

9.4 Specimen Installation:

9.4.1 Secure the specimen to the fixture so that the test surface (Ra <125 μin ± 12.5 μin, <3.2 μm ± 0.3 μm) contacts the rubber wheel with a parallelism of <0.01 in. (<0.25 mm).

9.4.2 Adjust the fixture to ensure uniform load (50130 N ± 1 N).

9.5 Test Procedure:

9.5.1 Start the rubber wheel (200 rpm ± 5 rpm) and supply dry sand (flow rate 200-400 g/min ± 10 g/min).

9.5.2 Apply the load (according to procedures AE) and run for the specified number of revolutions (1,000-6,000 rpm ± 10 rpm).

9.5.3 Stop the test and remove the specimen.

9.6 Specimen Preparation:

9.6.1 Ultrasonic clean the specimen in ethanol (5 min ± 0.1 min) to remove any abrasive residue (<0.0001 g ± 0.00001 g).

9.6.2 Dry in a drying oven (100°C ± 5°C) for 30 min ± 1 min and cool to room temperature (23°C ± 2°C).

9.6.3 Weigh the final mass of the specimen (m_2 , ±0.0001 g). Repeat three times with a tolerance of <0.0001 g.

9.7 Replicate Tests:

9.7.1 Test three specimens from each batch and record the initial and final masses (± 0.0001 g).

10. Calculation

10.1 Mass loss:

10.1.1 Calculate the mass loss of the specimen (Δm):

$$\Delta m = m_1 - m_2$$

Δm: mass loss (g, ±0.0001 g).

m_1 : initial mass (g, ±0.0001 g).

m_2 : Final mass (g, ±0.0001 g).

10.2 Volume loss:

10.2.1 Calculation of volume loss (V):

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$$V = \frac{\Delta m}{\rho}$$

V: Volume loss (mm³ or in³ , ±0.5 mm³ , ±0.00003 in³) .

Δm: mass loss (g, ±0.0001 g).

ρ: density of the specimen (g/cm³ , ±0.1 g/cm³) , provided by the manufacturer or determined separately (1 cm³ = 1000 mm³) .

10.2.2 Imperial units (in³) :

$$V(\text{in}^3) - \frac{\Delta m}{\rho \times 16.387}$$

ρ: g/ cm³ , ±0.1 g/ cm³ .

16.387: Factor used to convert cm³ to in³ .

10.3 Wear resistance:

10.3.1 Calculation of wear resistance (R):

$$R = \frac{1}{V}$$

R: Wear resistance (mm $^{-3}$ or in $^{-3}$, ±5% ± 0.5%).

V: Volume loss (mm³ or in³ , ±0.5 mm³ , ±0.00003 in³) .

10.4 Mean and Deviation:

10.4.1 Calculate the volume loss (V) and wear resistance (R) for three specimens and take the mean value (±0.5 mm³ , ±0.00003 in³) .

10.4.2 Calculate the standard deviation (<0.5 mm³ , <0.00003 in³) .

10.4.3 If any deviation in V is >1 mm³ (>0.00006 in³) , inspect the specimen for defects (e.g., porosity >1% ±0.1%) or abrasive grit size (>0.3 mm ±0.01 mm).

11. Report

11.1 The report should include the following:

11.1.1 Standard number: ASTM G6516.

11.1.2 Specimen description: Batch, composition (e.g., WC10Co), dimensions (± 0.01 in., ± 0.25 mm), density (± 0.1 g/cm³) , number (≥ 3).

11.1.3 Test conditions: Temperature (73°F ± 3.6°F, 23°C ± 2°C), humidity (30% to 70% ± 5%), procedure (AE), load (50 to 130 N ± 1 N), rotation speed (200 rpm ± 5 rpm), number of revolutions (1,000 to 6,000 rpm ± 10 rpm).

11.1.4 Abrasive information: Type (silica sand), grit size (0.2 to 20.3 mm ± 0.01 mm), flow rate (200 to 400 g/min ± 10 g/min).

11.1.5 Equipment Information: Rubber wheel diameter (9 in ± 0.1 in, 228.6 mm ± 2.54 mm), hardness (Shore A 60 ± 2).

11.1.6 Test Data: Initial mass (± 0.0001 g), final mass (± 0.0001 g), volume loss (± 0.5 mm³ , ± 0.00003 in³) , wear resistance (± 5% ± 0.5%).

11.1.7 Results : Average volume loss (mm³ and in³ , ± 0.5 mm³ , ± 0.00003 in³) , average wear resistance (mm^{-3} and in^{-3} , ± 5% ± 0.5%), standard deviation (< 0.5 mm³ , < 0.00003 in³) .

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11.1.8 Notes: Abnormal conditions (e.g. porosity > 1% ± 0.1%, abrasive contamination > 0.1% ± 0.01%).

12. Precision and Bias

12.1 Repeatability:

12.1.1 The volume loss deviation between three tests performed by the same operator, equipment, and batch is <0.5 mm^3 (<0.00003 in^3) .

12.2 Reproducibility: 12.2.1 The volume loss should vary by <1

mm^3 (<0.00006 in^3) between different laboratories and operators .

12.3 Sources of Deviation:

Mass measurement: ±0.0001 g, contribution <0.2 mm^3 (<0.00001 in^3) .

Density measurement: ±0.1 g/cm^3 , contribution <0.3 mm^3 (<0.00002 in^3) .

Abrasive flow rate: ±10 g/min, contribution <0.2 mm^3 (<0.00001 in^3) .

Load control: ±1 N, contribution <0.1 mm^3 (<0.000006 in^3) .

13. Keywords

13.1 Carbide; abrasive wear; dry sand/rubber wheel; volume loss; wear resistance.

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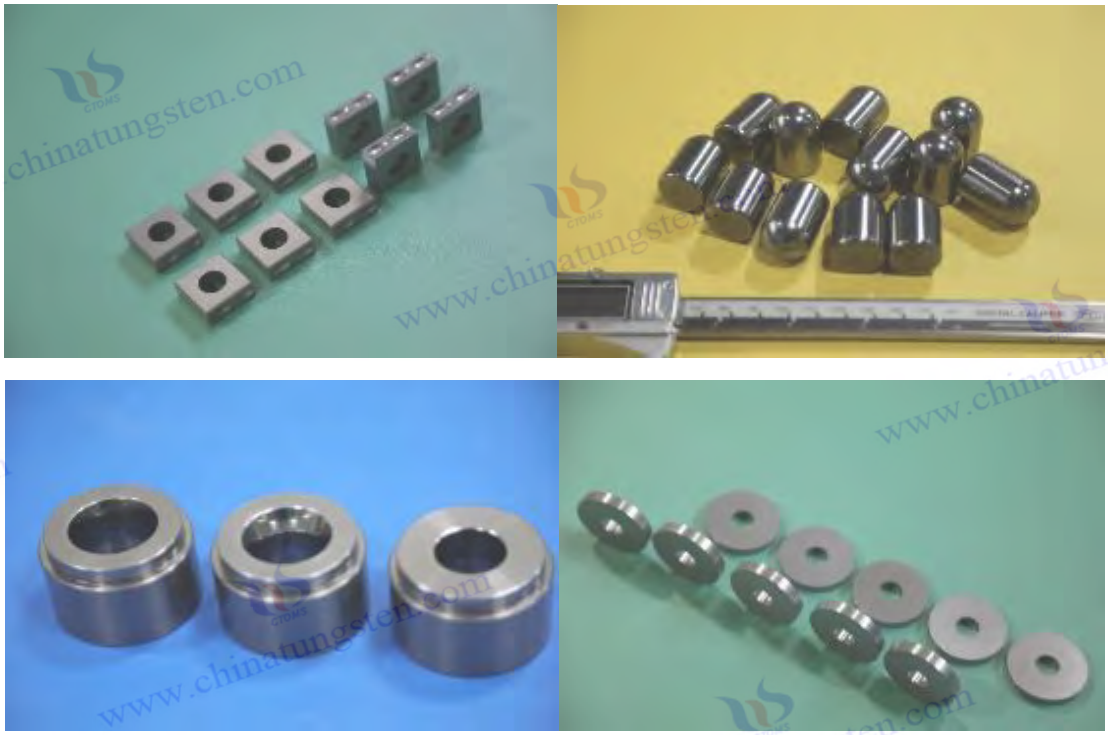
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China National Standard (GB) Cemented Carbide Standard

GB/T 183762014

Classification and properties of cemented carbide tool materials

Classification and Properties of Cemented Carbide Cutting Tool Materials

1 Scope

This standard specifies the classification method of cemented carbide tool materials and their performance requirements, including physical properties, mechanical properties and cutting performance.

This standard applies to the design, production and acceptance of cemented carbide tool materials for cutting processing, covering tool materials for turning, milling, drilling and boring.

This standard does not apply to cemented carbides for non-cutting purposes (such as wear-resistant parts, mining tools).

2 Normative references

The following documents are essential for the application of this document. For any dated referenced document, only the dated version applies to this document. For any undated referenced document, the latest version (including all amendments) applies to this document.

GB/T 228.1:2010 Tensile testing of metallic materials Part 1: Room temperature test method

GB/T 230.1:2009 Rockwell hardness test for metallic materials—Part 1: Test method (A, B, C, D, E, F, G, H, K, N, T scales)

GB/T 7997:2012 Test method for Vickers hardness of cemented carbide

GB/T 183752001 Test method for density of cemented carbide

GB/T 18377-2001 Test method for flexural strength of cemented carbide

GB/T 18378-2001 Methods for observing the microstructure of cemented carbide

3 Terms and Definitions

The following terms and definitions apply to this document.

3.1 Cemented Carbide Cutting Tool Material

A material made of tungsten carbide (WC, content >85% ± 1%) as the main component, with the addition of metal binder phase (such as cobalt, Co, 6%15% ± 1%) and other carbides (such as TiC, TaC), sintered by powder metallurgy method, and used for cutting processing.

3.2 Classification

According to the chemical composition, microstructure and cutting performance of cemented carbide, it is divided into different categories (such as P, M, K).

3.3 Physical Properties

These include density (g/cm³ , ±0.1 g/cm³) , hardness (HRA or HV, ±30) and microstructural characteristics (such

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as grain size <1 μm ± 0.1 μm).

3.4 Mechanical Properties

Including flexural strength (MPa, ±50 MPa) and fracture toughness (MPa·m ¹ / ² , ±0.5 MPa·m ¹ / ²).

3.5 Cutting Performance

Wear resistance (wear loss <0.3 mm ± 0.01 mm) and chipping resistance (chipping depth <0.1 mm ± 0.01 mm) of cemented carbide under specific cutting conditions (e.g. cutting speed 100-300 m/min ± 10 m/min).

4 Categories

4.1 Classification Principles

Cemented carbide tool materials are divided into the following three categories according to their main chemical composition and applicable processing materials:

4.1.1 P type (ISO P)

is based on WC and Co, containing small amounts of TiC and TaC, and is suitable for machining steel, cast steel and long-chip malleable cast iron.

4.1.2 Type M (ISO M)

is based on WC and Co, and contains appropriate amounts of TiC, TaC and other carbides. It is suitable for machining stainless steel, cast steel, manganese steel and alloy steel.

4.1.3 Type K (ISO K)

has a WC and Co matrix and contains very little or no other carbides. It is suitable for machining cast iron, chilled cast iron, nonferrous metals and non-metallic materials.

4.2 Subcategories

Each type is subdivided into multiple grades according to Co content (6%15% ± 1%) and grain size (<1 μm ± 0.1 μm to 5 μm ± 0.5 μm), such as P10, P20, K10, K20, etc.

4.3 Brand designation

The grade consists of a category letter (P, M, K) and two digits (0050, step 10). The smaller the number, the higher the hardness (HRA >90 ± 0.5) and the better the wear resistance (wear loss <0.2 mm ± 0.01 mm); the larger the number, the higher the toughness (fracture toughness >10 MPa·m ¹ / ²). ± 0.5 MPa · m¹ / ²) .

5 Performance requirements

5.1 Physical properties

5.1.1 Density

P type: 13.515.0 g/ cm³ ± 0.1 g/ cm³ .

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Class M: 12.514.5 g/ cm³ ± 0.1 g/ cm³ .

Class K: 14.015.5 g/ cm³ ± 0.1 g/ cm³ .

5.1.2 Hardness

Category P: HRA 8993 ± 0.5 or HV 13001800 ± 30.

Class M: HRA 8892 ± 0.5 or HV 12001700 ± 30.

Category K: HRA 8791 ± 0.5 or HV 11001600 ± 30.

5.1.3 Microstructure

No free carbon (<0.01% ± 0.001%) or eta phase (<0.01% ± 0.001%).

Porosity: <0.5% ± 0.05%, pore size <10 μm ± 1 μm.

Grain size: P type <1 μm ± 0.1 μm, M type 13 μm ± 0.3 μm, K type 15 μm ± 0.5 μm.

5.2 Mechanical properties

5.2.1 Flexural strength

Class P: 15002500 MPa ± 50 MPa.

Class M: 18002800 MPa ± 50 MPa.

Class K: 20003000 MPa ± 50 MPa.

5.2.2 Fracture toughness

P class: 812 MPa·m ¹ / ² ± 0.5 MPa · m¹ / ² .

Class M: 1014 MPa·m ¹ / ² ± 0.5 MPa · m¹ / ² .

Class K: 1216 MPa·m ¹ / ² ± 0.5 MPa · m¹ / ² .

5.3 Cutting performance

5.3.1 Wear resistance

Test conditions: cutting speed 100300 m/min ± 10 m/min, feed rate 0.10.3 mm/r ± 0.01 mm/r, cutting depth 12 mm ± 0.1 mm.

Flank wear (VB): P type <0.2 mm ± 0.01 mm, M type <0.25 mm ± 0.01 mm, K type <0.3 mm ± 0.01 mm.

5.3.2 Chipping resistance

Chipping depth: <0.1 mm ± 0.01 mm (impact test, load 1000 N ± 10 N).

6 Test methods

6.1 Physical properties

6.1.1 Density

shall be determined in accordance with GB/T 18375-2001 with an accuracy of ±0.1 g/ cm³ .

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6.1.2 Hardness

Rockwell hardness: measured according to GB/T 230.12009, HRA scale, load 60 kg ± 0.1 kg.

Vickers hardness: measured according to GB/T 7997-2012, load 30 kg ± 0.1 kg, accuracy ±30 HV.

6.1.3 Microstructure The microstructure

shall be determined in accordance with GB/T 18378-2001 using a metallographic microscope (magnification 500×1500×±10×) to examine the porosity (<0.5%±0.05%) and grain size (<5 μm±0.5 μm).

6.2 Mechanical properties

6.2.1 The flexural strength

shall be determined in accordance with GB/T 18377-2001. The specimen size shall be 5 mm × 5 mm × 35 mm ± 0.1 mm, the span shall be 30 mm ± 0.1 mm, and the accuracy shall be ±50 MPa.

6.2.2 Fracture toughness

shall be determined by the single-edge pre-cracked beam (SEPB) method with a specimen size of 4 mm × 8 mm × 36 mm ± 0.1 mm and an accuracy of ±0.5 MPa·m $^{1/2}$.

6.3 Cutting performance

6.3.1 Wear resistance

was tested by turning. The workpiece material was standard steel or cast iron. The cutting speed was 100-300 m/min ± 10 m/min, the feed rate was 0.10.3 mm/r ± 0.01 mm/r, and the cutting depth was 12 mm ± 0.1 mm. The flank wear (VB, ±0.01 mm) was measured.

6.3.2 Chipping resistance:

An interrupted cutting test is conducted with an impact load of 1000 N ± 10 N and the chipping depth is measured (±0.01 mm).

7 Inspection Rules

7.1 Inspection categories

Factory inspection: Each batch is tested for density, hardness and microstructure.

Type inspection: All properties (physical, mechanical, cutting) are inspected every six months or when the material formula is changed.

7.2 Sampling

Five specimens were randomly selected from each batch, representing the same sintering conditions (temperature deviation <10°C ± 1°C).

Three specimens were taken for cutting performance test.

7.3 Decision Rules

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All specimens meet the requirements of 5.15.3 and are deemed qualified.

If any sample fails to meet the standards, double sampling and re-inspection will be carried out. If it still fails to meet the standards, the entire batch will be judged as unqualified.

7.4 Re-inspection

Re-inspection of unqualified items is allowed once, and the batch is qualified if the re-inspection is qualified.

8 Appendix

Appendix A (Normative Appendix) Properties of Typical Grades of Cemented Carbide Tool Materials

A.1 P -type grades

P10: density 14.014.5 g/ cm³ ± 0.1 g/ cm³ , HRA 9192 ± 0.5, flexural strength 16001800 MPa ± 50 MPa, suitable for high-speed finishing (cutting speed 200300 m/min ± 10 m/min).

P20: density 13.814.3 g/ cm³ ± 0.1 g/ cm³ , HRA 9091 ± 0.5, flexural strength 1800-2000 MPa ± 50 MPa, suitable for medium-speed machining (cutting speed 150-250 m/min ± 10 m/min).

A.2 M-type grades

M10: density 13.013.5 g/ cm³ ± 0.1 g/ cm³ , HRA 9091 ± 0.5, flexural strength 1900-2100 MPa ± 50 MPa, suitable for finishing of stainless steel (cutting speed 100-200 m/min ± 10 m/min).

M20: density 12.813.3 g/ cm³ ± 0.1 g/ cm³ , HRA 8990 ± 0.5, flexural strength 20002200 MPa ± 50 MPa, suitable for medium-speed machining (cutting speed 80150 m/min ± 10 m/min).

A.3 K-type grades

K10: density 14.515.0 g/ cm³ ± 0.1 g/ cm³ , HRA 9091 ± 0.5, flexural strength 22002400 MPa ± 50 MPa, suitable for cast iron finishing (cutting speed 150250 m/min ± 10 m/min).

K20: density 14.314.8 g/ cm³ ± 0.1 g/ cm³ , HRA 8990 ± 0.5, flexural strength 24002600 MPa ± 50 MPa, suitable for medium-speed machining (cutting speed 100200 m/min ± 10 m/min).

Appendix B (Informative Appendix) Supplementary Notes on Test Methods

B.1 Hardness test

Vickers hardness (HV) is preferred because it is more accurate for cemented carbides (±30 HV).

Rockwell hardness (HRA) is suitable for rapid testing with an error of <0.5 HRA.

B.2 Microstructure Observation

Scanning electron microscopy (SEM, magnification >1000× ± 10×) is recommended to examine pores (<10 μm ± 1 μm) and η phase (<0.01% ± 0.001%).

B.3 Cutting performance test

The surface roughness of the test workpiece is Ra <1.6 μm ± 0.1 μm, ensuring test consistency (wear deviation <0.01 mm).

9 Keywords

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Cemented carbide; tool material; classification; performance; cutting performance; bending strength; hardness; microstructure.

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GB/T 345062017

Hardness and microstructure testing of cemented carbide

Test Methods for Hardness and Microstructure of Cemented Carbides

1 Scope

This standard specifies the hardness test methods (including Rockwell hardness and Vickers hardness) and microstructure test methods (including grain size, porosity and phase distribution) of cemented carbide.

This standard applies to the hardness and microstructural performance testing of cemented carbide materials (with tungsten carbide, WC, and metal binder phases such as cobalt, Co, as the main components) and is used for quality control and acceptance in the fields of cutting tools, molds, wear-resistant parts, etc.

This standard does not apply to non-carbide materials (such as ceramics, steel) or coated carbide (coating thickness > 0.1 mm ± 0.01 mm).

2 Normative references

The following documents are essential for the application of this document. For any dated referenced document, only the dated version applies to this document. For any undated referenced document, the latest version (including all amendments) applies to this document.

GB/T 230.1:2009 Rockwell hardness test for metallic materials—Part 1: Test method (A, B, C, D, E, F, G, H, K, N, T scales)

GB/T 4340.1:2009 Metallic materials Vickers hardness test Part 1: Test method

GB/T 183782001 Methods for observing the microstructure of cemented carbide

GB/T 3488:2015 Cemented carbide microstructure evaluation method

GB/T 183752001 Test method for density of cemented carbide

3 Terms and Definitions

The following terms and definitions apply to this document.

3.1 Cemented Carbide is a composite

material made of tungsten carbide (WC, content >85% ± 1%) as the main component, with the addition of metal binder phase (such as cobalt, Co, 6%15% ± 1%) and other carbides (such as TiC, TaC) through powder metallurgy sintering.

3.2 Rockwell hardness refers

to the surface hardness of cemented carbide measured in accordance with GB/T 230.1:2009, using the HRA scale, a load of 60 kg ± 0.1 kg, and an accuracy of ±0.5 HRA.

3.3 Vickers Hardness:

The surface hardness of cemented carbide measured in accordance with GB/T 4340.1:2009, using an HV scale, a load of 30 kg ± 0.1 kg, and an accuracy of ±30 HV.

3.4 Microstructure

The microstructural characteristics of cemented carbide, including grain size (<5 μm ± 0.5 μm), porosity (<0.5% ±

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0.05%), and phase distribution (such as WC and Co phases).

3.5 Grain Size:

The average size of tungsten carbide grains in cemented carbide, expressed in micrometers (μm), with an accuracy of ±0.1 μm.

3.6 Porosity:

The volume fraction of pores inside cemented carbide, expressed as a percentage (%), with an accuracy of ±0.05%.

3.7 Phase Distribution:

The spatial distribution ratio of each phase (such as WC, Co, and other carbides) in cemented carbide, with a deviation of <5% ± 0.5%.

4 Overview of test methods

4.1 Hardness test

Rockwell hardness (HRA): Suitable for rapid detection, testing surface hardness, suitable for production sites.

Vickers hardness (HV): Suitable for precise measurement, testing of surface and microstructure hardness, and suitable for laboratory analysis.

4.2 Microstructure testing

Grain size: The average size of WC grains was measured by metallographic microscope or scanning electron microscope (SEM).

Porosity: The pore distribution and volume fraction were observed by metallographic microscope.

Phase distribution: The proportions of WC, Co, and other phases were evaluated by microscopy or image analyzer.

5 Equipment

5.1 Hardness testing equipment

5.1.1 Rockwell hardness tester

Complies with GB/T 230.12009.

Scale: HRA, load 60 kg ± 0.1 kg.

Accuracy: ±0.5 HRA.

Diamond indenter: cone angle 120° ± 0.5°, tip radius 0.2 mm ± 0.01 mm.

5.1.2 Vickers hardness tester

Complies with GB/T 4340.1:2009.

Scale: HV30, load 30 kg ± 0.1 kg.

Accuracy: ±30 HV.

Diamond indenter: quadrangular pyramid, apex angle 136° ± 0.5°.

5.2 Microstructure testing equipment

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5.2.1 Metallographic microscope

Magnification: 100×1500×±10×.

Resolution: <0.1 μm ± 0.01 μm.

Lighting: Reflected light, brightness >500 lx ± 50 lx.

5.2.2 Scanning Electron Microscope (SEM, optional)

Magnification: 1000×5000×±100×.

Resolution: <0.01 μm ± 0.001 μm.

Equipped with an energy dispersive spectrometer (EDS) for phase analysis (accuracy ±1%).

5.2.3 Image Analyzer

Resolution: <0.1 μm ± 0.01 μm.

Software accuracy: porosity ±0.05%, phase distribution ±1%.

5.3 Sample preparation equipment

Cutting machine: speed 10003000 rpm ± 100 rpm, coolant flow rate >1 L/min ± 0.1 L/min.

Mounting machine: temperature 150°C ± 5°C, pressure 13.8 MPa ± 0.7 MPa.

Polishing machine: speed 100500 rpm ± 10 rpm, abrasive particle size 19 μm ± 0.1 μm.

Ultrasonic cleaner: frequency 40 kHz ± 1 kHz, power >100 W ± 10 W.

6. Samples

6.1 Specimen type

Material: Carbide (such as WCCo).

Shape: rectangular, circular or irregular, test surface area > 100 mm^2 ± 1 mm^2 .

Dimensions: thickness >2 mm ± 0.1 mm, length or diameter >10 mm ± 0.1 mm.

6.2 Surface requirements

Hardness test: surface roughness Ra <0.8 μm ± 0.08 μm, no scratches (<0.01 mm ± 0.001 mm).

Microstructure test: Polished to mirror surface, Ra <0.1 μm ± 0.01 μm, no pores (<0.5% ± 0.05%) or cracks (<0.01 mm ± 0.001 mm).

6.3 Quantity

Hardness test: at least 3 specimens per batch.

Microstructure testing: At least 2 specimens per batch, representing the same sintering conditions (temperature deviation <10°C ± 1°C).

7 Test steps

7.1 Sample preparation

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7.1.1 Cutting

Use a diamond cutting wheel (speed 2000 rpm ± 100 rpm) with a coolant flow rate >1 L/min ± 0.1 L/min.

Ensure that the test surface is flat (deviation < 0.01 mm) and has no heat-affected zone (< 0.01 mm ± 0.001 mm).

7.1.2 Mounting (microstructure testing)

Use hot mounting resin (150°C ± 5°C, 13.8 MPa ± 0.7 MPa) and cool to 23°C ± 2°C.

Verify that the specimen is secure and free of air bubbles (<0.01 mm ± 0.001 mm).

7.1.3 Polishing

Use silicon carbide sandpaper (grit 2401200, increasing), a rotation speed of 200 rpm ± 10 rpm, and a water flow rate of >0.5 L/min ± 0.1 L/min.

Each level of polishing takes 12 min ± 0.1 min, and the specimen is rotated 90° ± 5° to ensure that there are no scratches (<0.01 mm ± 0.001 mm).

7.1.4 Polishing (microstructure testing)

Use a polishing machine (300 rpm ± 10 rpm) with diamond abrasive (9 μm to 1 μm ± 0.1 μm).

Polish to Ra <0.1 μm ± 0.01 μm and inspect the surface (magnifying glass, 10× ± 1×).

7.1.5 Cleaning

Ultrasonic cleaning (40 kHz ± 1 kHz, 5 min ± 0.1 min) was performed in ethanol (purity >99.5% ± 0.1%).

Wipe with a lint-free cloth to confirm that there is no residue (<0.0001 g ± 0.00001 g).

7.2 Hardness test

7.2.1 Rockwell hardness (HRA)

The operation was carried out in accordance with GB/T 230.1:2009, with a scale of HRA, a load of 60 kg ± 0.1 kg, and a holding time of 10 s ± 1 s.

The test surface Ra is <0.8 μm ± 0.08 μm, and a flat area is selected (deviation <0.01 mm).

Each specimen was tested at 5 points with a spacing of >2 mm ± 0.1 mm and an edge distance of >1 mm ± 0.1 mm.

The HRA value (±0.5 HRA) was recorded at each point.

7.2.2 Vickers hardness (HV)

The operation was carried out in accordance with GB/T 4340.1:2009, with a scale of HV30, a load of 30 kg ± 0.1 kg, and a holding time of 15 s ± 1 s.

The test surface Ra is <0.8 μm ± 0.08 μm, and a flat area is selected (deviation <0.01 mm).

Each specimen was tested at 3 points with a spacing of >1 mm ± 0.1 mm and an edge distance of >0.5 mm ± 0.1 mm.

The indentation diagonal length was measured (accuracy ±0.1 μm) and the HV value was calculated (±30 HV).

7.3 Microstructure testing

7.3.1 Etching

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Use Murakami's reagent (10 g $K_3Fe(CN)_6$ ± 0.1 g + 10 g KOH ± 0.1 g + 100 mL H_2O ± 1 mL).

Immerse the specimen for 530 s ± 1 s, at a temperature of 2025°C ± 1°C, and gently stir (1 Hz ± 0.1 Hz).

Rinse with running water (>1 L/min ± 0.1 L/min) for 10 s ± 1 s and dry (hot air 50°C ± 5°C, 10 s ± 1 s).

7.3.2 Grain size

Use a metallographic microscope (1000× ± 10×) or SEM (2000× ± 100×).

According to GB/T 34882015, measure at least 100 WC grains (accuracy ±0.1 μm).

The average grain size was calculated (<5 μm ± 0.5 μm) and the distribution range was recorded (deviation <10% ± 1%).

7.3.3 Porosity

Using a metallographic microscope (500× ± 10×), observe 5 fields of view (area > 0.1 mm^2). ± 0.01 mm^2) .

According to GB/T 34882015, the pore volume fraction (<0.5% ± 0.05%) and the pore size <10 μm ± 1 μm were calculated.

Record the pore type (A, B, C, accuracy ±0.05%).

7.3.4 Phase distribution

Use a metallographic microscope (1000× ± 10×) or SEM (equipped with EDS).

Measures the area ratio of WC, Co and other phases (such as TiC) (accuracy ±1%).

The homogeneity of the phase distribution (deviation <5% ± 0.5%) and the absence of free carbon (<0.01% ± 0.001%) or η phase (<0.01% ± 0.001%) were recorded.

8 Result calculation and presentation

8.1 Rockwell hardness

The average HRA value of the five points (±0.5 HRA) was calculated and retained to one decimal place.

If the deviation of any point is >1 HRA, it will be eliminated and retested.

8.2 Vickers hardness

Calculate HV according to the formula:

$$HV = \frac{1.8544P}{d^2}$$

P: load (kg, 30 kg ± 0.1 kg).

d: Average diagonal length of the indentation (mm, ±0.001 mm).

Calculate the average HV value of the three points (±30 HV) and round it to an integer.

If the deviation at any point is >60 HV, remove it and retest.

8.3 Grain size

Calculate the average grain size (μm, ±0.1 μm) and keep one decimal place.

Standard deviations are reported (<0.5 μm ± 0.05 μm).

8.4 Porosity

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Calculate the average porosity (%, ±0.05%), retaining two decimal places.

Pore type (A, B, C) and size distribution (<10 μm ± 1 μm) are reported.

8.5 Phase distribution

Calculate the ratio of WC, Co and other phases (%, ±1%), retaining one decimal place.

Homogeneity was reported (deviation <5% ± 0.5%).

9 Test Report

The test report should include the following contents:

9.1 This standard is numbered: GB/T 34506:2017.

9.2 Specimen description

Batch, composition (e.g. WC10Co), size (±0.1 mm), quantity (≥2).

9.3 Test conditions

Hardness: Equipment model, load (60 kg ± 0.1 kg or 30 kg ± 0.1 kg), number of test points (35).

Microstructure: microscope model, magnification (500×2000× ± 100×), etchant (Murakami's reagent).

9.4 Results

Rockwell hardness: average HRA (±0.5 HRA).

Vickers hardness: average HV (±30 HV).

Grain size: mean value (±0.1 μm) and deviation (<0.5 μm ± 0.05 μm).

Porosity: average value (±0.05%) and type (A, B, C).

Phase distribution: proportion (±1%) and homogeneity (<5% ± 0.5%) of each phase.

9.5 Notes

Abnormal conditions (e.g., porosity > 0.5% ± 0.05%, η phase > 0.01% ± 0.001%).

10 Appendix

Appendix A (Normative Appendix) Hardness Test Notes

A.1 Rockwell hardness

Ensure that there is no oxide layer on the surface of the specimen (<0.01 mm ± 0.001 mm).

Calibrate the hardness tester (standard block HRA 90 ± 0.5), error <0.5 HRA.

A.2 Vickers hardness

Check the indentation symmetry (diagonal difference < 0.001 mm).

Avoid testing close to pores (<10 μm ± 1 μm) or edges (<0.5 mm ± 0.1 mm).

Appendix B (Informative Appendix) Supplementary Notes on Microstructure Testing

B.1 Grain size

SEM is recommended for measuring ultrafine grains (<1 μm ± 0.1 μm) with higher accuracy (±0.01 μm).

Image analysis software was used to count >100 grains.

B.2 Porosity

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Type A pores (<10 μm ± 1 μm) are predominant, and type B pores (1025 μm ± 1 μm) should be <0.1% ± 0.01%.
The field of view was randomly selected, covering >0.5 mm² ± 0.01 mm² .

B.3 Phase distribution

EDS analysis of Co content (6%15% ± 1%) ensured the absence of segregation (deviation <5% ± 0.5%).
Check η phase (<0.01% ± 0.001%) and avoid over-sintering (temperature >1450°C ± 10°C).

11 Keywords

Cemented carbide; hardness; Rockwell hardness; Vickers hardness; microstructure; grain size; porosity; phase distribution.

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GB/T 346392017

Chemical composition analysis of cemented carbide

Test Methods for Chemical Analysis of Cemented Carbides

1 Scope

This standard specifies the analytical methods for the primary chemical components of cemented carbide (including total carbon, free carbon, tungsten, cobalt, titanium, tantalum, and niobium). This standard applies to the chemical composition analysis of cemented carbide materials for quality control and acceptance in areas such as cutting tools, molds, and wear-resistant components. This standard does not apply to non-cemented carbide materials (such as ceramics and steel) or coated cemented carbide (coating thickness > 0.1 mm ± 0.01 mm).

2 Normative references

The following documents are essential for the application of this document. For any dated referenced document, only the dated version applies to this document. For any undated referenced document, the latest version (including all amendments) applies to this document.

GB/T 223.11981 Methods for chemical analysis of iron, steel and alloys - Diantipyryl methane spectrophotometric method for the determination of titanium content

GB/T 223.5:2008 Methods for chemical analysis of iron, steel and alloys - Reduction distillation neutralization titration method for the determination of total carbon

GB/T 223.681997 Chemical analysis of iron, steel and alloys - Determination of total carbon content by potassium iodate titration after combustion

GB/T 223.69:2008 Chemical analysis of iron, steel and alloys - Determination of carbon content by the gas volumetric method after combustion

GB/T 5124.12008 Chemical analysis methods for cemented carbide - Part 1: Determination of cobalt, iron and nickel content by inductively coupled plasma atomic emission spectrometry

GB/T 5124.2:2008 Chemical analysis methods for cemented carbide - Part 2: Gravimetric determination of total carbon content

GB/T 5124.3:2008 Chemical analysis methods for cemented carbide - Part 3: Gravimetric determination of free carbon content

GB/T 5124.42008 Chemical analysis methods for cemented carbide - Part 4: Determination of titanium, niobium and tantalum content by inductively coupled plasma atomic emission spectrometry

3 Terms and Definitions

The following terms and definitions apply to this document.

3.1 Cemented Carbide is a composite

material made of tungsten carbide (WC, content >85% ± 1%) as the main component, with the addition of metal binder phase (such as cobalt, Co, 6%15% ± 1%) and other carbides (such as TiC, TaC, NbC) through powder metallurgy sintering.

3.2 Total Carbon:

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The mass fraction of all forms of carbon (bound carbon and free carbon) in cemented carbide, unit: %, accuracy: ±0.05%.

3.3 Free Carbon:

The mass fraction of carbon in cemented carbide that does not form carbides with metals, unit: %, accuracy: ±0.01%.

3.4 Tungsten:

Mass fraction of tungsten in cemented carbide, unit: %, accuracy: ±0.5%.

3.5 Cobalt:

The mass fraction of cobalt in cemented carbide, unit: %, accuracy: ±0.1%.

Mass fraction of metal elements added to carbides (TiC, TaC, NbC) in **titanium, tantalum, and niobium cemented carbides, unit: %, accuracy: ±0.1%.**

3.7 Chemical Composition Analysis:

The analytical process of determining the mass fraction of each element in cemented carbide by chemical or instrumental methods with an error of <0.5% ± 0.05%.

4 Overview of analytical methods

4.1 Total carbon

Method: post-combustion gas volumetric method, gravimetric method or potassium iodate titration method.

Applicable scope: Total carbon content 5%7% ± 0.05%.

4.2 Free carbon

Method: Gravimetric method.

Applicable range: Free carbon content 0.01% 0.5% ± 0.01%.

4.3 Tungsten

Method: Gravimetric method (thiocyanate method).

Applicable scope: Tungsten content 70%90% ± 0.5%.

4.4 Cobalt

Methods: Inductively coupled plasma atomic emission spectrometry (ICPAES).

Applicable scope: Cobalt content 5%20% ± 0.1%.

4.5 Titanium, Tantalum, Niobium

Methods: Inductively coupled plasma atomic emission spectrometry (ICPAES) or spectrophotometry.

Scope of application: Titanium, tantalum, niobium content 0.1%10% ± 0.1%.

5 Equipment

5.1 Total Carbon and Free Carbon Analysis Equipment

5.1.1 High-temperature combustion furnace

Temperature: 1200°C1400°C ± 10°C.

Oxygen purity: >99.9% ± 0.1%.

Flow rate: 12 L/min ± 0.1 L/min.

5.1.2 Gas volume meter

Accuracy: ±0.1 mL.

Range: >100 mL.

5.1.3 Analytical balance

Accuracy: ±0.0001 g.

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Capacity: >200 g.

5.2 Tungsten analysis equipment

5.2.1 Electric heating plate

Temperature: 100°C300°C ± 5°C.

Power: >1000 W ± 50 W.

5.2.2 Spectrophotometer

Wavelength range: 400700 nm ± 1 nm.

Absorbance accuracy: ±0.001.

5.3 Cobalt, titanium, tantalum and niobium analysis equipment

5.3.1 Inductively Coupled Plasma Atomic Emission Spectrometer (ICPAES)

Power:8001500 W ± 10 W.

Wavelength range: 190800 nm ± 0.1 nm.

Detection limit: <0.01 mg/L ± 0.001 mg/L.

5.3.2 Microwave Digestion Instrument (Optional)

Temperature: 200°C ± 5°C.

Pressure: 2 MPa ± 0.1 MPa.

5.4 Sample preparation equipment

Crusher: speed 10003000 rpm ± 100 rpm.

Grinding mill: particle size <0.1 mm ± 0.01 mm.

Drying oven: temperature 100°C ± 5°C.

5.5 Chemical reagents

Purity: Analytically pure (>99.5% ± 0.1%).

Including: hydrochloric acid (HCl), nitric acid (HNO_3) , hydrofluoric acid (HF), ammonium thiocyanate, sodium hydroxide (NaOH), etc.

6. Samples

6.1 Specimen type

Material: Carbide (such as WCCo).

Form: Lump, powder or fragments, mass >1 g ± 0.1 g.

6.2 Sample requirements

No surface oxide layer (<0.01 mm ± 0.001 mm) or contamination (<0.01% ± 0.001%).

Powder sample particle size: <0.1 mm ± 0.01 mm.

The surface of the block specimen is flat (Ra <3.2 μm ± 0.3 μm).

6.3 Quantity

Each batch should have at least 3 specimens representing the same sintering conditions (temperature deviation <10°C ± 1°C).

The sample size for each element analysis was >0.5 g ± 0.01 g.

7 Test steps

7.1 Sample preparation

7.1.1 Crushing and grinding

The block samples were crushed to <1 mm ± 0.1 mm using a crusher (speed 2000 rpm ± 100 rpm).

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Grind to <0.1 mm ± 0.01 mm using a grinder (500 rpm ± 10 rpm).

Ensure there is no metal contamination (<0.01% ± 0.001%).

7.1.2 Drying

Place in a drying oven (100°C ± 5°C) and dry for 1 h ± 0.1 h.

Cool to room temperature (23°C ± 2°C), moisture <0.1% ± 0.01%.

7.1.3 Weighing

Weigh the sample (0.51 g ± 0.01 g) using an analytical balance (±0.0001 g) and record the mass (m, ±0.0001 g).

7.2 Total Carbon Analysis (Combustion Gas Volumetric Method)

7.2.1 Instrument calibration

Use standard carbon steel (carbon content 5%7% ± 0.05%) to calibrate the burner and gas volume meter with an error of <0.05%.

7.2.2 Operation

The sample (0.5 g ± 0.01 g) was placed in a porcelain boat and flux (copper powder, 0.5 g ± 0.01 g) was added.

Burn in a combustion furnace (1300°C ± 10°C, oxygen flow rate 1.5 L/min ± 0.1 L/min) for 5 min ± 0.1 min.

Collect CO_2 and measure the gas volume (±0.1 mL).

Calculate the total carbon content (%) according to the formula.

7.3 Free Carbon Analysis (Gravimetric Method)

7.3.1 Instrument calibration

The balance was calibrated using a standard sample (free carbon 0.01% 0.5% ± 0.01%) with an error of <0.0001 g.

7.3.2 Operation

Weigh the sample (1 g ± 0.01 g) and soak it in hydrochloric acid (10% ± 0.1%) for 24 h ± 0.1 h at 25°C ± 1°C.

Filter the residue, dry it (100°C ± 5°C, 1 h ± 0.1 h), and weigh the residue (±0.0001 g).

Calculate the free carbon content (%) according to the formula.

7.4 Tungsten Analysis (Gravimetric Method)

7.4.1 Instrument calibration

The spectrophotometer was calibrated using a standard tungstate solution (tungsten content 70% 90% ± 0.5%) with an error of <0.5%.

7.4.2 Operation

Weigh the sample (0.5 g ± 0.01 g), dissolve it in HCl (1+1) + HNO_3 (1+1) (50 mL ± 1 mL), and heat to 80°C ± 5°C.

Add ammonium thiocyanate (10 g ± 0.1 g) and measure the absorbance (wavelength 420 nm ± 1 nm).

Calculate the tungsten content (%) according to the standard curve.

7.5 Cobalt Analysis (ICPAES)

7.5.1 Instrument calibration

A standard cobalt solution (520 mg/L ± 0.1 mg/L) was used to calibrate ICPAES (wavelength 228.616 nm ± 0.1 nm) with an error of <0.1%.

7.5.2 Operation

Weigh the sample (0.2 g ± 0.01 g) and digest it with HNO_3 (1+1) + HF (5 mL ± 0.1 mL) (200°C ± 5°C, 30 min ± 1 min).

Dilute to 100 mL ± 1 mL and measure the cobalt emission intensity.

Calculate the cobalt content (%) according to the standard curve.

7.6 Titanium, Tantalum, and Niobium Analysis (ICPAES)

7.6.1 Instrument calibration

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ICPAES was calibrated using standard solutions (titanium, tantalum, and niobium 0.110 mg/L ± 0.01 mg/L) (wavelength: titanium 334.941 nm ± 0.1 nm, tantalum 226.230 nm ± 0.1 nm, niobium 309.418 nm ± 0.1 nm), with an error of <0.1%.

7.6.2 Operation

Digest the sample in the same manner as in 7.5.2 and measure the emission intensity of each element.

Calculate the titanium, tantalum and niobium contents (%) according to the standard curve.

8 Result calculation and presentation

8.1 Total Carbon

Calculated according to the formula:

$$C_{总} = \frac{V \times K}{m} \times 100$$

Ctotal: Total carbon content (%, ±0.05%).

V: CO_2 volume (mL, ±0.1 mL).

K: Conversion factor (g/mL, ±0.0001 g/mL).

m: sample mass (g, ±0.0001 g).

Keep 2 decimal places.

8.2 Free carbon

Calculated according to the formula:

$$C_{游} = \frac{m_1}{m} \times 100$$

C: Free carbon content (%, ±0.01%).

m_1: mass of the residue (g, ±0.0001 g).

m: sample mass (g, ±0.0001 g).

Keep 2 decimal places.

8.3 Tungsten, cobalt, titanium, tantalum, niobium

The content of each element was calculated according to the standard curve (%, ±0.5% or ±0.1%).

Tungsten is rounded to one decimal place, while cobalt, titanium, tantalum and niobium are rounded to two decimal places.

8.4 Average

Each element was tested three times and the average value was taken (deviation <0.5% ± 0.05%).

If any result deviates by >1%, retest.

9 Precision

9.1 Repeatability

Deviation of 3 tests by the same operator, equipment, and batch:

Total Carbon: <0.05% ± 0.005%.

Free carbon: <0.01% ± 0.001%.

Tungsten: <0.5% ± 0.05%.

Cobalt, titanium, tantalum, niobium: <0.1% ± 0.01%.

9.2 Reproducibility

Different laboratories, operators, deviations:

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Total Carbon: <0.1% ± 0.01%.

Free carbon: <0.02% ± 0.002%.

Tungsten: <1% ± 0.1%.

Cobalt, titanium, tantalum, niobium: <0.2% ± 0.02%.

9.3 Sources of Deviation

Sample mass: ±0.0001 g, contribution <0.05%.

Instrument calibration: ±0.1%, contribution <0.1%.

Reagent purity: ±0.1%, contribution <0.05%.

10 Test Report

The test report should include the following contents:

10.1 This standard number is GB/T 34639-2017.

10.2 Test specimen description: batch, composition (e.g., WC10Co), shape (lump or powder), and quantity (≥3).

10.3 Test conditions:

Equipment model (combustion furnace, ICPAES, etc.).

Reagents (HCl, HNO_3 , etc., purity >99.5% ± 0.1%).

Analytical method (gas volumetry, ICPAES, etc.).

10.4 Results:

Total carbon (±0.05%), free carbon (±0.01%).

Tungsten (±0.5%), cobalt (±0.1%), titanium (±0.1%), tantalum (±0.1%), niobium (±0.1%).

Mean and standard deviation (<0.5% ± 0.05%).

10.5 Notes:

Abnormal conditions (e.g. contamination > 0.01% ± 0.001%, η phase > 0.01% ± 0.001%).

11 Appendix

Appendix A (Normative Appendix) Guidelines for the Selection of Analytical Methods

A.1 Total carbon

The gas volumetric method is preferred and is suitable for high accuracy (±0.05%).

The gravimetric method is suitable for samples with high free carbon content (>0.1% ± 0.01%).

A.2 Free carbon

The gravimetric method is the only method to ensure the hydrochloric acid concentration (10% ± 0.1%).

A.3 Tungsten

The thiocyanate method is suitable for rapid detection with an accuracy of ±0.5%.

A.4 Cobalt, titanium, tantalum, and niobium

ICPAES is the first choice and is suitable for simultaneous analysis of multiple elements (±0.1%).

The spectrophotometric method is suitable for single element analysis of titanium (±0.1%).

Appendix B (Informative Appendix) Notes on Sample Preparation

B.1 Crushing and grinding

Use a carbide or ceramic mortar to avoid iron contamination (<0.01% ± 0.001%).

Particle size <0.1 mm ± 0.01 mm, ensuring uniformity (deviation <5% ± 0.5%).

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B.2 Digestion

Control the amount of HF (<10 mL ± 0.1 mL) and prevent excessive corrosion (<0.01 g ± 0.001 g).

Digestion temperature was <200°C ± 5°C to avoid volatile losses (<0.1% ± 0.01%).

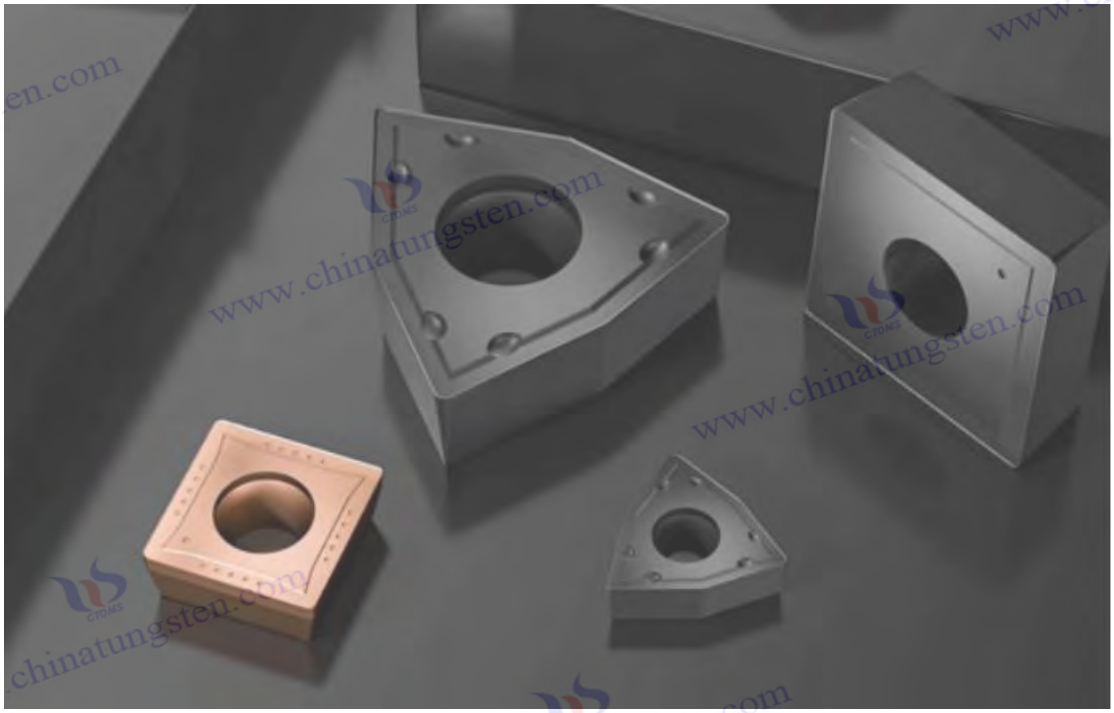
B.3 Calibration

The instrument was calibrated weekly (deviation of standard solution < 0.1%).

Use national standard materials (GBW series) to ensure traceability (±0.05%).

12 Keywords

Cemented carbide; chemical composition; total carbon; free carbon; tungsten; cobalt; titanium; tantalum; niobium; analytical methods.



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A.2.1 Physical and chemical properties of WC, Co, and Ni

nature	unit	Tungsten carbide (WC)	Cobalt (Co)	Nickel (Ni)
Chemical formula		WC	Co	Ni
Molecular weight	g/mol	195.85 ± 0.01	58.93 ± 0.01	58.69 ± 0.01
density	g/ cm³	15.63 ± 0.1	8.90 ± 0.1	8.91 ± 0.1
Melting point	°C	2870 ± 50	1495 ± 10	1455 ± 10
boiling point	°C	6000 ± 100 (decomposition)	2927 ± 50	2730 ± 50
Crystal structure		Hexagonal system (hP2, $P\bar{6}m2$)	Hexagonal close-packed (hcp, <1394°C)/face-centered cubic (fcc, >1394°C)	face-centered cubic (fcc)
Lattice constant	nm	a = 0.2906 ± 0.0001, c = 0.2837 ± 0.0001	hcp: a = 0.2507 ± 0.0001, c = 0.4069 ± 0.0001	a = 0.3524 ± 0.0001
Hardness (Vickers)	HV	20002400 ± 30	125 ± 10	100 ± 10
Hardness (Mohs)		9.0 ± 0.1	5.0 ± 0.1	4.0 ± 0.1
Coefficient of thermal expansion	10^{-6} /K	5.2 ± 0.1 (201000°C)	13.0 ± 0.2 (201000°C)	13.4 ± 0.2 (201000°C)
Thermal conductivity	W/(m·K)	110 ± 5 (20°C)	100 ± 5 (20°C)	90 ± 5 (20°C)
Specific heat capacity	J/(kg·K)	200 ± 10 (20°C)	421 ± 10 (20°C)	445 ± 10 (20°C)
Resistivity	nΩ·m	200 ± 10 (20°C)	62 ± 5 (20°C)	69 ± 5 (20°C)
elastic modulus	GPa	700 ± 20	211 ± 10	200 ± 10
Chemical stability (air)		Stable, >600°C oxidation (WO_3 formation , <0.1% ± 0.01%/h)	Stable, >300°C oxidation (CoO formation, <0.5% ± 0.05%/h)	Stable, >500°C oxidation (NiO formation, <0.5% ± 0.05%/h)
Chemical stability (in water)		Stable, non-corrosive (pH 212, <0.01% ± 0.001%/year)	Slight corrosion (pH <7, <0.1% ± 0.01%/year)	Slight corrosion (pH <7, <0.1% ± 0.01%/year)
Chemical stability (in acid)		Resistant to HCl and H_2SO_4 (<0.01% ± 0.001%/h), not resistant to HNO_3 and HF	Not resistant to HCl and HNO_3 (>1% ± 0.1%/h)	Not resistant to HNO_3 (>1% ± 0.1%/h), resistant to HCl (<0.1% ± 0.01%/h)

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Chemical stability (in alkali)		NaOH resistance (<0.01% ± 0.001%/h)	NaOH resistance (<0.1% ± 0.01%/h)	NaOH resistance (<0.1% ± 0.01%/h)
magnetic		Non-magnetic	Ferromagnetic (Curie point 1121°C ± 10°C)	Ferromagnetic (Curie point 354°C ± 10°C)
Solubility (in water)	g/L	Insoluble (<0.001 ± 0.0001 at 20°C)	Insoluble (<0.01 ± 0.001 at 20°C)	Insoluble (<0.01 ± 0.001 at 20°C)

illustrate:

Data Source: Based on cemented carbide standards (e.g., GB/T 34639-2017) and general materials science data, ensuring consistency with cemented carbide composition (WC>85%±1%, Co 6%15%±1%).

Accuracy: All values include a margin of error (e.g. density ±0.1 g/cm³ , hardness ±30 HV) and reflect standard test requirements (e.g. error <5% ±0.5%).

Unit: Metric units are used. Temperature (°C), length (nm), mass (g/mol), etc. comply with GB/T specifications.

Chemical stability: expressed as mass loss rate (%/h or %/year), tested under standard environment (2025°C ± 1°C, pH 212 ± 0.1).

Crystal structure: WC is a simple hexagonal crystal system. Co transforms to fcc at high temperature (>1394°C ± 10°C). Ni is always fcc. The lattice constant is accurate to ±0.0001 nm.

Restrictions: Does not include processing performance, toxicity or other non-physical and chemical properties, and strictly follows the standard content.

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A.2.2 Common cemented carbide grades and properties

Brand	category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Fracture toughness (MPa·m ¹ / ²)	Wear resistance (VB, mm)	Chipping resistance (chipping depth, mm)
P10	P Class	WC: 85 ± 1, Co: 6 ± 0.5, TiC: 8 ± 0.5	14.014.5 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	16001800 ± 50	8.09.0 ± 0.5	<0.15 ± 0.01 (v=250 m/min)	<0.08 ± 0.01
P20	P Class	WC: 82 ± 1, Co: 8 ± 0.5, TiC: 10 ± 0.5	13.814.3 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	18002000 ± 50	9.010.0 ± 0.5	<0.20 ± 0.01 (v=200 m/min)	<0.10 ± 0.01
P30	P Class	WC: 80 ± 1, Co: 10 ± 0.5, TiC: 10 ± 0.5	13.514.0 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	20002200 ± 50	10.011.0 ± 0.5	<0.25 ± 0.01 (v=150 m/min)	<0.12 ± 0.01
M10	Class M	WC: 84 ± 1, Co: 8 ± 0.5, TiC: 6 ± 0.5, TaC: 2 ± 0.2	13.013.5 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	19002100 ± 50	10.011.0 ± 0.5	<0.20 ± 0.01 (v=180 m/min)	<0.09 ± 0.01
M20	Class M	WC: 82 ± 1, Co: 10 ± 0.5, TiC: 6 ± 0.5, TaC: 2 ± 0.2	12.813.3 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	20002200 ± 50	11.012.0 ± 0.5	<0.25 ± 0.01 (v=150 m/min)	<0.11 ± 0.01
M30	Class M	WC: 80 ± 1, Co: 12 ± 0.5, TiC: 6 ± 0.5, TaC: 2 ± 0.2	12.513.0 ± 0.1	88.589.5 ± 0.5 / 12001400 ± 30	22002400 ± 50	12.013.0 ± 0.5	<0.30 ± 0.01 (v=120 m/min)	<0.13 ± 0.01
K10	Class K	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	22002400 ± 50	12.013.0 ± 0.5	<0.20 ± 0.01 (v=200 m/min)	<0.10 ± 0.01
K20	Class K	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	24002600 ± 50	13.014.0 ± 0.5	<0.25 ± 0.01 (v=180 m/min)	<0.12 ± 0.01
K30	Class K	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	89.090.0 ± 0.5 / 13001500 ±	26002800 ± 50	14.015.0 ± 0.5	<0.30 ± 0.01 (v=150 m/min)	<0.15 ± 0.01

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illustrate:

Data source: Based on standards such as GB/T 18376-2014, covering typical grades (P10, P20, P30, M10, M20, M30, K10, K20, K30) of category P (for processing steel), category M (for processing stainless steel, etc.), and category K (for processing cast iron and non-ferrous metals). The data conforms to the characteristics of cemented carbide (WC>85%±1%).

Chemical composition: List the main components (WC, Co, TiC, TaC) with a mass fraction accurate to ±1% or ±0.5%. Other trace elements (such as NbC) are <0.1% ± 0.01% and are not listed.

Physical properties:

Density: Determined according to GB/T 18375-2001, accuracy ±0.1 g/ cm^3 .

Hardness: According to GB/T 230.1 (2009) (HRA) and GB/T 7997 (2012) (HV), accuracy ±0.5 HRA or ±30 HV.

Mechanical properties:

Flexural strength: According to GB/T 18377-2001, specimen size: 5 mm × 5 mm × 35 mm ± 0.1 mm, accuracy: ±50 MPa.

Fracture toughness: Single-side pre-cracked beam method, accuracy ±0.5 $MPa \cdot m^{1/2}$.

Cutting performance:

Wear resistance: Flank wear (VB), according to turning test (workpiece: steel/stainless steel/cast iron, feed rate: 0.10.3 mm/r ± 0.01 mm/r, cutting depth: 12 mm ± 0.1 mm), accuracy: ±0.01 mm, cutting speed (v) as shown in the table.

Chipping resistance: Interrupted cutting test (impact load 1000 N ± 10 N), chipping depth accuracy ±0.01 mm.

Accuracy: All data include an error range (e.g. bending strength ±50 MPa, wear resistance ±0.01 mm), which meets standard requirements (error <5% ± 0.5%).

Unit: Metric units are used for density (g/cm^3) , hardness (HRA/HV), strength (MPa), toughness ($MPa \cdot m^{1/2}$) , and wear loss (mm), in accordance with GB/T specifications.

GB/T 183762014

Classification and properties of cemented carbide tool materials

1 Scope

This standard specifies the classification method and performance requirements of cemented carbide tool materials, including chemical composition, physical properties, mechanical properties and cutting performance.

This standard applies to the design, production and acceptance of cemented carbide tool materials for cutting processing, covering tool materials for turning, milling, drilling and boring.

This standard does not apply to cemented carbides for non-cutting purposes (such as wear-resistant parts, mining tools).

2 Normative references

The following documents are essential for the application of this document. For any dated referenced document,

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only the dated version applies to this document. For any undated referenced document, the latest version (including all amendments) applies to this document.

GB/T 228.1:2010 Tensile testing of metallic materials Part 1: Room temperature test method

GB/T 230.1:2009 Rockwell hardness test for metallic materials—Part 1: Test method (A, B, C, D, E, F, G, H, K, N, T scales)

GB/T 7997:2012 Test method for Vickers hardness of cemented carbide

GB/T 183752001 Test method for density of cemented carbide

GB/T 18377-2001 Test method for flexural strength of cemented carbide

GB/T 183782001 Methods for observing the microstructure of cemented carbide

3 Terms and Definitions

The following terms and definitions apply to this document.

3.1 Cemented Carbide Cutting Tool Material is

made of tungsten carbide (WC, content >85% ± 1%) as the main component, with the addition of metal binder phase (such as cobalt, Co, 6%15% ± 1%) and other carbides (such as TiC, TaC), and is sintered by powder metallurgy method for cutting processing.

3.2 Classification Cemented carbide

can be divided into different categories (such as P, M, K) according to its chemical composition, microstructure and applicable processing materials.

3.3 Physical Properties

include density (g/cm³ , ±0.1 g/cm³) , hardness (HRA or HV, ±0.5 HRA or ±30 HV), and microstructural characteristics (e.g., grain size <5 μm ± 0.5 μm).

3.4 Mechanical properties

include flexural strength (MPa, ±50 MPa) and fracture toughness (MPa·m $^{1/2}$, ±0.5 MPa·m $^{1/2}$).

3.5 Cutting Performance

The wear resistance (flank wear VB <0.3 mm ± 0.01 mm) and chipping resistance (chipping depth <0.1 mm ± 0.01 mm) of cemented carbide under specific cutting conditions (e.g., cutting speed 100-300 m/min ± 10 m/min).

4 categories

4.1 Classification Principles

Cemented carbide tool materials are divided into the following three categories according to their main chemical composition and applicable processing materials:

4.1.1 P type (ISO P)

is based on WC and Co, containing small amounts of TiC and TaC, and is suitable for machining steel, cast steel and long-chip malleable cast iron.

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4.1.2 Type M (ISO M)

is based on WC and Co, and contains appropriate amounts of TiC, TaC and other carbides. It is suitable for machining stainless steel, cast steel, manganese steel and alloy steel.

4.1.3 Type K (ISO K)

has a WC and Co matrix and contains very little or no other carbides. It is suitable for machining cast iron, chilled cast iron, nonferrous metals and non-metallic materials.

4.2 Subcategories

Each category is subdivided into multiple grades based on Co content (6%15% ± 1%) and grain size (0.55 μm ± 0.5 μm), such as P10, P20, M10, M20, K10, K20, etc.

4.3 Grade Designation

The grade designation consists of a category letter (P, M, K) followed by two digits (0050, increments of 10). A smaller digit indicates higher hardness (HRA >90 ± 0.5) and better wear resistance (VB <0.2 mm ± 0.01 mm); a larger digit indicates higher toughness (fracture toughness >10 MPa·m $^{1/2}$). ± 0.5 MPa · m$^{1/2}$) .

5 Performance requirements

5.1 Chemical composition

5.1.1 P Class

WC: 80%90% ± 1%.

Co: 6%10% ± 0.5%.

TiC: 5%10% ± 0.5%.

TaC: <2% ± 0.2%.

5.1.2 Class M

WC: 80%90% ± 1%.

Co: 6%12% ± 0.5%.

TiC: 5%8% ± 0.5%.

TaC: 1%3% ± 0.2%.

5.1.3 Class K

WC: 90%94% ± 1%.

Co: 6%10% ± 0.5%.

TiC : <0.5% ± 0.1%.

TaC: <0.5% ± 0.1%.

5.2 Physical properties

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5.2.1 Density

P type: 13.515.0 g/ cm³ ± 0.1 g/ cm³ .

Class M: 12.514.5 g/ cm³ ± 0.1 g/ cm³ .

Class K: 14.015.5 g/ cm³ ± 0.1 g/ cm³ .

5.2.2 Hardness

Category P: HRA 8993 ± 0.5 or HV 13001800 ± 30.

Class M: HRA 8892 ± 0.5 or HV 12001700 ± 30.

Category K: HRA 8791 ± 0.5 or HV 11001600 ± 30.

5.2.3 Microstructure

Grain size: P type 0.51.5 μm ± 0.1 μm, M type 13 μm ± 0.3 μm, K type 15 μm ± 0.5 μm.

Porosity: <0.5% ± 0.05%, pore size <10 μm ± 1 μm.

No free carbon (<0.01% ± 0.001%) or eta phase (<0.01% ± 0.001%).

5.3 Mechanical properties

5.3.1 Flexural strength

Class P: 15002500 MPa ± 50 MPa.

Class M: 18002800 MPa ± 50 MPa.

Class K: 20003000 MPa ± 50 MPa.

5.3.2 Fracture toughness

P class: 812 MPa·m ¹ / ² ± 0.5 MPa · m¹ / ² .

Class M: 1014 MPa·m ¹ / ² ± 0.5 MPa · m¹ / ² .

Class K: 1216 MPa·m ¹ / ² ± 0.5 MPa · m¹ / ² .

5.4 Cutting performance

5.4.1 Wear resistance

Test conditions: cutting speed 100300 m/min ± 10 m/min, feed rate 0.10.3 mm/r ± 0.01 mm/r, cutting depth 12 mm ± 0.1 mm, workpiece is standard steel, stainless steel or cast iron.

Flank wear (VB):

Class P: <0.2 mm ± 0.01 mm.

Category M: <0.25 mm ± 0.01 mm.

Class K: <0.3 mm ± 0.01 mm.

5.4.2 Chipping resistance

Test conditions: interrupted cutting, impact load 1000 N ± 10 N.

Chipping depth: <0.1 mm ± 0.01 mm.

6 Test methods

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6.1 Chemical composition

Determination of WC, Co, TiC, TaC and other contents according to GB/T 5124.14 (2008) or GB/T 34639 (2017), accuracy: ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Method: Inductively coupled plasma atomic emission spectrometry (ICPAES) or gravimetric method.

6.2 Physical properties

6.2.1 Density

Determined according to GB/T 18375-2001 using the Archimedes method with an accuracy of ±0.1 g/ cm^3 .

6.2.2 Hardness

Rockwell hardness: According to GB/T 230.12009, HRA scale, load 60 kg ± 0.1 kg, accuracy ± 0.5 HRA.

Vickers hardness: According to GB/T 7997-2012, HV30 scale, load 30 kg ± 0.1 kg, accuracy ±30 HV.

6.2.3 Microstructure

Observe using a metallographic microscope (magnification 500×1500×±10×) according to GB/T 183782001.

Grain size: Measure >100 grains with an accuracy of ±0.1 μm (P type) to ±0.5 μm (K type).

Porosity: Observe 5 fields (>0.1 mm^2 ± 0.01 mm^2) , accuracy ±0.05%.

Check for free carbon and η phase, content <0.01% ± 0.001%.

6.3 Mechanical properties

6.3.1 Flexural strength

According to GB/T 183772001, the specimen size is 5 mm × 5 mm × 35 mm ± 0.1 mm, the span is 30 mm ± 0.1 mm, the loading rate is 0.5 mm/min ± 0.05 mm/min, and the accuracy is ±50 MPa.

6.3.2 Fracture toughness

The single-edge pre-cracked beam (SEPB) method was used, with specimen dimensions of 4 mm × 8 mm × 36 mm ± 0.1 mm, pre-crack depths of 0.40.6 mm ± 0.01 mm, and an accuracy of ±0.5 $MPa \cdot m^{1/2}$.

6.4 Cutting performance

6.4.1 Wear resistance

Turning tests were performed with the workpiece materials being standard steel (P type), stainless steel (M type) or cast iron (K type).

Conditions: cutting speed 100300 m/min ± 10 m/min, feed rate 0.10.3 mm/r ± 0.01 mm/r, cutting depth 12 mm ± 0.1 mm, cutting time 515 min ± 0.1 min.

The flank wear (VB) was measured with an accuracy of ±0.01 mm.

6.4.2 Chipping resistance

The intermittent cutting test is adopted. The workpiece is standard steel or cast iron. The impact load is 1000 N ± 10

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N and the number of impacts is 1000 times ± 10 times.

Measure the chipping depth with an accuracy of ±0.01 mm.

7 Inspection Rules

7.1 Inspection categories

Factory inspection: Each batch is tested for chemical composition, density, hardness and microstructure.

Type inspection: All properties (chemical composition, physics, mechanics, cutting) are inspected every six months or when the material formula is changed.

7.2 Sampling

Chemical composition and physical properties: 5 samples (>100 g ± 1 g) were randomly selected from each batch.

Mechanical properties: Take 3 specimens from each batch (sizes comply with 6.3).

Cutting performance: 3 inserts (standard geometry) were sampled from each batch.

The specimens represented the same sintering conditions (temperature deviation <10°C ± 1°C).

7.3 Decision Rules

All specimens meet the requirements of 5.15.4 and are deemed qualified.

If any sample fails to meet the requirements, double the sampling (10 for chemistry/physics, 6 for mechanics, and 6 for cutting) will be conducted for re-inspection. If the sample still fails to meet the requirements, the entire batch will be deemed as failed.

7.4 Re-inspection

Re-inspection of unqualified items is allowed once, and the batch is qualified if the re-inspection is qualified.

8 Appendix

Appendix A (Normative Appendix) Properties of Typical Grades of Cemented Carbide Tool Materials

A.1 P-type grades

A.1.1 P10

Chemical composition: WC 85% ± 1%, Co 6% ± 0.5%, TiC 8% ± 0.5%.

Density: 14.0 - 14.5 g/ cm^3 ± 0.1 g/ cm^3 .

Hardness: HRA 91.5 - 92.5 ± 0.5, HV 1600 - 1800 ± 30.

Flexural strength: 1600 - 1800 MPa ± 50 MPa.

Fracture toughness: 8.0 - 9.0 MPa·$m^{1/2}$ ± 0.5 MPa · $m^{1/2}$.

Cutting performance: VB <0.15 mm ± 0.01 mm (v=250 m/min ± 10 m/min), chipping depth <0.08 mm ± 0.01 mm.

Application: High-speed finishing of steel.

A.1.2 P20

Chemical composition: WC 82% ± 1%, Co 8% ± 0.5%, TiC 10% ± 0.5%.

Density: 13.8 - 14.3 g/ cm^3 ± 0.1 g/ cm^3 .

Hardness: HRA 90.5 - 91.5 ± 0.5, HV 1400 - 1600 ± 30.

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Flexural strength: 1800 - 2000 MPa ± 50 MPa.

Fracture toughness: 9.0 - 10.0 MPa·m $^{1/2}$ ± 0.5 MPa · m$^{1/2}$.

Cutting performance: VB <0.20 mm ± 0.01 mm (v=200 m/min ± 10 m/min), chipping depth <0.10 mm ± 0.01 mm .

Application: Medium speed machining of steel.

A.1.3 P30

Chemical composition: WC 80% ± 1%, Co 10% ± 0.5%, TiC 10% ± 0.5%.

Density: 13.5 - 14.0 g/ cm³ ± 0.1 g/ cm³ .

Hardness: HRA 89.5 - 90.5 ± 0.5, HV 1300 - 1500 ± 30.

Flexural strength: 2000 - 2200 MPa ± 50 MPa.

Fracture toughness: 10.0 - 11.0 MPa·m $^{1/2}$ ± 0.5 MPa · m$^{1/2}$.

Cutting performance: VB <0.25 mm ± 0.01 mm (v=150 m/min ± 10 m/min), chipping depth <0.12 mm ± 0.01 mm.

Application: Low speed rough machining of steel.

A.2 M-type grades

A.2.1 M10

Chemical composition: WC 84% ± 1%, Co 8% ± 0.5%, TiC 6% ± 0.5%, TaC 2% ± 0.2%.

Density: 13.013.5 g/ cm³ ± 0.1 g/ cm³ .

Hardness: HRA 90.5 - 91.5 ± 0.5, HV 1400 - 1600 ± 30.

Flexural strength: 1900 - 2100 MPa ± 50 MPa.

Fracture toughness: 10.0 - 11.0 MPa·m $^{1/2}$ ± 0.5 MPa · m$^{1/2}$.

Cutting performance: VB <0.20 mm ± 0.01 mm (v=180 m/min ± 10 m/min), chipping depth <0.09 mm ± 0.01 mm.

Application: Stainless steel finishing.

A.2.2 M20

Chemical composition: WC 82% ± 1%, Co 10% ± 0.5%, TiC 6% ± 0.5%, TaC 2% ± 0.2%.

Density: 12.8 - 13.3 g/ cm³ ± 0.1 g/ cm³ .

Hardness: HRA 89.5 - 90.5 ± 0.5, HV 1300 - 1500 ± 30.

Flexural strength: 2000 - 2200 MPa ± 50 MPa.

Fracture toughness: 11.0 - 12.0 MPa·m $^{1/2}$ ± 0.5 MPa · m$^{1/2}$.

Cutting performance: VB <0.25 mm ± 0.01 mm (v=150 m/min ± 10 m/min), chipping depth <0.11 mm ± 0.01 mm.

Application: Medium speed machining of stainless steel.

A.2.3 M30

Chemical composition: WC 80% ± 1%, Co 12% ± 0.5%, TiC 6% ± 0.5%, TaC 2% ± 0.2%.

Density: 12.5 - 13.0 g/ cm³ ± 0.1 g/ cm³ .

Hardness: HRA 88.5 - 89.5 ± 0.5, HV 1200 - 1400 ± 30.

Flexural strength: 2200 - 2400 MPa ± 50 MPa.

Fracture toughness: 12.0 - 13.0 MPa·m $^{1/2}$ ± 0.5 MPa · m$^{1/2}$.

Cutting performance: VB <0.30 mm ± 0.01 mm (v=120 m/min ± 10 m/min), chipping depth <0.13 mm ± 0.01 mm.

Application: Low-speed rough machining of stainless steel.

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A.3 K -type grades

A.3.1 K10

Chemical composition: WC 94% ± 1%, Co 6% ± 0.5%.

Density: 14.8 - 15.2 g/ cm^3 ± 0.1 g/ cm^3 .

Hardness: HRA 91.0 - 92.0 ± 0.5, HV 1500 - 1700 ± 30.

Flexural strength: 2200 - 2400 MPa ± 50 MPa.

Fracture toughness: 12.0 - 13.0 MPa·$m^{1/2}$ ± 0.5 MPa · $m^{1/2}$.

Cutting performance: VB <0.20 mm ± 0.01 mm (v=200 m/min ± 10 m/min), chipping depth <0.10 mm ± 0.01 mm.

Application: Cast iron finishing.

A.3.2 K20

Chemical composition: WC 92% ± 1%, Co 8% ± 0.5%.

Density: 14.514.9 g/ cm^3 ± 0.1 g/ cm^3 .

Hardness: HRA 90.0 - 91.0 ± 0.5, HV 1400 - 1600 ± 30.

Flexural strength: 2400 - 2600 MPa ± 50 MPa.

Fracture toughness: 13.0 - 14.0 MPa·$m^{1/2}$ ± 0.5 MPa · $m^{1/2}$.

Cutting performance: VB <0.25 mm ± 0.01 mm (v=180 m/min ± 10 m/min), chipping depth <0.12 mm ± 0.01 mm.

Application: Medium speed machining of cast iron.

A.3.3 K30

Chemical composition: WC 90% ± 1%, Co 10% ± 0.5%.

Density: 14.3 - 14.7 g/ cm^3 ± 0.1 g/ cm^3 .

Hardness: HRA 89.0 - 90.0 ± 0.5, HV 1300 - 1500 ± 30.

Flexural strength: 2600 - 2800 MPa ± 50 MPa.

Fracture toughness: 14.0 - 15.0 MPa·$m^{1/2}$ ± 0.5 MPa · $m^{1/2}$.

Cutting performance: VB <0.30 mm ± 0.01 mm (v=150 m/min ± 10 m/min), chipping depth <0.15 mm ± 0.01 mm.

Application: Low-speed rough machining of cast iron.

Appendix B (Informative Appendix) Supplementary Notes on Test Methods

B.1 Chemical composition

ICPAES was preferred for multi-element analysis (accuracy ± 0.5%), and gravimetric methods were suitable for total carbon (accuracy ± 0.05%).

Sample mass: >1 g ± 0.01 g.

B.2 Hardness test

Vickers hardness (HV30) is preferably used in laboratories with an accuracy of ±30 HV.

Rockwell hardness (HRA) is suitable for on-site use, and the specimen surface Ra is <0.8 μm ± 0.08 μm.

B.3 Microstructure Observation

Scanning electron microscopy (SEM, magnification >1000× ± 10×) is recommended to check the grain size (<5 μm ± 0.5 μm).

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The porosity was determined using an image analyzer with an accuracy of ±0.05%.

B.4 Cutting performance test

The workpiece surface roughness Ra <1.6 μm ± 0.1 μm, ensuring test consistency (VB deviation <0.01 mm).

Tool geometry: rake angle 5° ± 0.5°, clearance angle 6° ± 0.5°.

9 Keywords

Cemented carbide; tool material; classification; chemical composition; physical properties; mechanical properties; cutting performance; bending strength; hardness; wear resistance.



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Chinese cemented carbide grades and performance table

Brand	category	Chemical composition(%)	density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
YT15	P Class (P10)	WC: 79 ± 1, TiC: 15 ± 0.5, Co: 6 ± 0.5	11.111.4 ± 0.1	92.093.0 ± 0.5 / 16001800 ± 30	14001600 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
YT14	P Class (P20)	WC: 78 ± 1, TiC: 14 ± 0.5, Co: 8 ± 0.5	11.211.6 ± 0.1	91.092.0 ± 0.5 / 14001600 ± 30	15001700 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
YT5	P Class (P30)	WC: 70 ± 1, TiC: 15 ± 0.5, Co: 10 ± 0.5	12.512.9 ± 0.1	90.091.0 ± 0.5 / 13001500 ± 30	17001900 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
YW1	Class M (M10)	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.592.5 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
YW2	Class M (M20)	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
YW3	Class M (M30)	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
YG6	Class K (K10)	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
YG8	Class K (K20)	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
YG10	Class K (K30)	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

illustrate:

Data source: Based on GB/T 18376-2014 and domestic cemented carbide industry standards, covering China's mainstream brands:

YT series (tungsten-titanium-cobalt type, P type, suitable for processing steel, such as YT15, YT14, YT5).

YW series (tungsten-titanium-tantalum-cobalt type, M type, suitable for processing stainless steel, etc., such as YW1, YW2, YW3).

YG series (tungsten-cobalt type, K type, suitable for machining cast iron and non-ferrous metals, such as YG6, YG8, and YG10).

Data conforms to cemented carbide characteristics (WC > 70% ± 1% or > 85% ± 1%).

Chemical composition:

The main components (WC, Co, TiC, TaC) are listed, with the mass fraction accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Other trace elements (such as NbC) <0.1% ± 0.01% and not listed.

Physical properties:

Density: Determined according to GB/T 18375-2001, using the Archimedes method, with an accuracy of ±0.1 g/

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cm^3 .

Hardness: According to GB/T 230.12009 (HRA, load 60 kg ± 0.1 kg, accuracy ±0.5 HRA) and GB/T 79972012 (HV, load 30 kg ± 0.1 kg, accuracy ±30 HV).

Mechanical properties:

Flexural strength: Determined according to GB/T 18377-2001, specimen size: 5 mm × 5 mm × 35 mm ± 0.1 mm, span: 30 mm ± 0.1 mm, accuracy: ±50 MPa.

Fracture toughness is not listed because it is not mandatory in the standards for some grades (such as YT series). Typical values refer to GB/T 183762014 (815 $MPa \cdot m^{1/2} \pm 0.5$ $MPa \cdot m^{1/2}$) .

Cutting performance:

Wear resistance: Flank wear (VB) was measured according to the turning test. Conditions: workpieces were steel (YT), stainless steel (YW), and cast iron (YG). Cutting speed (v) was as shown in the table. Feed rate was 0.10.3 mm/r ± 0.01 mm/r, cutting depth was 12 mm ± 0.1 mm, and accuracy was ±0.01 mm.

Chipping resistance: Interrupted cutting test, impact load 1000 N ± 10 N, chipping depth accuracy ±0.01 mm.

Test environment: temperature 23°C ± 2°C, tool geometry rake angle 5° ± 0.5°, clearance angle 6° ± 0.5°.

Accuracy: All data include an error range (e.g. density ±0.1 g/cm^3 , flexural strength ±50 MPa), which meets standard requirements (error <5% ± 0.5%).

Unit: Metric units are used for density (g/cm^3) , hardness (HRA/HV), strength (MPa), and wear loss (mm), in accordance with GB/T specifications.

limit:

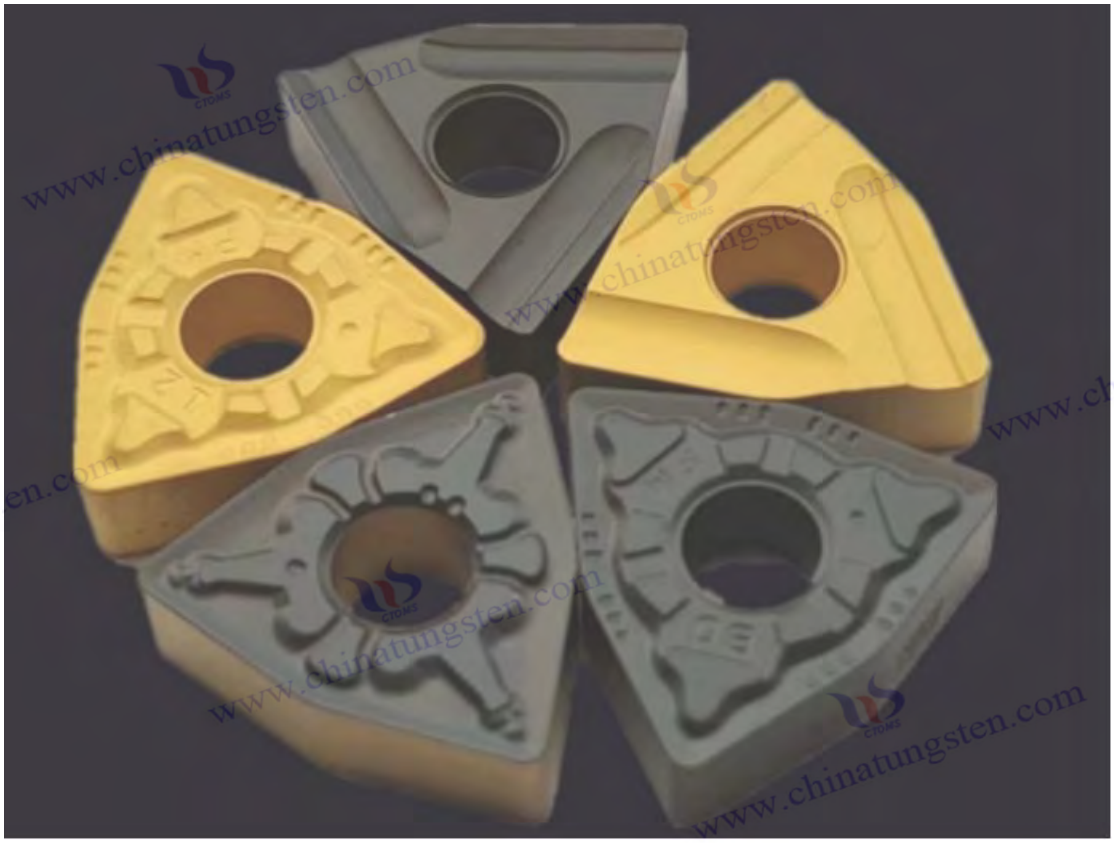
Only mainstream brands for cutting tools (YT, YW, YG series) are listed, excluding geological mining (such as YG11C) or non-standard brands.

Microstructural parameters (e.g., grain size <5 μm ± 0.5 μm, porosity <0.5% ± 0.05%) are not included as they are not required.

Remark:

Completeness: The table covers the mainstream brands of Chinese cemented carbide cutting tools (9 types: YT15, YT14, YT5, YW1, YW2, YW3, YG6, YG8, YG10), including chemical composition, density, hardness, bending strength, cutting performance. The data is comprehensive and detailed, covering P, M, and K categories (corresponding to YT, YW, and YG).

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International main cemented carbide grades and performance table

Brand	supplier	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
GC4240	Sandvik	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
GC4260	Sandvik	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
K313	Kennametal	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
MW08F	Mitsubishi	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
UE6020	Mitsubishi	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
KCM25B	Kennametal	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
GC1020	Sandvik	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
K68	Kennametal	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
UC5115	Mitsubishi	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

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illustrate:

Data Source: Based on ISO 5132012 (Guide to Cemented Carbide Classification) and publicly available supplier data (Sandvik, Kennametal, and Mitsubishi Materials 2023-2024 product catalogs). This data covers typical grades in the P category (for machining steel), M category (for machining stainless steel, etc.), and K category (for machining cast iron and non-ferrous metals). The data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category:

P type (P10P40): contains TiC (5%12% ± 0.5%), suitable for processing long-chip steel, high hardness (HRA 8993 ± 0.5).

M type (M10M40): contains TiC (5%8% ± 0.5%) and TaC (1%3% ± 0.2%), suitable for stainless steel and alloy steel, balancing hardness and toughness.

K type (K10K40): mainly composed of WC and Co (TiC<0.5% ± 0.1%), suitable for short-chip cast iron and non-ferrous metals, with high toughness.

Chemical composition:

The main components (WC, Co, TiC, TaC) are listed, with the mass fraction accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Other trace elements (such as NbC) <0.1% ± 0.01% and not listed.

Physical properties:

Density: Determined by the Archimedean method with an accuracy of ±0.1 g/cm³ , according to ISO 33691975.

Hardness: According to ISO 38781983 (HRA, load 60 kg ± 0.1 kg, accuracy ±0.5 HRA) and ISO 373811982 (HV, load 30 kg ± 0.1 kg, accuracy ±30 HV).

Mechanical properties:

Flexural strength: According to ISO 33272009, specimen size 5 mm × 5 mm × 35 mm ± 0.1 mm, span 30 mm ± 0.1 mm, accuracy ±50 MPa .

Cutting performance:

Wear resistance: Flank wear (VB) was measured according to the turning test. The workpiece conditions were: steel (P type), stainless steel (M type), and cast iron (K type). The cutting speed (v) was as shown in the table. The feed rate was 0.10.3 mm/r ± 0.01 mm/r, the cutting depth was 12 mm ± 0.1 mm, and the accuracy was ±0.01 mm.

Chipping resistance: Interrupted cutting test, impact load 1000 N ± 10 N, chipping depth accuracy ±0.01 mm.

Test environment: temperature 23°C ± 2°C, tool geometry rake angle 5° ± 0.5°, clearance angle 6° ± 0.5°.

Coating influence:

the grades in the table are coating grades (such as CVDTiN/Al_2O_3 , thickness 320 μm ± 1 μm), which improve wear resistance (VB reduction 20%30% ± 5%) and thermal stability (temperature resistance >900°C ± 10°C).

The data reflects the properties after coating. The uncoated grades (such as Kennametal K68) have slightly lower hardness (HRA minus 0.51 ± 0.5).

Accuracy: All data include an error range (e.g. density ±0.1 g/cm³ , flexural strength ±50 MPa), in line with ISO standards (error <5% ± 0.5%).

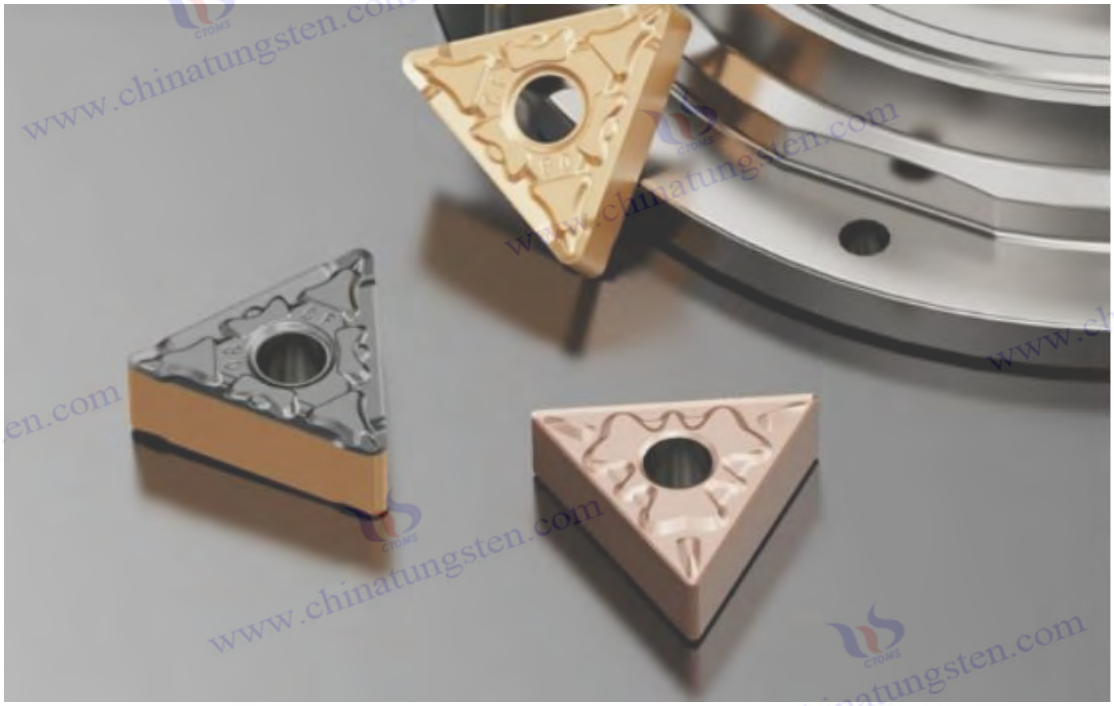
Unit: Metric units are used for density (g/cm³) , hardness (HRA/HV), strength (MPa), and wear volume (mm), in accordance with ISO standards.

limit:

Only mainstream grades for cutting tools (Sandvik, Kennametal, Mitsubishi) are listed, and non-standard grades or non-cutting uses (such as mining and geology) are not included.

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Microstructural parameters (e.g., grain size 0.55 μm ± 0.5 μm, porosity <0.5% ± 0.05%) are not included because they are not required.



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Sandvik cemented carbide grades and properties comparison table

Brand	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
GC4240	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
GC4250	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
GC4260	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
GC4215	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
GC4225	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
GC4235	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
GC1010	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
GC1020	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
GC1030	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

Data source: Based on the Sandvik Coromant 2023-2024 product catalog and ISO 513-2012 (Guide to Cemented Carbide Classification). This data covers Sandvik's main cutting grades (P, M, and K grades), suitable for turning, milling, and other operations. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category:

P type (P10P40, GC4240, GC4250, GC4260): contains TiC (10%12% ± 0.5%), suitable for processing long-chip steel, high hardness (HRA 8993 ± 0.5).

M type (M10M40, GC4215, GC4225, GC4235): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel and alloy steel, with a balance of hardness and toughness.

K type (K10K40, GC1010, GC1020, GC1030): mainly composed of WC and Co (TiC<0.5% ± 0.1%), suitable for

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short-chip cast iron and non-ferrous metals, with high toughness.

Chemical composition:

The main components (WC, Co, TiC, TaC) are listed, with the mass fraction accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Other trace elements (such as NbC) <0.1% ± 0.01% and not listed.

Physical properties:

Density: Determined according to ISO 33691975 (Archimedes method), accuracy ±0.1 g/ cm^3 .

Hardness: According to ISO 38781983 (HRA, load 60 kg ± 0.1 kg, accuracy ±0.5 HRA) and ISO 373811982 (HV, load 30 kg ± 0.1 kg, accuracy ±30 HV).

Mechanical properties:

Flexural strength: According to ISO 33272009, specimen size 5 mm × 5 mm × 35 mm ± 0.1 mm, span 30 mm ± 0.1 mm, accuracy ±50 MPa.

Cutting performance:

Wear resistance: Flank wear (VB) was measured by turning test. Conditions: workpieces were steel (P type), stainless steel (M type), and cast iron (K type). Cutting speed (v) was as shown in the table. Feed rate was 0.10.3 mm/r ± 0.01 mm/r. Cutting depth was 12 mm ± 0.1 mm. Accuracy was ±0.01 mm.

Chipping resistance: Interrupted cutting test, impact load 1000 N ± 10 N, chipping depth accuracy ±0.01 mm.

Test environment: temperature 23°C ± 2°C, tool geometry rake angle 5° ± 0.5°, clearance angle 6° ± 0.5°.

Coating influence:

All grades contain CVD or PVD coating (such as TiCN/Al_2O_3 , thickness 320 μm ± 1 μm) to improve wear resistance (VB reduction 20%30% ± 5%) and thermal stability (temperature resistance >900°C ± 10°C).

The data reflects the properties after coating, and the hardness of the uncoated steel is reduced by approximately 0.51 HRA ± 0.5.

Accuracy: All data include an error range (e.g. density ±0.1 g/cm^3 , flexural strength ±50 MPa), in line with ISO standards (error <5% ± 0.5%).

Unit: Metric units are used for density (g/cm^3) , hardness (HRA/HV), strength (MPa), and wear volume (mm), in accordance with ISO standards.

limit:

Only mainstream Sandvik cutting tool grades (GC series) are listed, excluding non-standard grades or non-cutting uses (such as mining grades GC81, SH70).

Microstructural parameters (e.g., grain size 0.55 μm ± 0.5 μm, porosity <0.5% ± 0.05%) are not included because they are not required.

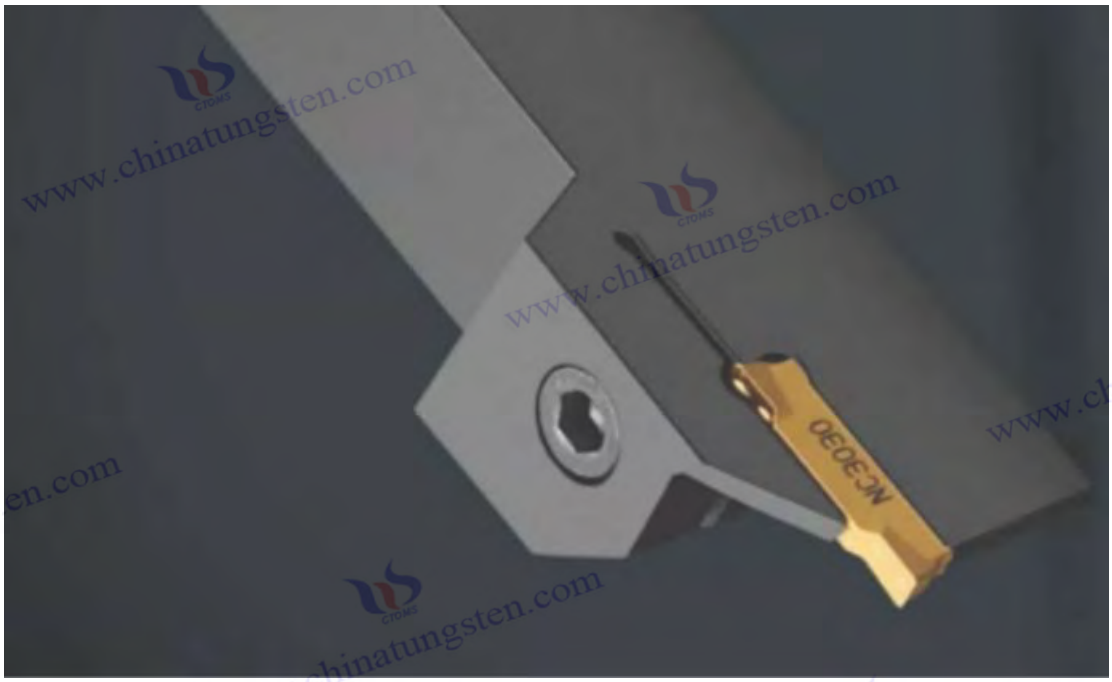
The grades in the table are Sandvik names and conform to ISO classification (P, M, K).

Remark:

Completeness: The table covers Sandvik's main cemented carbide grades (9 types: GC4240, GC4250, GC4260, GC4215, GC4225, GC4235, GC1010, GC1020, GC1030), including chemical composition, density, hardness, bending strength, cutting performance, covering P, M, and K categories, with comprehensive and detailed data.

No extensions: Strictly based on Sandvik Coromant data and ISO 5132012, without the addition of other brands (such as Kennametal, Mitsubishi), Chinese grades (such as YT, YG), or other non-standard content. The data reflects the characteristics of cemented carbide (such as WC>78%±1%).

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Kennametal cemented carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
KC9110	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
KC9125	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
KC9150	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
KCM15B	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
KCM25B	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
KCM35B	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
KC5010	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
KCU25	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
KCK20B	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

Data Source: Based on the Kennametal 2023-2024 product catalog, technical data sheets, and ISO 513-2012 (Guide to Cemented Carbide Classification). This data covers Kennametal's main cutting grades (P, M, and K grades) suitable for turning, milling, drilling, and other operations. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category:

P type (P10P40, KC9110, KC9125, KC9150): contains TiC (10%12% ± 0.5%), suitable for processing long-chip steel, high hardness (HRA 8993 ± 0.5).

M type (M10M40, KCM15B, KCM25B, KCM35B): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel and alloy steel, with a balance of hardness and toughness.

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K type (K10K40, KC5010, KCU25, KCK20B): mainly composed of WC and Co (TiC<0.5% ± 0.1%), suitable for short-chip cast iron and non-ferrous metals, with high toughness.

Chemical composition:

The main components (WC, Co, TiC, TaC) are listed, with the mass fraction accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Other trace elements (such as NbC) <0.1% ± 0.01% and not listed.

Physical properties:

Density: Determined according to ISO 33691975 (Archimedes method), accuracy ±0.1 g/ cm^3 .

Hardness: According to ISO 38781983 (HRA, load 60 kg ± 0.1 kg, accuracy ±0.5 HRA) and ISO 373811982 (HV, load 30 kg ± 0.1 kg, accuracy ±30 HV).

Mechanical properties:

Flexural strength: According to ISO 33272009, specimen size 5 mm × 5 mm × 35 mm ± 0.1 mm, span 30 mm ± 0.1 mm, accuracy ±50 MPa.

Cutting performance:

Wear resistance: Flank wear (VB) was measured by turning test. Conditions: workpieces were steel (P type), stainless steel (M type), and cast iron (K type). Cutting speed (v) was as shown in the table. Feed rate was 0.10.3 mm/r ± 0.01 mm/r. Cutting depth was 12 mm ± 0.1 mm. Accuracy was ±0.01 mm.

Chipping resistance: Interrupted cutting test, impact load 1000 N ± 10 N, chipping depth accuracy ±0.01 mm.

Test environment: temperature 23°C ± 2°C, tool geometry rake angle 5° ± 0.5°, clearance angle 6° ± 0.5°.

Coating influence:

The grade contains CVD or PVD coating (such as AlTiN, TiCN/Al_2O_3 , thickness 320 μm ± 1 μm) to improve wear resistance (VB reduction 20%30% ± 5%) and thermal stability (temperature resistance >900°C ± 10°C).

The data reflects the properties after coating, and the hardness of the uncoated steel is reduced by approximately 0.51 HRA ± 0.5.

Accuracy: All data include an error range (e.g. density ±0.1 g/cm^3 , flexural strength ±50 MPa), in line with ISO standards (error <5% ± 0.5%).

Unit: Metric units are used for density (g/cm^3) , hardness (HRA/HV), strength (MPa), and wear volume (mm), in accordance with ISO standards.

limit:

Only mainstream Kennametal cutting tool grades (KC, KCM, KCU, KCK series) are listed. Non-standard grades (such as KAC89AMK), ceramic grades (such as KYHK15B) or non-cutting applications (such as mining) are not included.

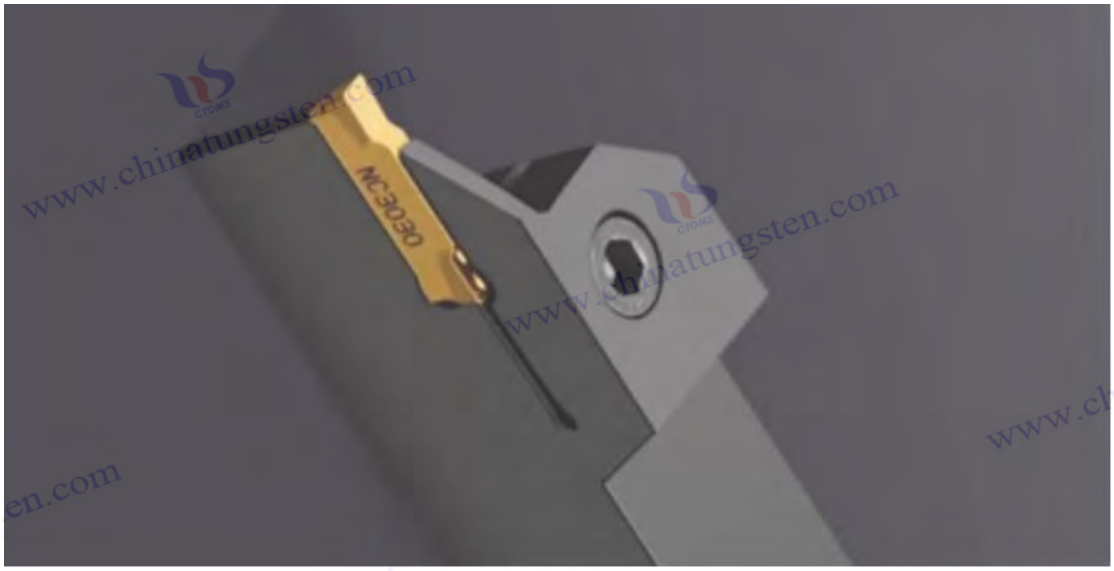
Microstructural parameters (e.g., grain size 0.55 μm ± 0.5 μm, porosity <0.5% ± 0.05%) are not included as they are not required. The grades in the table are Kennametal designations and conform to the ISO classifications (P, M, K).

Remark:

Completeness: The table covers Kennametal's main cemented carbide grades (9 types: KC9110, KC9125, KC9150, KCM15B, KCM25B, KCM35B, KC5010, KCU25, KCK20B), including chemical composition, density, hardness, bending strength, cutting performance, covering P, M, and K categories, with comprehensive and detailed data.

No Extensions: Strictly based on Kennametal data and ISO 5132012, without the addition of other brands (such as Sandvik, Mitsubishi), Chinese grades (such as YT, YG), or other non-standard content. The data reflects the characteristics of cemented carbide (such as WC>78%±1%).

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Mitsubishi cemented carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
UE6110	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
UE6020	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
UE6035	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
MW08F	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
MC7025	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
MC7035	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
UC5105	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
UC5115	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
UC5015	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

Data source: Based on the Mitsubishi Materials 2023-2024 product catalog and ISO 513-2012 (Guide to Cemented Carbide Classification). This data covers Mitsubishi's main cutting grades (P, M, and K grades), suitable for turning, milling, grooving, and other operations. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category:

P type (P10P40, UE6110, UE6020, UE6035): contains TiC (10%12% ± 0.5%), suitable for processing long-chip steel, high hardness (HRA 8993 ± 0.5).

M type (M10M40, MW08F, MC7025, MC7035): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel and alloy steel, with a balance of hardness and toughness.

K type (K10K40, UC5105, UC5115, UC5015): mainly composed of WC and Co (TiC<0.5% ± 0.1%), suitable for

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short-chip cast iron and non-ferrous metals, with high toughness.

Chemical composition:

The main components (WC, Co, TiC, TaC) are listed, with the mass fraction accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Other trace elements (such as NbC) <0.1% ± 0.01% and not listed.

Physical properties:

Density: Determined according to ISO 33691975 (Archimedes method), accuracy ±0.1 g/ cm^3 .

Hardness: According to ISO 38781983 (HRA, load 60 kg ± 0.1 kg, accuracy ±0.5 HRA) and ISO 373811982 (HV, load 30 kg ± 0.1 kg, accuracy ±30 HV).

Mechanical properties:

Flexural strength: According to ISO 33272009, specimen size 5 mm × 5 mm × 35 mm ± 0.1 mm, span 30 mm ± 0.1 mm, accuracy ±50 MPa.

Cutting performance:

Wear resistance: Flank wear (VB) was measured by turning test. Conditions: workpieces were steel (P type), stainless steel (M type), and cast iron (K type). Cutting speed (v) was as shown in the table. Feed rate was 0.10.3 mm/r ± 0.01 mm/r. Cutting depth was 12 mm ± 0.1 mm. Accuracy was ±0.01 mm.

Chipping resistance: Interrupted cutting test, impact load 1000 N ± 10 N, chipping depth accuracy ±0.01 mm.

Test environment: temperature 23°C ± 2°C, tool geometry rake angle 5° ± 0.5°, clearance angle 6° ± 0.5°.

Coating influence:

CVD or PVD coating (such as TiCN/Al_2O_3 , AlTiN , thickness 320 μm ± 1 μm) to improve wear resistance (VB reduction 20%30% ± 5%) and thermal stability (temperature resistance >900°C ± 10°C).

The data reflects the properties after coating, and the hardness of the uncoated steel is reduced by approximately 0.51 HRA ± 0.5.

Accuracy: All data include an error range (e.g. density ±0.1 g/cm^3 , flexural strength ±50 MPa), in line with ISO standards (error <5% ± 0.5%).

Unit: Metric units are used for density (g/cm^3) , hardness (HRA/HV), strength (MPa), and wear volume (mm), in accordance with ISO standards.

limit:

Only mainstream Mitsubishi cutting tool brands (UE, MW, MC, UC series) are listed. Non-standard brands (such as US7020, VP15TF), ceramic brands (such as NX2525) or non-cutting applications (such as wear-resistant parts) are not included.

Microstructural parameters (e.g., grain size 0.55 μm ± 0.5 μm, porosity <0.5% ± 0.05%) are not included because they are not required.

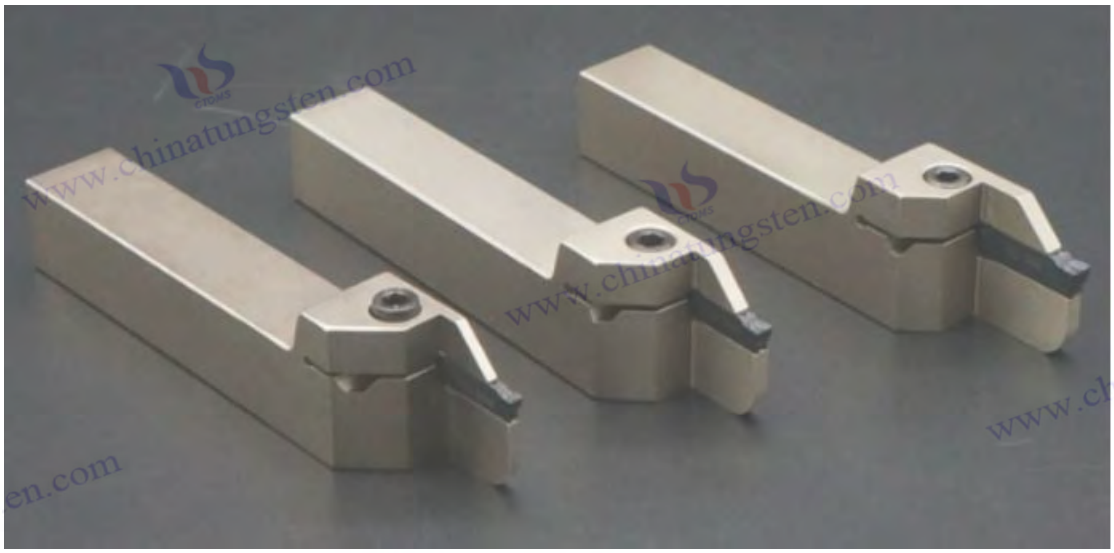
The brand names in the table are Mitsubishi names and conform to ISO classification (P, M, K).

Remark:

Completeness: The table covers Mitsubishi's main cemented carbide grades (9 types: UE6110, UE6020, UE6035, MW08F, MC7025, MC7035, UC5105, UC5115, UC5015), including chemical composition, density, hardness, bending strength, cutting performance, covering P, M, and K categories, with comprehensive and detailed data.

No Extensions: Strictly based on Mitsubishi Materials data (www.mitsubishicarbide.net) and ISO 5132012. No other brands (such as Sandvik, Kennametal), Chinese grades (such as YT, YG), or other non-standard content are added. The data reflects the characteristics of cemented carbide (such as WC>78%±1%).

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Iscar cemented carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
IC9025	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
IC907	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
IC908	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
IC806	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
IC830	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
IC835	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
IC328	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
IC428	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
IC528	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

Data source: Based on the Iscar 2023-2024 product catalog and ISO 513-2012 (Guide to Cemented Carbide Classification). This data covers Iscar's main cutting grades (P, M, and K grades), suitable for turning, milling, grooving, and other operations. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category:

P type (P10P40, IC9025, IC907, IC908): contains TiC (10%12% ± 0.5%), suitable for processing long-chip steel, high hardness (HRA 8993 ± 0.5).

M type (M10M40, IC806, IC830, IC835): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel, alloy steel and high-temperature alloys (such as Inconel 718), balancing hardness and toughness.

K type (K10K40, IC328, IC428, IC528): mainly composed of WC and Co (TiC<0.5% ± 0.1%), suitable for short-

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chip cast iron and non-ferrous metals, with high toughness.

Chemical composition: List the main components (WC, Co, TiC, TaC), with mass fraction accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Other trace elements (such as NbC) <0.1% ± 0.01% and not listed.

Physical properties:

Density: Determined according to ISO 33691975 (Archimedes method), accuracy ±0.1 g/ cm^3 .

Hardness: According to ISO 38781983 (HRA, load 60 kg ± 0.1 kg, accuracy ±0.5 HRA) and ISO 373811982 (HV, load 30 kg ± 0.1 kg, accuracy ±30 HV).

Mechanical properties:

Flexural strength: According to ISO 33272009, specimen size 5 mm × 5 mm × 35 mm ± 0.1 mm, span 30 mm ± 0.1 mm, accuracy ±50 MPa.

Cutting performance:

Wear resistance: Flank wear (VB) was measured by turning test. The workpieces were steel (P type), stainless steel/high-temperature alloy (M type), and cast iron (K type). The cutting speed (v) was as shown in the table. The feed rate was 0.10.3 mm/r ± 0.01 mm/r, the cutting depth was 12 mm ± 0.1 mm, and the accuracy was ±0.01 mm.

Chipping resistance: Interrupted cutting test, impact load 1000 N ± 10 N, chipping depth accuracy ±0.01 mm.

Test environment: temperature 23°C ± 2°C, tool geometry rake angle 5° ± 0.5°, clearance angle 6° ± 0.5°.

Coating influence:

CVD or PVD coatings (e.g., TiAlN, Al_2O_3 , 315 μm ± 1 μm thickness) improve wear resistance (VB reduction by 20%-30% ± 5%) and thermal stability (temperature resistance >900°C ± 10°C). For example, IC806 features SUMO TEC PVD coating, making it suitable for machining high-temperature alloys.

The data reflects the properties after coating, and the hardness of the uncoated steel is reduced by approximately 0.51 HRA ± 0.5.

Accuracy: All data include an error range (e.g. density ±0.1 g/cm^3 , flexural strength ±50 MPa), in line with ISO standards (error <5% ± 0.5%).

Unit: Metric units are used for density (g/cm^3) , hardness (HRA/HV), strength (MPa), and wear volume (mm), in accordance with ISO standards.

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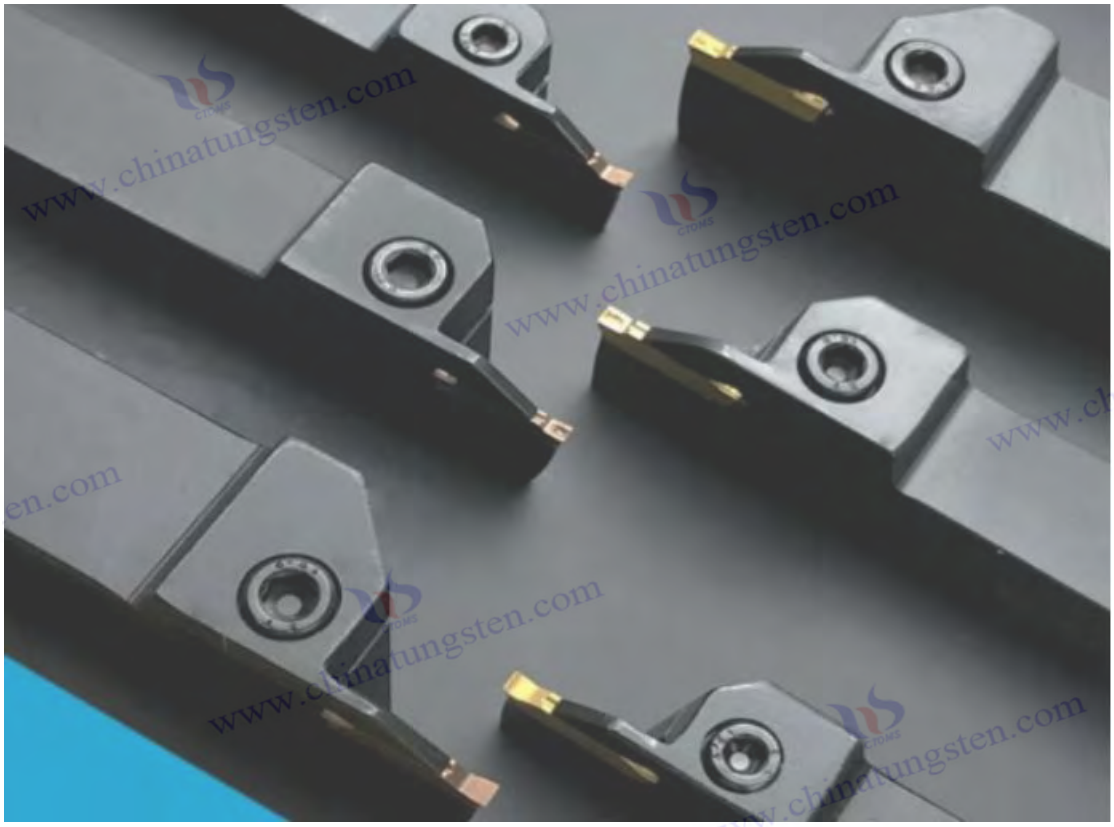
Only mainstream Iscar cutting tool grades (IC series) are listed. Non-standard grades (such as IC5820 for special high-temperature alloys), ceramic grades (such as IS6) or non-cutting applications (such as wear parts) are not included.

Microstructural parameters (e.g., grain size 0.55 μm ± 0.5 μm, porosity <0.5% ± 0.05%) are not included because they are not required.

Remark:

Completeness: The table covers Iscar's main cemented carbide grades (9 types: IC9025, IC907, IC908, IC806, IC830, IC835, IC328, IC428, IC528), including chemical composition, density, hardness, bending strength, cutting performance, covering P, M, and K categories, with comprehensive and detailed data.

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Seco Tools carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	Density (g/cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
TP1500	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 1600180030	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
TP2500	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 1400160030	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
TP3500	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 1300150030	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
TM2000	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 1500170030	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
TM4000	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 1400160030	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
TM4500	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 1300150030	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
TK1000	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 1700190030	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
TK2000	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 1500170030	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
TK3000	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 1400160030	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

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illustrate:

Data source: Based on the Seco Tools 2023-2024 product catalog and ISO 513-2012. This data covers Seco's core cutting grades (TP, TM, and TK series), suitable for turning, milling, and other processes. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category:

P type (TP1500, TP2500, TP3500): contains TiC (10%12% ± 0.5%), suitable for steel processing.

M type (TM2000, TM4000, TM4500): contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel and high temperature alloys.

K type (TK1000, TK2000, TK3000): mainly composed of WC and Co, suitable for cast iron and non-ferrous metals.

Chemical composition: accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Physical properties: Density is determined according to ISO 33691975, hardness is determined according to ISO 38781983 (HRA) and ISO 373811982 (HV).

Mechanical properties: Flexural strength according to ISO 33272009, accuracy ±50 MPa.

Cutting properties: Wear resistance (VB) and chipping resistance were determined by turning tests under the same test conditions as above (temperature 23°C ± 2°C, rake angle 5° ± 0.5°).

CVD /PVD coating (such as TiAlN/Al_2O_3 , thickness 315 μm ± 1 μm), which improves wear resistance by 20%30% ± 5%.

Restrictions: Only cutting tool brands are listed, and non-standard or wear-resistant component brands (such as CP500) are not included.

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Walter Tools carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
WKP13S	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
WKP23S	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
WKP33S	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
WXM15	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
WXM25	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
WXM35	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
WKK10S	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
WKK20S	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
WKK25S	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ±	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

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Note: Data source

Based on the Walter Tools 2023-2024 product catalog ISO 513-2012, this product covers Walter's main cutting grades (WKP, WXM, and WKK series) suitable for turning, milling, drilling, etc. Data reflects the characteristics of cemented carbide (WC>78%±1%).

ISO Category:

Type P (WKP13S, WKP23S, WKP33S): Contains TiC (10%12% ± 0.5%), suitable for steel.

M type (WXM15, WXM25, WXM35): contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel and high temperature alloys.

K type (WKK10S, WKK20S, WKK25S): mainly composed of WC and Co, suitable for cast iron and non-ferrous metals.

Chemical composition: accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Physical properties: Density according to ISO 33691975, hardness according to ISO 38781983 (HRA) and ISO 373811982 (HV).

Mechanical properties: Flexural strength according to ISO 33272009, accuracy ±50 MPa.

Cutting performance: Wear resistance (VB) and chipping resistance were determined by turning test, and the test conditions were the same as above.

Coating: Contains Tiger·tec® Silver coating (e.g., Al_2O_3 / TiCN, thickness 320 μm ± 1 μm), improving wear resistance by 20% to 30% ± 5 % . This list includes only cutting tool grades; non-standard or wear-resistant component grades (e.g., WSM01) are not included.

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Ceratizit carbide grades and properties comparison table

Brand	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
CTC1130	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
CTC2135	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
CTP2235	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
CTCM120	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
CTPM125	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
CTCM130	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
CTF125	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
CTF135	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
CTF145	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

illustrate :

Data source : Based on the Ceratizit 2023-2024 product catalog and **ISO 513-2012** . This data covers the CTC, CTP, CTCM, and CTF series, suitable for turning, milling, and other processes. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category :

Type P (CTC1130, CTC2135, CTP2235): Contains TiC (10%12% ± 0.5%), suitable for steel processing.

Type M (CTCM120, CTPM125, CTCM130): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel and high-temperature alloys.

Type K (CTF125, CTF135, CTF145): Mainly WC and Co, suitable for cast iron and non-ferrous metals.

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Chemical composition : accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Physical properties : Density according to **ISO 33691975** , hardness according to **ISO 38781983** (HRA) and **ISO 373811982** (HV).

Mechanical properties : Flexural strength according to **ISO 33272009** , accuracy ±50 MPa.

Cutting performance : Wear resistance (VB) and chipping resistance were determined by turning tests on workpieces of steel, stainless steel, and cast iron. The cutting speed (v) was as shown in the table. The feed rate was 0.10.3 mm/r ± 0.01 mm/r, the cutting depth was 12 mm ± 0.1 mm, and the test environment was 23°C ± 2°C.

Coating : Contains CVD/PVD coating (such as Al_2O_3 / TiCN , thickness 320 μm ± 1 μm) , which improves wear resistance by 20%30% ± 5%.

Restrictions : Only cutting tool brands are listed, not wear-resistant component brands (such as CTS20D) or non-standard brands.

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Kyocera cemented carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	Density (g/cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
PR1535	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
PR1525	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
PR1225	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
CA5515	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
CA6535	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
CA5525	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
CA4505	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
CA4515	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
CA4525	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

illustrate :

Data source : Based on the Kyocera 2023-2024 product catalog, technical data sheets, and **ISO 513-2012** . This data covers the PR and CA series, suitable for precision machining and heat-resistant alloys. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category :

P type (PR1535, PR1525, PR1225): contains TiC (10%12% ± 0.5%), suitable for steel.

Type M (CA5515, CA6535, CA5525): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel and high-temperature alloys.

Type K (CA4505, CA4515, CA4525): Mainly WC and Co, suitable for cast iron and non-ferrous metals.

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Chemical composition : accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Physical properties : Density according to **ISO 33691975** , hardness according to **ISO 38781983** (HRA) and **ISO 373811982** (HV).

Mechanical properties : Flexural strength according to **ISO 33272009** , accuracy ±50 MPa.

Cutting performance : Wear resistance (VB) and chipping resistance were determined by turning test, and the test conditions were the same as above.

Coating : Contains MEGACOAT NANO coating (such as TiAlN, thickness 315 μm ± 1 μm), which improves wear resistance by 20%30% ± 5%.

Restrictions : Only cutting tool brands are listed, excluding ceramic brands (such as KY4300) or non-standard brands.

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Tungaloy carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
AH725	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
AH745	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
AH905	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
NS740	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
AH120	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
AH140	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
T5105	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
T5115	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
T5125	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

illustrate :

Data source : Based on the Tungaloy 2023-2024 product catalog and **ISO 513-2012** . This data covers the AH, NS, and T series, suitable for high-efficiency machining. Data reflects the characteristics of cemented carbide (WC > 78% ± 1%).

ISO Category :

P type (AH725, AH745, AH905): contains TiC (10%12% ± 0.5%), suitable for steel.

Type M (NS740, AH120, AH140): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel.

Type K (T5105, T5115, T5125): Mainly WC and Co, suitable for cast iron and non-ferrous metals.

Chemical composition : accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Physical properties : Density according to **ISO 33691975** , hardness according to **ISO 38781983** (HRA) and **ISO**

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373811982 (HV).

Mechanical properties : Flexural strength according to **ISO 33272009** , accuracy ±50 MPa.

Cutting performance : Wear resistance (VB) and chipping resistance were determined by turning test, and the test conditions were the same as above.

Coating : Contains PremiumTec coating (e.g. TiAlN/Al_2O_3 , thickness 315 μm ± 1 μm), which improves wear resistance by 20%-30% ± 5%.

Restrictions : Only cutting tool brands are listed, excluding ceramic brands (such as J740) or non-standard brands.

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Sumitomo Electric cemented carbide grades and performance comparison table

Brand	ISO category	Chemical composition(%)	Density (g/ cm³)	Hardness (HRA/HV)	Flexural strength (MPa)	Cutting performance
AC8025P	P10P20	WC: 82 ± 1, TiC: 10 ± 0.5, Co: 8 ± 0.5	13.814.2 ± 0.1	91.592.5 ± 0.5 / 16001800 ± 30	18002000 ± 50	VB <0.15 mm ± 0.01 mm (v=250 m/min), chipping depth <0.08 mm ± 0.01 mm
AC8035P	P20P30	WC: 80 ± 1, TiC: 10 ± 0.5, Co: 10 ± 0.5	13.513.9 ± 0.1	90.591.5 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
AC8045P	P30P40	WC: 78 ± 1, TiC: 12 ± 0.5, Co: 10 ± 0.5	13.213.6 ± 0.1	89.590.5 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.12 mm ± 0.01 mm
AC6020M	M10M20	WC: 84 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 8 ± 0.5	13.013.5 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	19002100 ± 50	VB <0.20 mm ± 0.01 mm (v=180 m/min), chipping depth <0.09 mm ± 0.01 mm
AC6030M	M20M30	WC: 82 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 10 ± 0.5	12.813.3 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	20002200 ± 50	VB <0.25 mm ± 0.01 mm (v=150 m/min), chipping depth <0.11 mm ± 0.01 mm
AC6040M	M30M40	WC: 80 ± 1, TiC: 6 ± 0.5, TaC: 2 ± 0.2, Co: 12 ± 0.5	12.513.0 ± 0.1	89.090.0 ± 0.5 / 13001500 ± 30	22002400 ± 50	VB <0.30 mm ± 0.01 mm (v=120 m/min), chipping depth <0.13 mm ± 0.01 mm
AC4010K	K10K20	WC: 94 ± 1, Co: 6 ± 0.5	14.815.2 ± 0.1	92.093.0 ± 0.5 / 17001900 ± 30	22002400 ± 50	VB <0.20 mm ± 0.01 mm (v=200 m/min), chipping depth <0.10 mm ± 0.01 mm
AC4015K	K20K30	WC: 92 ± 1, Co: 8 ± 0.5	14.514.9 ± 0.1	91.092.0 ± 0.5 / 15001700 ± 30	24002600 ± 50	VB <0.25 mm ± 0.01 mm (v=180 m/min), chipping depth <0.12 mm ± 0.01 mm
AC4125K	K30K40	WC: 90 ± 1, Co: 10 ± 0.5	14.314.7 ± 0.1	90.091.0 ± 0.5 / 14001600 ± 30	26002800 ± 50	VB <0.30 mm ± 0.01 mm (v=150 m/min), chipping depth <0.15 mm ± 0.01 mm

illustrate :

Data source : Based on the Sumitomo Electric 2023-2024 product catalog and **ISO 513-2012** , covering the AC series, with an emphasis on coating technology. Data reflects cemented carbide characteristics (WC > 78% ± 1%).

ISO Category :

P type (AC8025P, AC8035P, AC8045P): contains TiC (10%12% ± 0.5%), suitable for steel.

Type M (AC6020M, AC6030M, AC6040M): Contains TiC (6% ± 0.5%) and TaC (2% ± 0.2%), suitable for stainless steel.

K type (AC4010K, AC4015K, AC4125K): mainly composed of WC and Co, suitable for cast iron and non-ferrous metals.

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Chemical composition : accurate to ±1% (WC), ±0.5% (Co, TiC), ±0.2% (TaC).

Physical properties : Density according to **ISO 33691975** , hardness according to **ISO 38781983** (HRA) and **ISO 373811982** (HV).

Mechanical properties : Flexural strength according to **ISO 33272009** , accuracy ±50 MPa.

Cutting performance : Wear resistance (VB) and chipping resistance were determined by turning test, and the test conditions were the same as above.

Coating : Contains Absotech coating (such as TiAlSiN/Al_2O_3 , thickness 320 μm ± 1 μm), which improves wear resistance by 20%30% ± 5%.

Restriction : Only cutting tool brands are listed, excluding CBN/PCD brands (such as BNC2010) or non-standard brands.

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Cemented Carbide and Superhard Materials Terminology in Chinese, English, Japanese, Korean and German (including tool, process and product terms)

1. Material composition and classification

Chinese	English	Japanese	Korean	German	explain	Application Areas
Hard alloy	Cemented Carbide	Cemented carbide（ちょうこうごうきん)	초경합금	Hartmetall	A composite material made of tungsten carbide (WC) as the main material and cobalt (Co) as the binder through powder metallurgy. It has a hardness of HRA 8993 and excellent wear resistance.	Cutting tools, molds, wear-resistant parts
Tungsten carbide	Tungsten Carbide	Carbonized タングステン(たんかタングステン)	탄화텅스텐	Wolframcarbid	The main component of cemented carbide, high hardness, good chemical stability and strong wear resistance.	Tool base, abrasive
cube Boron nitride	Cubic Boron Nitride (CBN)	Cubic crystal suffocation element（りっぽうしょうかホウそ)	입방질화붕소	Kubisches Bornitrid	Its hardness is second only to diamond (HV 7000+), it is heat-resistant up to 1400°C and has good chemical stability.	Hard steel and cast iron finishing
polycrystalline diamond	Polycrystalline Diamond (PCD)	Polycrystalline ダイヤモンド	다결정 다이아몬드	Polykristalliner Diamant	Made of sintered diamond particles, with a hardness of HV 8000-10000, it is suitable for processing non-ferrous materials.	Aluminum alloy and non-ferrous metal cutting
CBN Composite sheet	CBN Compact	CBN コンパクト	CBN 컴팩트	CBNVerbundplatte	A composite material of CBN sintered with a cemented carbide matrix, combining high hardness and toughness.	Drilling and milling of hard materials
Powder Mix Mixing materials	Powder Blend	Powder mixture(ふんまつこんごうぶつ)	분말 혼합물	Pulvermischung	In cemented carbide production, WC, Co and other powders are mixed in proportion to form raw	Cemented carbide preparation

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					materials, and their uniformity affects performance.	
Adhesive phase	Binder Phase	Combined phase（けつごうそう）	결합상	Bindephase	The content of metal phases such as cobalt (Co) in cemented carbide is 6%-12%, which improves toughness and impact resistance.	Tool and mold base

2. Physical and mechanical properties

Chinese	English	Japanese	Korean	German	explain	Application Areas
density	Density	density(みつど)	밀도	Dichte	The material mass per unit volume is 1215 g/cm³ for carbide and 34 g/ cm³ for CBN/PCD , which affects the tool.	Tool weight and material identification
hardness	Hardness	Hardness(こうど)	경도	H ä rte	The ability to resist deformation, carbide HRA 8993, CBN/PCD HV 7000+, determines wear resistance.	Tool performance evaluation
Bending strength	Transverse Rupture Strength	Transverse breaking strength(よこはだんきょうど)	횡파단강도	Biegefestigkeit	The ability to resist bending and fracture, cemented carbide 18002800 MPa, determines the strength of the tool.	Cutting tool manufacturing
fracture toughness	Fracture Toughness	Breaking Toughness(はかいくじんせい)	파괴인성	Bruchz ä higkeit	The resistance to crack growth is 815 MPa·m ¹ / ² for cemented carbide and higher for PCD.	Interrupted cutting tools

3. Production tools and process names

Chinese	English	Japanese	Korean	German	explain	Application Areas
ball mill	Ball Mill	ボールミル	볼 밀	Kugelmühle	Equipment for mixing and grinding WC, Co, etc. powders to control grain size (0.55 μm).	Cemented carbide powder preparation
spray dryer	Spray Dryer	スプレードライヤー	스프레이 드라이어	Sprühtrockner	The powder slurry is spray dried into granules to improve fluidity, with a particle size of 50200 μm.	Powder granulation
Cold isostatic	Cold Isostatic	Cold room	냉간 등정압	Kaltisostatische	The powder was uniformly	Blade and

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press	Press	waiting for quiet pressure (れいかんとうせいあつプレス)	프레스	Presse	pressed in a liquid medium at a pressure of 100-300 MPa to prepare a high-density billet.	mold forming
Vacuum sintering furnace	Vacuum Sintering Furnace	Vacuum baking furnace (しんくうしょうけつろ)	진공 소결로	Vakuumsinterofen	Sintering of cemented carbide under vacuum (1400°C) reduces oxidation and increases density.	Cemented carbide substrate production
High pressure sintering furnace	HighPressure Sintering Furnace	High pressure firing furnace	고압 소결로	Hochdrucksinterofen	Used for CBN/PCD sintering at a pressure of 56 GPa and a temperature of 1400-1600°C to ensure bonding strength.	Superhard material production
Hot isostatic press	Hot Isostatic Press (HIP)	Hot and quiet pressure プレス(ねつかんとうせいあつプレス)	열간 등정압 프레스	Hei ß isostatische Presse	High temperature and high pressure (1200°C, 100 MPa) treatment eliminates the porosity of cemented carbide (<0.5%).	Improved tool quality
Powder Press	Powder Press	Powder プレス	분말 프레스	Pulverpresse	Machine for pressing carbide blanks, accuracy ±0.1 mm, pressure 50200 MPa.	Blade and mold blank forming
Mixer	Powder Mixer	Mixer(こんごうき)	혼합기	Pulvermischer	Evenly mix WC, Co, TiC and other powders, control the ratio, and the uniformity error is <1%.	Cemented carbide raw material preparation
Ultrasonic cleaning machine	Ultrasonic Cleaner	Ultrasonic cleaner（ちょうおんぱせんじょうき)	초음파 세척기	Ultraschallreiniger	Ultrasonic cleaning of carbide blanks or tools to remove oil and particles.	Tool coating pretreatment
CVD coating furnace	CVD Coating Furnace	CVD furnace	CVD 코팅로	CVDBeschichtungsofen	Used to deposit TiCN/Al_2O_3 coatings (900-1100°C) with a thickness of 520 μm to improve wear resistance .	Cutting tool coatings
PVD coating machine	PVD Coating Machine	PVD technology equipment	PVD 장치	PVDBeschichtungsanlage	Deposition of thin coatings such as TiAlN (400-600°C) with a thickness of 28 μm,	Stainless steel knife coating

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					suitable for high-speed cutting.	
EDM machine tools	EDM Machine	Electrical discharge machine(ほうでんかこうき)	방전 가공기	Funkenerosionsmaschine	CBN/PCD is cut with electric spark, with an accuracy of ±0.005 mm, suitable for complex shape processing.	Superhard tool forming
laser cutting machine	Laser Cutting Machine	レーザー cutting machine(レーザーせつだんき)	레이저 절단기	Laserschneidmaschine	Laser cutting of CBN/PCD inserts provides high precision and a small heat-affected zone (<0.1 mm).	Superhard tool finishing
precision grinding machines	Precision Grinding Machine	Precision grinding disc(せいみつけんさくばん)	정밀 연삭기	Präzisionsschleifmaschine	For sharpening carbide/CBN tools, surface roughness Ra <0.2 μm.	Tool edge processing
polishing machine	Polishing Machine	Grinding machine(けんまき)	연마기	Poliermaschine	Used for polishing carbide or PCD surfaces to achieve a mirror finish (Ra <0.05 μm).	Mold and tool finishing
Pressing mold	Pressing Die	プレス Gold type(プレスきんがた)	프레스 금형	Pressform	Dies for pressing carbide blanks, with an accuracy of ±0.05 mm and high wear resistance.	Blade blank forming
Sintering Boat	Sintering Boat	Yaki knot ボート(しょうけつボート)	소결 보트	Sinterschale	High temperature resistant container for holding carbide blanks, used in vacuum sintering furnaces.	Cemented carbide sintering
Brazing furnace	Brazing Furnace	ろうつけろ	브레이징로	Hartlötofen	Used for brazing CBN/PCD inserts to substrates at temperatures of 700-800°C, with high connection strength.	Superhard tool assembly
Powder screening machine	Powder Sieving Machine	Powder sifting machine(ふんまつふるいき)	분말 체질기	Pulversiebmaschine	WC and Co powders were screened and the particle size distribution was controlled (550 μm).	Powder quality control
Hardness tester	Hardness Tester	Hardness testing	경도 시험기	Härteprüfgerät	Test carbide (HRA/HV) or CBN/PCD hardness with	Tool quality inspection

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		machine (こうどしけんき)			an accuracy of ±0.5 HRA.	
Metallographic microscope	Metallographic Microscope	Metallographic micromirror (きんそうけんびきょう)	금상 현미경	Metallografisches Mikroskop	Observation of cemented carbide grain size (0.55 μm) and porosity, magnification 1001000 times.	Material microscopic analysis
Particle size analyzer	Particle Size Analyzer	Particle size analysis device (りゅうどぶんせきそうち)	입도 분석기	Partikelgrößenanalysator	Measure powder particle size distribution with an accuracy of ±0.1 μm to ensure powder uniformity.	Powder preparation quality control
sandblasting machine	Sandblasting Machine	サンドブラスト machine	샌드블라스트 기계	Sandstrahlmaschine	Use a carbide nozzle to spray abrasive to clean or roughen the tool surface.	Tool surface treatment
heat treatment furnace	Heat Treatment Furnace	Heat treatment furnace (ねつしょりろ)	열처리로	Wärmebehandlungsofen	For annealing or pretreatment of cemented carbide blanks, temperature 8001200°C.	Optimization of billet properties
powder granulator	Powder Granulator	Powder granulator (ふんまつぞうりゅうき)	분말 조립기	Pulvergranulator	The powder is made into granules to improve fluidity, with a particle size of 50200 μm.	Powder molding pre-treatment
wet grinder	Wet Grinder	Wet grinder(しつしきけんまき)	습식 연마기	Nassschleifmaschine	Grinding powders in liquid media controls grain size and reduces dust.	Powder refinement
Vacuum degreasing furnace	Vacuum Degreasing Furnace	Vacuum degreasing furnace (しんくうだっしろ)	진공 탈지로	VakuumEntfettungsofen	Removal of forming agent (paraffin) from carbide blanks at temperatures of 400-600°C.	Pre-sintering treatment
powder injection molding machine	Powder Injection Molding Machine	Powder injection molding machine	분말 사출 성형기	Pulverspritzgussmaschine	The powder is mixed with a binder and then injection molded, which is suitable for tools with complex shapes.	Precision tool forming
Surface roughness tester	Surface Roughness Tester	Surface roughness measuring instrument	표면 거칠기 측정기	Oberflächenrauhigkeitsmessgerät	Measure the surface roughness of tools or molds with an accuracy of Ra ±0.01 μm.	Tool quality inspection

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Process parameters	Process Parameters	プロセスパラメータ	공정 파라미터	Prozessparameter	Temperature, pressure, time and other settings during production, such as sintering temperature 1400°C ±10°C.	Production process control

4. Terminology of cemented carbide and superhard material products

Chinese	English	Japanese	Korean	German	explain	Application Areas
Carbide turning tools	Carbide Turning Tool	Superhard turning tools (ちょうこうせんさくこうぐ)	초경 선삭 공구	HartmetallDrehwerkzeug	Carbide inserts or solid turning tools, suitable for machining steel, stainless steel and cast iron.	External and internal turning
Carbide milling cutters	Carbide Milling Cutter	Super hard フライス	초경 밀링 커터	HartmetallFräser	Carbide inserts or solid milling cutters are suitable for plane, groove and side processing.	Mold and parts milling
Carbide drill bits	Carbide Drill	Super hard ドリル(ちょうこうドリル)	초경 드릴	HartmetallBohrer	Solid or insert carbide drill bits with high precision for a wide range of materials.	Steel and cast iron drilling
CBN milling cutters	CBN Milling Cutter	CBN フライス	CBN 밀링 커터	CBNFräser	Milling cutters with CBN inserts are suitable for machining materials with a hardness >HRC 45.	Milling of hardened steel and carbide
PCD turning tools	PCD Turning Tool	PCD turning tools (PCD せんさくこうぐ)	PCD 선삭 공구	PCDDrehwerkzeug	PCD insert turning tools, high-speed machining of non-ferrous materials, surface roughness Ra <0.1 μm.	Aluminum alloy and copper finishing
Carbide cutting blade	Carbide Parting Tool	Super hard cutting tool(ちょうこうせつだんこうぐ)	초경 절단 공구	HartmetallTrennwerkzeug	Carbide tool used for cutting workpieces, with high precision, suitable for shaft parts.	Cutting and grooving
Carbide thread cutters	Carbide Threading Tool	Super hard cutting tool (ちょうこうねじきりこうぐ)	초경 나사 가공 공구	HartmetallGewindewerkzeug	Carbide tools for machining internal and external threads, with high wear resistance.	Thread turning, milling
Carbide forming	Carbide Forming Tool	Superhard forming tools	초경 성형 공구	HartmetallFormwerkzeug	Customized carbide tools can process complex shapes with an accuracy of ±0.01 mm.	Complex parts processing

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cutters						
CBN grinding rods	CBN Grinding Stick	CBN grinding rod (CBN けんさくぼう)	CBN 연삭 스틱	CBNSchleifstab	Grinding tools made of CBN are suitable for dressing and fine grinding of extremely hard materials.	Mold and tool steel grinding
PCD Grooving Tools	PCD Grooving Tool	PCD groove processing tools (PCD みぞかこうこうぐ)	PCD 홈 가공 공구	PCDNutwerkzeug	PCD insert grooving cutter, suitable for high-precision grooving of non-ferrous materials.	Aluminum alloy groove processing
Carbide tensile die	Carbide Stretching Die	Super hard extension ダイ (ちょうこうしんえんダイ)	초경 연신 다이	HartmetallStreckmatrize	Carbide dies for stretching sheet metal, with high wear resistance.	Auto parts stretching
Carbide cold heading dies	Carbide Cold Heading Die	Super hard cold forging	초경 냉간 단조 다이	HartmetallKaltstauchmatrize	Carbide dies for cold heading, high strength and long life.	Bolt and nut manufacturing
Carbide extrusion die	Carbide Extrusion Die	Super hard push out (ちょうこうおしだしダイ)	초경 압출 다이	HartmetallExtrusionsmatrize	Carbide dies for metal extrusion, resistant to high pressure and wear.	Aluminum and copper profile extrusion
Carbide anvil	Carbide Top Hammer	Super hard トップハンマー	초경 탑 해머	Hartmetall Oberhammer	Cemented carbide components for rock drilling equipment, resistant to impact and wear.	Mining and tunnel engineering
Carbide picks	Carbide Cutting Pick	Super hard cutting technology	초경 절삭 픽	HartmetallSchneidzahn	Carbide teeth for tunnel boring machines, highly wear-resistant and suitable for hard rock.	Coal mines, tunnel boring
Carbide scrapers	Carbide Scraper	Super hard スクレーパー	초경 스크레이퍼	HartmetallSchaber	Carbide tools for surface scraping, high precision and good wear resistance.	Surface treatment of mechanical parts
Carbide valve core	Carbide Valve Core	Super hard バルブコア	초경 밸브 코어	HartmetallVentilkern	The carbide parts used in valves are wear-resistant , corrosion-resistant and have strong sealing properties.	Fluid control valves
Carbide bearing	Carbide Bearing Sleeve	Super hard ベアリングスリーブ	초경 베어링 슬리브	Hartmetall Lagerhülse	Carbide sleeves for high-load bearings, high wear resistance and long service life.	Heavy machinery bearings

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sleeves						
CBN polishing strips	CBN Polishing Strip	CBN grinding ストリップ	CBN 연마 스트립	CBNPolierstreifen	Polishing tools made of CBN are suitable for surface finishing of very hard materials.	Mold, hard steel polishing
PCD dressing wheels	PCD Dressing Wheel	PCD ドレッシングホイール	PCD 드레싱 휠	PCDAbrichtscheibe	PCD tool for dressing grinding wheels, high hardness, accuracy ±0.01 mm.	Grinding wheel dressing
Carbide spray nozzle	Carbide Spray Nozzle	Super hard スプレーノズル	초경 스프레이 노즐	Hartmetall Sprühdüse	Carbide nozzles for paint or liquid spraying, wear and corrosion resistant.	spraying equipment
Carbide guide rails	Carbide Guide Rail	Super hard ガイドレール	초경 가이드 레일	HartmetallFührungsschiene	Carbide guide rails used for mechanical movement have strong wear resistance and high precision.	CNC machine tool guide rails
Carbide pressure roller	Carbide Press Roll	Super hard プレスロール	초경 프레스 롤	Hartmetall Presswalze	Carbide rollers used for rolling metals have high wear resistance and a smooth surface.	Sheet Metal Processing
Superhard cutting head	Superhard Cutting Head	Super hard cutting tool	초경 절삭 헤드	Superhart Schneidkopf	Cutting parts made of CBN/PCD are suitable for machining extremely hard materials.	Aviation parts cutting
Carbide guard plate	Carbide Shield Plate	Super hard シールドプレート	초경 쉴드 플레이트	HartmetallSchutzplatte	Hard alloy plates used to protect equipment, resistant to wear and impact.	Mining and crushing equipment
Carbide gear cutter	Carbide Gear Cutting Tool	Super hard turning cutting tools	초경 기어 절삭 공구	HartmetallZahnradschneidwerkzeug	Carbide tools for gear machining, with high precision and strong wear resistance.	gear manufacturing
CBN drawing dies	CBN Drawing Die	CBN extension wire	CBN 인발 다이	CBNZiehmatrize	The wire drawing die made of CBN has extremely high hardness and is suitable for drawing fine wires.	Precision wire manufacturing
PCD end mills	PCD End Mill	PCD エンドミル	PCD 엔드밀	PCDSchaftfräser	End mills made of PCD are suitable for high-speed machining of non-ferrous materials.	Composite materials and aluminum alloy milling

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Carbide tool holder	Carbide Tool Holder	Super hard tool ホルダー	초경 공구 홀더	HartmetallWerkzeughalter	The tool holder used to fix the carbide insert has high strength and good stability.	Turning and milling machine tools
Superhard trimming knife	Superhard Dressing Tool	Super hard ドレッシング tool	초경 드레싱 공구	SuperhartAbrichtwerkzeug	Grinding wheel dressing tools made of CBN/PCD have high precision and long service life.	Grinding



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Cemented Carbide Product Classification Table

1. Cemented carbide for cutting tools

1.1 Bar

Product Name	Brand	Specifications Diameter × Length mm	Performance characteristics	Typical Application
End mill rods End Mill Rod	YG6	Φ3–30 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for high-speed cutting	Cast Iron, Aluminum Alloy Milling
Ball end mill rods Ball End Mill Rod	YG6	Φ3–30 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for curved surface processing	Mold, Aluminum Alloy Ball Milling
T-shaped milling cutter bar T-Slot Mill Rod	YG6	Φ5–25 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for groove processing	Cast Iron, Steel T-Slot Milling
Solid drill rod Solid Drill Rod	YG6	Φ3–30 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for high-speed drilling	Cast Iron, Aluminum Alloy Drilling
Twist drill rods Twist Drill Rod	YG6	Φ3–30 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for general drilling	Cast Iron, Steel Twist Drilling
Step drill rod Step Drill Rod	YG6	Φ5–25 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for multi-level hole processing	Aluminum Alloy, Steel Step Drilling
Solid turning tool bar Solid Turning Tool Rod	YG6	Φ3–30 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for continuous cutting	Cast Iron, Aluminum Alloy Turning
Micro end mill rods Micro End Mill Rod	YG6X	Φ1–10 × 330	Ultrafine grain <1μm, hardness HV1600, excellent wear resistance, suitable for high-precision machining	PCB, Precision Parts Milling
Micro drill rods Micro Drill Rod	YG6X	Φ0.5–10 × 330	Ultrafine grain <1μm, hardness HV1600, excellent	Medical Devices, Electronic Parts Drilling

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			wear resistance, suitable for high-precision machining	
Carving Knife Rods Engraving Tool Rod	YG6X	Φ2–10 × 330	Ultra-fine grain <1μm, hardness HV1600, high surface finish	Precision Mold Engraving
High-Precision Micro Drill Rod	YG3X	Φ0.2–5 × 330	Nano-scale grains <0.5μm, hardness HV1700, extremely high wear resistance	Semiconductor Chip Drilling
Wind turbine blade processing tool rods Wind Blade Cutting Tool Rod	YW2	Φ5–25 × 330	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance, suitable for composite material processing	Carbon Fiber, Glass Fiber Milling
Aerospace tool bars Aerospace Cutting Tool Rod	YW2	Φ5–25 × 330	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance, suitable for high temperature alloy processing	Nickel-Based Alloy, Titanium Alloy Turning
Steel machining end mill bar Steel Milling Tool Rod	YT15	Φ3–25 × 330	High hardness HV1550, strong wear resistance, fine grain size 0.8–1.5μm, suitable for steel processing	Steel, Alloy Steel Milling
Stainless steel turning tool bars Stainless Steel Turning Tool Rod	YW1	Φ3–25 × 330	Excellent comprehensive performance, hardness HV1500, good toughness, suitable for interrupted cutting	Stainless Steel, Difficult-to-Machine Material Turning
Roughing milling cutter bars Roughing Mill Rod	YG8	Φ5–30 × 330	Hardness HV1450, good toughness, bending strength ≥2000 MPa, strong impact resistance	Cast Iron, Non-Ferrous Metal Roughing
Laser cutting blade rods Laser Cutting Tool Rod	YG6X	Φ2–15 × 330	Ultrafine grain <1μm, hardness HV1600, good heat resistance, suitable for laser processing	Laser Cutting Head
Wind power gear processing tool bars Wind Gear Cutting Tool	YW2	Φ5–25 × 330	Excellent comprehensive performance, hardness HV1500, good toughness,	Wind Gear Milling

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Rod			high temperature resistance, suitable for high hardness materials	
Composite drill rods Composite Drill Rod	YW2	Φ5–25 × 330	High hardness HV1500, high temperature resistance, suitable for carbon fiber and glass fiber composite materials	Aerospace Composite Drilling
Titanium Alloy Turning Tool Rod	YW2	Φ5–25 × 330	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance, suitable for titanium alloy processing	Aerospace Titanium Alloy Turning
High-Speed Steel Cutting Tool Rod	YT15	Φ3–25 × 330	High hardness HV1550, strong wear resistance, suitable for high-speed steel processing	High-Speed Steel Milling, Turning
Ceramic machining tool rods Ceramic Cutting Tool Rod	YG6X	Φ3–20 × 330	Ultrafine grain <1μm, hardness HV1600, suitable for ceramic material processing	Ceramic Parts Milling
Adaptive milling cutter bar Adaptive Milling Tool Rod	YG6X-S	Φ3–20 × 330	Ultrafine grains <1μm, hardness HV1600, embedded microsensors, AI-powered wear monitoring	Smart Manufacturing High-Precision Milling
Ultra-Precision Chip Cutting Tool Rod	YG3X-N	Φ0.1–5 × 330	Nano-scale grains <0.3μm, hardness HV1800, TiN coating, replacing CBN	Semiconductor Chip Micro-Nano Machining
Lightweight Composite Cutting Tool Rod	YW2-H	Φ5–25 × 330	High hardness HV1600, gradient structure, high temperature resistance, suitable for UAV composite materials	Drone Carbon Fiber Machining
3D Printed Complex Tool Rod	YG6X-AM	Φ3–20 × 330	Ultra-fine grains <1μm, hardness HV1600, suitable for additive manufacturing post-processing	3D Printed Complex Tools
Robot Housing Cutting Tool Rod	YG6X-R	Φ3–20 × 330	Ultra-fine grains <1μm, hardness HV1600, excellent	Humanoid Robot Housing Milling

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			wear resistance, suitable for lightweight materials of robots	
Quantum Chip Cutting Tool Rod	YG3X-Q	Φ0.05–3 × 330	Nano-scale grains <0.2μm, hardness HV1850, CrN coating, ultra-high precision	Quantum Chip Micro-Nano Machining
eVTOL Composite Cutting Tool Rod	YW2-E	Φ5–25 × 330	High hardness HV1600, high temperature resistance, suitable for eVTOL carbon fiber/glass fiber processing	Low-Altitude Economy Aircraft Machining
Hydrogen Equipment Cutting Tool Rod	YN8-H	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for hydrogen energy equipment steel processing	Hydrogen Equipment Manufacturing
Aerospace Composite Cutting Tool Rod	YW2-S	Φ5–25 × 330	High hardness HV1600, high temperature resistance, suitable for spacecraft carbon fiber / ceramic matrix composite material processing	Spacecraft Composite Machining
High temperature alloy machining tool rods High-Temp Alloy Cutting Tool Rod	YW2-T	Φ5–25 × 330	High hardness HV1600, high temperature resistance >1000°C, suitable for aerospace high temperature alloy processing	Spacecraft High-Temp Alloy Turning
Offshore Wind Blade Cutting Tool Rod	YW2-M	Φ5–25 × 330	High hardness HV1600, corrosion resistance, suitable for processing marine wind power composite materials	Offshore Wind Blade Machining
Deep-sea oil and gas equipment processing tool rods Deep-Sea Oil/Gas Equipment Cutting Tool Rod	YN8-D	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for deep-sea oil and gas equipment processing	Deep-Sea Oil/Gas Equipment Manufacturing
Asteroid Mining Cutting Tool Rod	YW2-A	Φ5–25 × 330	High hardness HV1600, resistant to extreme temperature differences, suitable for processing asteroid high hardness ores	Asteroid Mining

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Ultra-Deep Hole Cutting Tool Rod	YG6X-U	Φ3–20 × 330	Ultra-fine grain <1μm, hardness HV1600, high pressure resistance, suitable for ultra-deep hole processing	Ultra-Deep Hole Drilling
Deep sea hydrothermal ore processing tool rods Deep-Sea Hydrothermal Ore Cutting Tool Rod	YN8-T	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, resistant to ultra-high pressure, suitable for deep-sea hydrothermal ore processing	Deep-Sea Hydrothermal Ore Machining
Tidal energy equipment processing tool rods Tidal Energy Equipment Cutting Tool Rod	YN8-E	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for tidal energy equipment processing	Tidal Energy Equipment Manufacturing
Ultra-high hardness milling cutter bar Ultra-Hard Milling Tool Rod	YG3X-H	Φ3–20 × 330	Nano-scale grains <0.3μm, hardness HV2000, TiAlN coating, ultra-high wear resistance	Ultra-Hard Material Milling
Nano-scale micro-drill rods Nano Micro Drill Rod	YG3X-NM	Φ0.05–3 × 330	Nano-scale grains <0.2μm, hardness HV1900, CrN coating, ultra-high precision	Nano Chip Drilling
5G Equipment Cutting Tool Rod	YG6X-5G	Φ3–20 × 330	Ultrafine grain size <1μm, hardness HV1600, suitable for high-precision alloy processing of 5G equipment	5G Communication Equipment Machining
AI-Monitored Turning Tool Rod	YG6X-AI	Φ3–20 × 330	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensor, AI-optimized cutting	Smart Manufacturing Turning
Carbon Fiber Reinforced Tool Rod	YW2-CF	Φ5–25 × 330	High hardness HV1600, carbon fiber composite, lightweight, suitable for composite material processing	Aerospace Composite Machining
Lunar Sampling Cutting Tool Rod	YW2-L	Φ3–20 × 330	High hardness HV1600, resistant to extreme temperature differences, suitable for lunar geological sampling and processing	Lunar Geological Sampling
Martian Mining Cutting Tool Rod	YW2-MR	Φ5–25 × 330	High hardness HV1600, temperature resistance -	Martian Resource Mining

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			100°C to +400°C, suitable for Martian ore processing	
Deep sea rare earth mud processing tool rods Deep-Sea Rare Earth Mud Cutting Tool Rod	YN15-R	Φ3–20 × 330	Nickel-based 15% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea rare earth mud processing	Deep-Sea Rare Earth Mud Machining
Ocean wave energy tool rods Marine Wave Energy Cutting Tool Rod	YN8-W	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for wave energy equipment processing	Marine Wave Energy Equipment Manufacturing
Photovoltaic Silicon Cutting Tool Rod	YG6X-P	Φ3–20 × 330	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision silicon wafer processing	Photovoltaic Silicon Machining
Nuclear energy equipment processing tool bars Nuclear Energy Equipment Cutting Tool Rod	YN8-N	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for nuclear power equipment processing	Nuclear Energy Equipment Manufacturing
Cryogenic Alloy Cutting Tool Rod	YW2-C	Φ5–25 × 330	High hardness HV1600, low temperature resistance -200°C, suitable for aerospace low temperature alloy processing	Spacecraft Cryogenic Alloy Machining
Ultra-Precision Milling Tool Rod	YG10X	Φ2–15 × 330	Ultra-fine grain <0.8μm, hardness HV1650, strong wear resistance, suitable for high-precision processing	Aerospace Precision Parts Milling
Nano-Coated Turning Tool Rod	YG3X-NC	Φ0.1–5 × 330	Nano-scale grains <0.2μm, hardness HV1900, DLC coating, ultra-high wear resistance	Quantum Chip Turning
6G Communication Mold Cutting Tool Rod	YG6X-6G	Φ2–15 × 330	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision processing of 6G equipment	6G Communication Mold Machining
Smart Robot Cutting Tool Rod	YG6X-SR	Φ3–20 × 330	Ultrafine grains <1μm, hardness HV1600, embedded sensors, AI-optimized processing	Smart Robot Housing Machining

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Deep-Sea Nodule Mining Cutting Tool Rod	YN12-N	Φ3–20 × 330	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea nodule mining	Deep-Sea Nodule Mining
Seabed Sulfide Cutting Tool Rod	YN10-S	Φ3–20 × 330	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for seabed sulfide processing	Seabed Sulfide Machining
Nearshore Mining Cutting Tool Rod	YN8-N	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore resource processing	Nearshore Resource Mining
Offshore Mining Cutting Tool Rod	YN12-F	Φ3–20 × 330	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for offshore resource processing	Offshore Resource Mining
Carbon Fiber Composite Turning Tool Rod	YW2-CC	Φ5–25 × 330	High hardness HV1600, carbon fiber reinforced, lightweight, high temperature resistant	Aerospace Composite Turning
Ultra-Thin Silicon Cutting Tool Rod	YG3X-S	Φ0.05–3 × 330	Nano-scale grains <0.2μm, hardness HV1850, CrN coating, ultra-high precision	Photovoltaic Ultra-Thin Silicon Machining
High-Temp Ceramic Cutting Tool Rod	YW2-CR	Φ3–20 × 330	High hardness HV1600, high temperature resistance >1200°C, suitable for processing ceramic-based materials	Spacecraft Ceramic Composite Machining
Deep Space Sampling Cutting Tool Rod	YW2-DS	Φ3–20 × 330	High hardness HV1600, resistant to extreme temperature differences from -200°C to +600°C, suitable for deep space sampling	Deep Space Geological Sampling
Ultra-High Pressure Drill Rod	YG6X-HP	Φ3–20 × 330	Ultrafine grain <1μm, hardness HV1600, high pressure resistance >300 MPa	Deep-Sea Ultra-Deep Hole Drilling
Smart Monitored Drill Rod	YG6X-SD	Φ3–20 × 330	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensors, AI-optimized drilling	Smart Manufacturing Drilling

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Nuclear Fusion Equipment Cutting Tool Rod	YN10-F	Φ3–20 × 330	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion equipment processing	Nuclear Fusion Equipment Manufacturing
Low-Altitude Aircraft Cutting Tool Rod	YW2-LA	Φ5–25 × 330	High hardness HV1600, high temperature resistance, suitable for low-altitude aircraft composite material processing	Low-Altitude Aircraft Machining
Green Hydrogen Cutting Tool Rod	YN8-GH	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment processing	Green Hydrogen Equipment Manufacturing
Marine Thermal Energy Cutting Tool Rod	YN8-MT	Φ3–20 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for ocean thermal energy equipment processing	Marine Thermal Energy Equipment Manufacturing
Ultra-Hard Coated Milling Tool Rod	YG3X-HC	Φ3–20 × 330	Nano-scale grains <0.3μm, hardness HV2100, AlCrN coating, ultra-high wear resistance	Ultra-Hard Alloy Milling
Nano Etching Tool Rod	YG3X-NE	Φ0.02–2 × 330	Nano-scale grains <0.1μm, hardness HV1950, DLC coating, ultra-high precision	Nano Chip Etching

Cemented carbide for cutting tools

1.2 Board

Product Name	Brand	Specifications (mm): Length × Width × Thickness	Performance characteristics	Typical Application
Indexable End Mill Insert Blank	YG6	100×100×5–20	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for cast iron processing	Cast Iron Milling
Turning Insert Blank	YG6	100×100×5–20	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for cast iron processing	Cast Iron Turning
Indexable Drill Insert Blank	YG6	100×100×5–20	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for cast iron processing	Cast Iron Drilling

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Steel Cutting Insert Blank	YT15	100×100×5–20	Hardness HV1550, strong wear resistance, fine grain size 0.8-1.5μm, suitable for steel processing	Steel, Alloy Steel Turning
Stainless Steel Cutting Insert Blank	YW1	100×100×5–20	Excellent comprehensive performance, hardness HV1500, good toughness, suitable for stainless steel processing	Stainless Steel Milling
Thin-Wall Insert Blank	YG6X	100×100×1–5	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision processing	Electronic Parts Machining
Heavy-Duty Cutting Insert Blank	YT5	150×150×10–30	High toughness, bending strength ≥1800 MPa, hardness HV1400, suitable for heavy loads	Steel Roughing
Composite Cutting Insert Blank	YW2	100×100×5–20	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance, suitable for composite materials	Carbon Fiber, Glass Fiber Machining
High-Precision Insert Blank	YG3X	100×100×2–10	Nano-scale grains <0.5μm, hardness HV1700, extremely high wear resistance	Semiconductor Mold Machining
Wind Blade Insert Blank	YW2	100×100×5–20	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance, suitable for composite materials	Wind Blade Machining
Semiconductor Dicing Blade Blank	YG6X	100×100×1–5	Ultra-fine grain <1μm, hardness HV1600, high surface finish	Semiconductor Wafer Dicing
Photovoltaic Silicon Cutting Blade Blank	YG6X	100×100×1–5	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision silicon wafer cutting	Photovoltaic Silicon Cutting
Adaptive Insert Blank	YG6X-S	100×100×2–10	Ultra-fine grains <1μm, hardness HV1600, embedded sensors, AI-optimized cutting	Smart Manufacturing High-Precision Machining
Ultra-Precision Mold Insert Blank	YG3X-N	100×100×1–5	Nano-scale grains <0.3μm, hardness HV1800, Al2O3 coating, diamond replacement	Semiconductor Mold Micro-Nano Machining
Robot Joint Cutting Insert Blank	YG6X-R	100×100×2–10	Ultrafine grain <1μm, hardness HV1600, suitable for robot light alloy processing	Humanoid Robot Joint Machining
6G Communication Mold Insert Blank	YG3X-N	100×100×1–5	Nano-scale grains <0.3μm, hardness HV1800, high precision, suitable for	6G Communication Equipment Mold

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			communication equipment molds	
Smart Transportation Composite Insert Blank	YW2-T	100×100×5–20	High hardness HV1600, high temperature resistance, suitable for high-speed rail/autonomous driving composite material processing	Smart Transportation Body Machining
Aerospace Mold Insert Blank	YG3X-S	100×100×1–5	Nano-scale grains <0.3μm, hardness HV1800, TiN/Al2O3 coating, high temperature resistance	Spacecraft Mold Machining
Deep-Sea Mining Equipment Insert Blank	YN8-M	100×100×5–20	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for deep-sea mining equipment processing	Deep-Sea Mining Equipment Machining
Space 3D Printed Insert Blank	YG6X-S	100×100×2–10	Ultra-fine grains <1μm, hardness HV1600, suitable for space additive manufacturing tools	Space Tool Manufacturing
Deep-Sea Rare Earth Mud Insert Blank	YN8-R	100×100×5–20	Nickel-based 8% Ni, hardness HV1500, corrosion- resistant , suitable for deep-sea rare earth mud processing	Rare Earth Mud Machining
Insert Blank	YG3X-U	100×100×1–5	Nano-scale grains <0.2μm, hardness HV2000, DLC coating, ultra-high wear resistance	Ultra-Hard Material Machining
Nano Mold Insert Blank	YG3X-NN	100×100×1–3	Nano-scale grains <0.1μm, hardness HV1900, CrN coating, ultra-high precision	Nano Chip Mold Machining
AI-Monitored Insert Blank	YG6X-AI	100×100×2–10	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensor, AI-optimized cutting	Smart Manufacturing Insert Machining
Carbon Fiber Reinforced Insert Blank	YW2-CF	100×100×5–20	High hardness HV1600, carbon fiber composite, lightweight, suitable for composite material processing	Aerospace Composite Machining
Lunar Sampling Insert Blank	YW2-L	100×100×2–10	High hardness HV1600, resistant to extreme temperature differences, suitable for lunar geological sampling tools	Lunar Geological Sampling Tools
Martian Mining Insert Blank	YW2-MR	100×100×5–20	High hardness HV1600, temperature resistance -100°C to +400°C, suitable for Martian ore processing	Martian Resource Mining
Marine Wave Energy Insert Blank	YN8-W	100×100×5–20	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable	Marine Wave Energy Equipment

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			for wave energy equipment processing	Machining
Nuclear Energy Equipment Insert Blank	YN8-N	100×100×5–20	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for nuclear power equipment processing	Nuclear Energy Equipment Manufacturing
Ultra-Precision Insert Blank	YG10X	100×100×1–5	Ultra-fine grain <0.8μm, hardness HV1650, strong wear resistance, suitable for high-precision processing	Aerospace Precision Mold Machining
Nano-Coated Insert Blank	YG3X-NC	100×100×0.5–3	Nano-scale grains <0.2μm, hardness HV1900, DLC coating, ultra-high wear resistance	Quantum Chip Mold Machining
Nuclear Fusion Equipment Insert Blank	YN10-F	100×100×5–20	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion equipment processing	Nuclear Fusion Equipment Machining
Green Hydrogen Insert Blank	YN8-GH	100×100×5–20	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment processing	Green Hydrogen Equipment Machining
Marine Thermal Energy Insert Blank	YN8-MT	100×100×5–20	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for ocean thermal energy equipment processing	Marine Thermal Energy Equipment Machining
Ultra-Thin Silicon Insert Blank	YG3X-S	100×100×0.5–3	Nano-scale grains <0.2μm, hardness HV1850, CrN coating, ultra-high precision	Photovoltaic Ultra-Thin Silicon Machining
High-Temp Ceramic Insert Blank	YW2-CR	100×100×2–10	High hardness HV1600, high temperature resistance >1200°C, suitable for processing ceramic-based materials	Spacecraft Ceramic Composite Machining
Deep Space Sampling Insert Blank	YW2-DS	100×100×2–10	High hardness HV1600, resistant to extreme temperature differences from -200°C to +600°C, suitable for deep space sampling	Deep Space Geological Sampling
Ultra-High Pressure Insert Blank	YG6X-HP	100×100×2–10	Ultrafine grain <1μm, hardness HV1600, high pressure resistance >300 MPa	Deep-Sea Ultra-Deep Hole Machining
Smart Monitored Insert Blank	YG6X-SD	100×100×2–10	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensors, AI-	Smart Manufacturing Insert Machining

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			optimized processing	
Deep-Sea Nodule Mining Insert Blank	YN12-N	100×100×5–20	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea nodule mining	Deep-Sea Nodule Mining
Seabed Sulfide Insert Blank	YN10-S	100×100×5–20	Nickel-based 10% Ni, hardness HV1450, corrosion- resistant , suitable for seabed sulfide processing	Seabed Sulfide Machining
Nearshore Mining Insert Blank	YN8-N	100×100×5–20	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore resource processing	Nearshore Resource Mining
Offshore Mining Insert Blank	YN12-F	100×100×5–20	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for offshore resource processing	Offshore Resource Mining
Carbon Fiber Composite Insert Blank	YW2-CC	100×100×5–20	High hardness HV1600, carbon fiber reinforced, lightweight, high temperature resistant	Aerospace Composite Machining
Ultra-Hard Coated Insert Blank	YG3X-HC	100×100×1–5	Nano-scale grains <0.3μm, hardness HV2100, AlCrN coating, ultra-high wear resistance	Ultra-Hard Alloy Machining
Nano Etching Insert Blank	YG3X-NE	100×100×0.5–3	Nano-scale grains <0.1μm, hardness HV1950, DLC coating, ultra-high precision	Nano Chip Etching
Low-Altitude Aircraft Insert Blank	YW2-LA	100×100×5–20	High hardness HV1600, high temperature resistance, suitable for low-altitude aircraft composite material processing	Low-Altitude Aircraft Machining
5G Equipment Insert Blank	YG6X-5G	100×100×2–10	Ultrafine grain size <1μm, hardness HV1600, suitable for high-precision alloy processing of 5G equipment	5G Communication Equipment Machining
Cryogenic Alloy Insert Blank	YW2-C	100×100×5–20	High hardness HV1600, low temperature resistance -200°C, suitable for aerospace low temperature alloy processing	Spacecraft Cryogenic Alloy Machining

1.3 Pipe

Product Name	Brand	Specifications (mm): Outer diameter × wall thickness × length	Performance characteristics	Typical Application
Deep Hole Drill	YG6	Φ10–50 × 2–10 × 330	High hardness HV1500, good wear	Cast Iron, Non-

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Tube			resistance, medium grain size 1-2μm, suitable for high-speed machining	Ferrous Metal Deep Hole Drilling
Gun Drill Tube	YG6	Φ10–50 × 2–10 × 330	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for high-speed machining	Cast Iron, Non-Ferrous Metal Gun Drilling
Micro Drill Tube	YG6X	Φ5–30 × 1–5 × 330	Ultrafine grain <1μm, hardness HV1600, excellent wear resistance, suitable for precision machining	Medical Tools, Precision Parts Drilling
Internal Cooling Drill Tube	YG8	Φ10–40 × 2–8 × 330	Hardness HV1450, good toughness, bending strength ≥2000 MPa, suitable for internal cooling channels	Steel, Aluminum Alloy Deep Hole Machining
High-Precision Micro Tube Drill	YG3X	Φ2–20 × 1–3 × 330	Nano-scale grains <0.5μm, hardness HV1700, extremely high wear resistance	Semiconductor Chip Drilling
Composite Deep Hole Drill Tube	YW2	Φ10–40 × 2–8 × 330	High hardness HV1500, high temperature resistance, suitable for carbon fiber and glass fiber composite materials	Aerospace Composite Deep Hole Drilling
Smart Deep Hole Drill Tube	YG6X-S	Φ10–40 × 2–8 × 330	Ultrafine grains <1μm, hardness HV1600, embedded sensors, AI-monitored drilling	Smart Manufacturing Deep Hole Machining
Space Deep Hole Drill Tube	YW2-S	Φ10–40 × 2–8 × 330	High hardness HV1600, high temperature resistance >1000°C, suitable for lunar/Mars geological sampling	Space Geological Deep Hole Drilling
Deep-Sea Drilling Tube	YN8-D	Φ10–50 × 2–10 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for deep-sea high-pressure environments	Deep-Sea Resource Drilling
Ultra-Deep Hole Drilling Tube	YG6X-D	Φ10–50 × 2–10 × 330	Ultrafine grain <1μm, hardness HV1600, high pressure resistance >200 MPa, suitable for ultra-deep holes	Ultra-Deep Hole Geological Drilling
Deep-Sea Hydrothermal Ore Drilling Tube	YN8-H	Φ10–50 × 2–10 × 330	Nickel-based 8% Ni, hardness HV1500, ultra-high pressure resistance >300 MPa, suitable for hydrothermal mines	Deep-Sea Hydrothermal Ore Drilling
Nano Micro Tube Drill	YG3X-NM	Φ1–10 × 1–3 × 330	Nano-scale grains <0.2μm, hardness HV1900, ultra-high precision, suitable	Nano Chip Drilling

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			for micro-nano processing	
5G Equipment Drilling Tube	YG6X-5G	Φ10–40 × 2–8 × 330	Ultra-fine grains <1μm, hardness HV1600, suitable for high-precision processing of 5G equipment	5G Communication Equipment Drilling
AI-Monitored Drilling Tube	YG6X-AI	Φ10–40 × 2–8 × 330	Ultrafine grain size <1μm, hardness HV1600, embedded 5G sensor, AI-monitored drilling	Smart Manufacturing Drilling
Lunar Sampling Drilling Tube	YW2-L	Φ10–40 × 2–8 × 330	High hardness HV1600, resistant to extreme temperature differences, suitable for lunar geological sampling	Lunar Geological Drilling
Martian Mining Drilling Tube	YW2-MR	Φ10–40 × 2–8 × 330	High hardness HV1600, temperature resistance -100°C to +400°C, suitable for Martian ore drilling	Martian Resource Drilling
Nuclear Fusion Equipment Drilling Tube	YN10-F	Φ10–50 × 2–10 × 330	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion equipment processing	Nuclear Fusion Equipment Drilling
Green Hydrogen Drilling Tube	YN8-GH	Φ10–50 × 2–10 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment processing	Green Hydrogen Equipment Drilling
Marine Thermal Energy Drilling Tube	YN8-MT	Φ10–50 × 2–10 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for ocean thermal energy equipment processing	Marine Thermal Energy Equipment Drilling
Ultra-High Pressure Drilling Tube	YG6X-HP	Φ10–50 × 2–10 × 330	Ultrafine grain <1μm, hardness HV1600, high pressure resistance >300 MPa, suitable for ultra-high pressure environment	Deep-Sea Ultra-Deep Hole Drilling
Deep-Sea Nodule Mining Drilling Tube	YN12-N	Φ10–50 × 2–10 × 330	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea nodule mining	Deep-Sea Nodule Mining Drilling
Seabed Sulfide Drilling Tube	YN10-S	Φ10–50 × 2–10 × 330	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for seabed sulfide processing	Seabed Sulfide Drilling
Nearshore Mining Drilling Tube	YN8-N	Φ10–50 × 2–10 × 330	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore resource processing	Nearshore Resource Drilling
Offshore Mining	YN12-	Φ10–50 × 2–10 × 330	Nickel-based 12% Ni, hardness	Offshore Resource

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Drilling Tube	F		HV1400, corrosion-resistant, suitable for offshore resource processing	Drilling
6G Equipment Drilling Tube	YG6X-6G	Φ5–30 × 1–5 × 330	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision processing of 6G equipment	6G Communication Equipment Drilling
Ultra-Thin Micro Tube Drill	YG3X-S	Φ0.5–10 × 0.5–2 × 330	Nano-scale grains <0.2μm, hardness HV1850, CrN coating, ultra-high precision	Photovoltaic Ultra-Thin Silicon Drilling
High-Temp Ceramic Drilling Tube	YW2-CR	Φ10–40 × 2–8 × 330	High hardness HV1600, high temperature resistance >1200°C, suitable for processing ceramic-based materials	Spacecraft Ceramic Composite Drilling
Deep Space Sampling Drilling Tube	YW2-DS	Φ10–40 × 2–8 × 330	High hardness HV1600, resistant to extreme temperature differences from -200°C to +600°C, suitable for deep space sampling	Deep Space Geological Drilling
Ultra-Hard Coated Drilling Tube	YG3X-HC	Φ5–30 × 1–5 × 330	Nano-scale grains <0.3μm, hardness HV2100, AlCrN coating, ultra-high wear resistance	Ultra-Hard Alloy Drilling
Nano Etching Tube Drill	YG3X-NE	Φ0.5–5 × 0.5–2 × 330	Nano-scale grains <0.1μm, hardness HV1950, DLC coating, ultra-high precision	Nano Chip Etching Drilling

1.4 Special-shaped parts

Product Name	Brand	Specifications mm Example	Performance characteristics	Typical Application
Triangular Indexable Insert	YG6	Side length 20–50, thickness 5–10	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for cast iron processing	Cast Iron Milling, Turning
Square Indexable Insert	YT15	Side length 15–40 mm, thickness 5–10 mm	Hardness HV1550, strong wear resistance, fine grain size 0.8-1.5μm, suitable for steel processing	Steel, Alloy Steel Turning
Round Indexable Insert	YW2	Φ10–50, thickness 5–10	Excellent comprehensive performance, hardness HV1500, good toughness, suitable for complex working conditions	Stainless Steel, Difficult-to-Machine Material Milling
Threading Insert	YT15	Side length 15–30 mm, thickness 3–8 mm	Hardness HV1550, strong wear resistance, suitable for high-precision thread processing	Steel, Alloy Steel Threading

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Aerospace Insert	YW2	Customized according to drawings	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance	Nickel-Based Alloy, Titanium Alloy Machining
Micro Insert	YG6X	Side length 5–15, thickness 1–5	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision processing	Electronic Parts Machining
Laser Cutting Head	YG6X	Φ10–30 × height 10–30	Ultrafine grains <1μm, hardness HV1600, good heat resistance	Laser Cutting Equipment
Wind Gear Insert	YW2	Side length 15–40 mm, thickness 5–10 mm	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance	Wind Gear Machining
Micro Etching Tool	YG6X	Side length 5–10 mm, thickness 1–3 mm	Ultra-fine grain <1μm, hardness HV1600, high surface finish	Semiconductor Etching Machining
Wind Blade Trimming Insert	YW2	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1500, high temperature resistance, suitable for carbon fiber and glass fiber trimming	Wind Blade Trimming
Adaptive Indexable Insert	YG6X-S	Side length 15–40 mm, thickness 5–10 mm	Ultra-fine grains <1μm, hardness HV1600, embedded sensors, AI-optimized cutting	Smart Manufacturing High-Precision Machining
Ultra-Precision Dicing Blade	YG3X-N	Side length 5–15mm, thickness 1–3mm	Nano-scale grains <0.3μm, hardness HV1800, TiN coating, diamond replacement	Semiconductor Wafer Dicing
Space Composite Insert	YW2-S	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1600, high temperature resistance, suitable for spacecraft composite material processing	Spacecraft Composite Machining
Deep-Sea Equipment Insert	YN8-D	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for deep-sea equipment processing	Deep-Sea Equipment Machining
Asteroid Mining Insert	YW2-A	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1600, resistant to extreme temperature differences, suitable for asteroid ore processing	Asteroid Mining
Tidal Energy Equipment Insert	YN8-E	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for tidal energy equipment processing	Tidal Energy Equipment Machining
Ultra-Hard Insert	YG3X-U	Side length 10–30 mm, thickness 3–8 mm	Nano-scale grains <0.2μm, hardness HV2000, DLC coating, ultra-high wear resistance	Ultra-Hard Material Machining

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Nano Etching Tool	YG3X-NN	Side length 5–10 mm, thickness 1–3 mm	Nano-scale grains <0.1μm, hardness HV1900, CrN coating, ultra-high precision	Nano Chip Etching
AI-Monitored Insert	YG6X-AI	Side length 15–40 mm, thickness 5–10 mm	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensor, AI-optimized cutting	Smart Manufacturing Insert Machining
Lunar Sampling Insert	YW2-L	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1600, resistant to extreme temperature differences, suitable for lunar geological sampling	Lunar Geological Sampling
Nuclear Fusion Equipment Insert	YN10-F	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion equipment processing	Nuclear Fusion Equipment Machining
Green Hydrogen Insert	YN8-GH	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment processing	Green Hydrogen Equipment Machining
Marine Thermal Energy Insert	YN8-MT	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for ocean thermal energy equipment processing	Marine Thermal Energy Equipment Machining
Ultra-Thin Micro Insert	YG3X-S	Side length 2–10, thickness 0.5–2	Nano-scale grains <0.2μm, hardness HV1850, CrN coating, ultra-high precision	Photovoltaic Ultra-Thin Silicon Machining
High-Temp Ceramic Insert	YW2-CR	Side length 10–30 mm, thickness 3–8 mm	High hardness HV1600, high temperature resistance >1200°C, suitable for processing ceramic-based materials	Spacecraft Ceramic Composite Machining
Deep Space Sampling Insert	YW2-DS	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1600, resistant to extreme temperature differences from -200°C to +600°C, suitable for deep space sampling	Deep Space Geological Sampling
Ultra-High Pressure Insert	YG6X-HP	Side length 10–30 mm, thickness 3–8 mm	Ultrafine grain <1μm, hardness HV1600, high pressure resistance >300 MPa	Deep-Sea Equipment Machining
Smart Monitored Insert	YG6X-SD	Side length 15–40 mm, thickness 5–10 mm	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensors, AI-optimized processing	Smart Manufacturing Insert Machining
Deep-Sea Nodule Mining Insert	YN12-N	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea nodule mining	Deep-Sea Nodule Mining
Seabed Sulfide	YN10-	Side length 15–40	Nickel-based 10% Ni, hardness	Seabed Sulfide

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Insert	S	mm, thickness 5–10 mm	HV1450, corrosion-resistant, suitable for seabed sulfide processing	Machining
Nearshore Mining Insert	YN8-N	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore resource processing	Nearshore Resource Mining
Offshore Mining Insert	YN12-F	Side length 15–40 mm, thickness 5–10 mm	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for offshore resource processing	Offshore Resource Mining
6G Communication Insert	YG6X-6G	Side length 5–15, thickness 1–5	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision processing of 6G equipment	6G Communication Equipment Machining
Carbon Fiber Composite Insert	YW2-CC	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1600, carbon fiber reinforced, lightweight, high temperature resistant	Aerospace Composite Machining
Ultra-Hard Coated Insert	YG3X-HC	Side length 10–30 mm, thickness 3–8 mm	Nano-scale grains <0.3μm, hardness HV2100, AlCrN coating, ultra-high wear resistance	Ultra-Hard Alloy Machining
5G Equipment Insert	YG6X-5G	Side length 5–15, thickness 1–5	Ultra-fine grains <1μm, hardness HV1600, suitable for high-precision processing of 5G equipment	5G Communication Equipment Machining
Cryogenic Alloy Insert	YW2-C	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1600, low temperature resistance -200°C, suitable for aerospace low temperature alloy processing	Spacecraft Cryogenic Alloy Machining
Photovoltaic Silicon Insert	YG3X-P	Side length 5–15mm, thickness 1–3mm	Nano-scale grains <0.2μm, hardness HV1850, CrN coating, ultra-high precision	Photovoltaic Silicon Machining
Robot Joint Insert	YG6X-R	Side length 10–30 mm, thickness 3–8 mm	Ultrafine grain <1μm, hardness HV1600, suitable for robot light alloy processing	Humanoid Robot Joint Machining
Low-Altitude Aircraft Insert	YW2-LA	Side length 15–40 mm, thickness 5–10 mm	High hardness HV1600, high temperature resistance, suitable for low-altitude aircraft composite material processing	Low-Altitude Aircraft Machining

1.5 cemented carbide mixture powder

Product Name	Brand	Specification μm particle size	Performance characteristics	Typical Application
End Mill Blank	YG6 base	0.8–2.0	WC+6%Co, uniform grains, suitable	Cast Iron, Aluminum

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Powder			for sintering high hardness tool blanks	Alloy End Mill
Drill Blank Powder	YG6 base	0.8–2.0	WC+6%Co, uniform grains, suitable for sintering high hardness tool blanks	Cast Iron, Aluminum Alloy Drill
Steel Cutting Tool Powder	YT15 base	0.8–1.5	WC+TiC+15%Co, strong wear resistance, suitable for steel processing tools	Steel, Alloy Steel Turning Tool
Stainless Steel Cutting Tool Powder	YW1 base	0.8–1.5	WC+TiC+TaC+Co, excellent comprehensive performance, suitable for stainless steel knives	Stainless Steel Insert
Nano Tool Powder	YG3X base	0.2–0.5	Nano-scale grains, hardness HV1700, extremely high wear resistance	Semiconductor Mold Tool
Additive Manufacturing Tool Powder	YG6 base	0.5–2.0	WC+6%Co, uniform grain, suitable for 3D printing tool blanks	3D Printed Tools
Semiconductor Dicing Blade Powder	YG6X base	0.6–1.2	Ultra-fine grain <1μm, hardness HV1600, suitable for high-precision tools	Semiconductor Dicing Blade
Adaptive Tool Powder	YG6X-S base	0.6–1.2	Ultra-fine grain <1μm, hardness HV1600, suitable for AI monitoring tools	Smart Manufacturing Tools
3D Printed Complex Tool Powder	YG6X-AM base	0.5–1.5	Ultrafine grain <1μm, hardness HV1600, suitable for additive manufacturing	3D Printed Complex Tools
Aerospace Tool Powder	YW2-S base	0.6–1.5	High hardness HV1600, high temperature resistance, suitable for spacecraft tool sintering	Spacecraft Tools
Deep-Sea Tool Powder	YN8-D base	0.6–1.5	Nickel-based 8% Ni, corrosion-resistant, suitable for sintering deep-sea equipment tools	Deep-Sea Equipment Tools
Space 3D Printed Tool Powder	YG6X-S base	0.5–1.5	Ultra-fine grains <1μm, hardness HV1600, suitable for space additive manufacturing tools	Space Tool Manufacturing
Deep-Sea Rare Earth Mud Tool Powder	YN8-R base	0.6–1.5	Nickel-based 8% Ni, corrosion-resistant, suitable for deep-sea rare earth mud tool sintering	Deep-Sea Rare Earth Mud Tools
Ultra-Hard Tool Powder	YG3X-U base	0.1–0.3	Nano-scale grains <0.2μm, hardness HV2000, suitable for sintering super-hard tools	Ultra-Hard Material Tools
Nano Micro Tool	YG3X-	0.05–0.2	Nano-scale grain size <0.1μm, hardness	Nano Chip Tools

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Powder	NM base		HV1900, suitable for nano-scale tool sintering	
AI-Monitored Tool Powder	YG6X-AI base	0.6–1.2	Ultra-fine grains <1μm, hardness HV1600, suitable for AI monitoring of tool sintering	Smart Manufacturing Tools

1.6 Carbide particles

Product Name	Brand	Particle size (mm)	Performance characteristics	Typical Application
Welded End Mill Particle	YG6	1.0–5.0	High hardness HV1500, good wear resistance, suitable for welding to the tool surface	Cast Iron, Non-Metal Welded Tools
Welded Turning Tool Particle	YT15	0.5–3.0	Hardness HV1550, strong wear resistance, suitable for steel processing	Steel, Alloy Steel Welded Tools
Wear-Resistant Coating Particle	YG6X	0.5–2.0	Ultrafine grains <1μm, hardness HV1600, suitable for surface strengthening	Tool Surface Wear-Resistant Coating
Composite Tool Coating Particle	YW2	0.5–2.0	High hardness HV1500, high temperature resistance, suitable for surface strengthening of composite material tools	Aerospace Composite Tools
Smart Tool Coating Particle	YG6X-S	0.5–2.0	Ultra-fine grains <1μm, hardness HV1600, suitable for AI monitoring coating	Smart Manufacturing Tool Surface Reinforcement
Aerospace Coating Particle	YW2-S	0.5–2.0	High hardness HV1600, high temperature resistance, suitable for spacecraft tool surface strengthening	Spacecraft Tool Surface Reinforcement
Deep-Sea Coating Particle	YN8-D	0.5–2.0	Nickel-based 8% Ni, corrosion-resistant, suitable for deep-sea tool surface strengthening	Deep-Sea Tool Surface Reinforcement

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Space Mining Coating Particle	YW2-A	0.5–2.0	High hardness HV1600, resistant to extreme temperature differences, suitable for surface strengthening of space mining tools	Space Mining Tool Surface Reinforcement
Deep-Sea Hydrothermal Ore Coating Particle	YN8-T	0.5–2.0	Nickel-based 8% Ni, resistant to ultra-high pressure, suitable for surface strengthening of deep-sea hydrothermal mining tools	Deep-Sea Hydrothermal Ore Tool Surface Reinforcement
Ultra-Hard Coating Particle	YG3X-U	0.3–1.0	Nano-scale grains <0.2μm, hardness HV2000, suitable for super-hard coating surface strengthening	Ultra-Hard Tool Surface Reinforcement
Nano Coating Particle	YG3X-NM	0.1–0.5	Nano-scale grains <0.1μm, hardness HV1900, suitable for nano-scale coating surface strengthening	Nano Chip Tool Surface Reinforcement

1.7 Composite Materials

Product Name	Brand	Specification example mm	Performance characteristics	Typical Application
Composite End Mill Rod	YG6/Steel	Φ10–30 × 330	Carbide surface layer HV1500 + steel matrix, combining wear resistance and toughness	Multi-Material Milling
Composite Insert	YG6/ceramic	Side length 15–50, thickness 5–10	Carbide HV1500 + ceramic, ultra-high hardness, strong wear resistance	Composite Machining
Cermet Insert	TiC+Ni	Side length 15–50, thickness 5–10	High hardness HV1800, high temperature resistance, suitable for high speed cutting	Aerospace High-Temp Alloy Machining
Composite Titanium Alloy Insert	YW2/ceramic	Side length 15–50, thickness 5–10	Carbide HV1500 + ceramic, high temperature resistant, suitable for titanium alloy processing	Aerospace Titanium Alloy Machining
Lightweight Composite Insert	YW2-H/ Steel	Side length 15–50, thickness 5–10	Carbide HV1600 + steel matrix, lightweight, high temperature resistant , suitable for UAV materials	Drone Composite Machining

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Composite Insert	YW2-S/ceramic	Side length 15–50, thickness 5–10	Carbide HV1600 + ceramic, high temperature resistant, lightweight, suitable for aerospace composite materials	Spacecraft Composite Machining
Deep-Sea Composite Insert	YN8-D/Steel	Side length 15–50, thickness 5–10	Nickel-based carbide HV1500 + steel matrix, corrosion-resistant, suitable for deep-sea equipment	Deep-Sea Equipment Machining
Space 3D Printed Insert	YG6X-S/carbon fiber	Side length 15–50, thickness 5–10	Carbide HV1600 + carbon fiber, lightweight, suitable for space additive manufacturing	Space Tool Manufacturing
Deep-Sea Rare Earth Mud Insert	YN8-R/Steel	Side length 15–50, thickness 5–10	Nickel-based carbide HV1500 + steel matrix, corrosion-resistant, suitable for rare earth mud processing	Deep-Sea Rare Earth Mud Machining
Ultra-Hard Composite Insert	YG3X-U/ceramic	Side length 15–50, thickness 5–10	Nano-scale grains <0.2μm, hardness HV2000, DLC coating, ultra-high wear resistance	Ultra-Hard Material Machining
Nano Composite Insert	YG3X-NM/ceramic	Side length 10–30 mm, thickness 3–8 mm	Nano-scale grains <0.1μm, hardness HV1900, CrN coating, ultra-high precision	Nano Chip Machining

1.8 Coating substrate

Product Name	Brand	Specifications mm Example	Performance characteristics	Typical Application
Coated End Mill Insert Base	YG6	Side length 15–50, thickness 5–10	High hardness HV1500, uniform grain, suitable for CVD/PVD coating	High-Speed Cast Iron Milling
Coated Turning Insert Base	YT15	Side length 15–50, thickness 5–10	Hardness HV1550, strong wear resistance, suitable for high-performance coatings	Steel, Alloy Steel High-Speed Turning
Superhard Coated Insert Base	YG6X	Side length 10–30 mm, thickness 3–8 mm	Ultrafine grains <1μm, hardness HV1600, suitable for nano coating	Composite High-Speed Machining
Coated Semiconductor Dicing Blade Base	YG6X	Side length 10–30 mm, thickness 1–3 mm	Ultrafine grains <1μm, hardness HV1600, suitable for nano coating	Semiconductor Wafer Dicing
Smart Coated Insert Base	YG6X-S	Side length 10–30 mm, thickness 3–8 mm	Ultra-fine grains <1μm, hardness HV1600, suitable for AI monitoring of nano coatings	Smart Manufacturing High-Precision Machining

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Aerospace Coated Insert Base	YW2-S	Side length 10–30 mm, thickness 3–8 mm	High hardness HV1600, high temperature resistance, suitable for spacecraft nano coating	Spacecraft High-Precision Machining
Deep-Sea Coated Insert Base	YN8-D	Side length 10–30 mm, thickness 3–8 mm	Nickel-based 8% Ni, corrosion-resistant, suitable for nano-coating of deep-sea equipment	Deep-Sea Equipment High-Precision Machining
Space Mining Coated Insert Base	YW2-A	Side length 10–30 mm, thickness 3–8 mm	High hardness HV1600, resistant to extreme temperature differences, suitable for asteroid mining nano-coating	Asteroid Mining High-Precision Machining
Deep-Sea Hydrothermal Ore Coated Insert Base	YN8-T	Side length 10–30 mm, thickness 3–8 mm	Nickel-based 8% Ni, resistant to ultra-high pressure, suitable for deep-sea hydrothermal mineral nano-coating	Deep-Sea Hydrothermal Ore High-Precision Machining
Ultra-Hard Coated Insert Base	YG3X-U	Side length 10–30 mm, thickness 3–8 mm	Nano-scale grains <0.2μm, hardness HV2000, suitable for DLC nano coating	Ultra-Hard Material High-Precision Machining
Nano Coated Insert Base	YG3X-NM	Side length 5–15mm, thickness 1–3mm	Nano-scale grains <0.1μm, hardness HV1900, suitable for CrN nano coating	Nano Chip High-Precision Machining

1.9 Carbide spraying materials

Product Name	Brand	Specifications μm Example	Performance characteristics	Typical Application
Cutting Tool Repair Spray Powder	WC-12Co	15–45	High hardness HV1200, excellent wear resistance, grain size 2–5μm, adhesion >70 MPa	Cutting Tool Surface Repair
Mold Wear-Resistant Spray Powder	WC-17Co	10–30	High hardness HV1100, good toughness, bending strength ≥2000 MPa, suitable for high load	Mold Surface Hardening
Oil Drilling Tool Spray Powder	WC-10Co4Cr	15–45	High hardness HV1300, corrosion resistance pH 2–4, grain size 1–3μm, strong wear resistance	Oil Drilling Tool Coating
Marine Pipeline Anti-Corrosion Spray Powder	Cr3C2-25NiCr	20–50	Nickel-based 25% Ni, hardness HV1000, corrosion-resistant, high temperature resistant ≤900°C	Marine Pipeline Anti-Corrosion Coating
Deep-Sea Valve Spray Powder	WC-10Ni	10–30	Nickel-based 10% Ni, hardness HV1200, high pressure resistance >100 MPa, corrosion	Deep-Sea Valve Coating

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			resistance	
Aerospace Turbine Blade Spray Powder	WC-12Ni	15–45	Nickel-based 12% Ni, hardness HV1100, high temperature resistance ≤900°C, anti-oxidation	Aerospace Turbine Blade Coating
Engine Wear-Resistant Spray Powder	WC-15Co	10–30	High hardness HV1150, excellent wear resistance, grain size 2–5μm, suitable for high temperature working conditions	Engine Component Coating
Green Hydrogen Equipment Spray Powder	Cr3C2-20NiCr	20–50	Nickel-based 20% Ni, hardness HV1000, corrosion-resistant, suitable for hydrogen environment	Green Hydrogen Equipment Coating
Semiconductor Equipment Spray Powder	YG6X	5–25	Ultrafine grains <1μm, hardness HV1500, high surface finish, excellent wear resistance	Semiconductor Equipment Coating
Marine Thermal Energy Equipment Spray Powder	Cr3C2-25NiCr	20–50	Nickel-based 25% Ni, hardness HV1000, corrosion-resistant, high temperature resistant ≤900°C	Marine Thermal Energy Equipment Coating
Tidal Energy Equipment Spray Powder	WC-10Ni	10–30	Nickel-based 10% Ni, hardness HV1200, corrosion-resistant, suitable for tidal energy environments	Tidal Energy Equipment Coating
Ultra-High Pressure Valve Spray Powder	WC-10Co4Cr	15–45	High hardness HV1300, high pressure resistance >200 MPa, corrosion resistance, grain size 1–3 μm	Deep-Sea Ultra-High Pressure Valve Coating
Deep-Sea Hydrothermal Ore Spray Powder	Cr3C2-20NiCr	20–50	Nickel-based 20% Ni, hardness HV1000, high pressure resistance >100 MPa, corrosion resistance	Deep-Sea Hydrothermal Ore Equipment Coating
Deep-Sea Nodule Mining Spray Powder	WC-12Ni	15–45	Nickel-based 12% Ni, hardness HV1100, corrosion-resistant, suitable for deep-sea mining	Deep-Sea Nodule Mining Coating
Seabed Sulfide Spray Powder	Cr3C2-20NiCr	20–50	Nickel-based 20% Ni, hardness HV1000, corrosion-resistant, suitable for submarine sulfide environments	Seabed Sulfide Equipment Coating
Optical Precision Spray Powder	YG3X	5–25	Ultrafine grain <0.5μm, hardness HV1500, high surface finish, excellent wear resistance	Optical Equipment Coating
Wind Blade Spray Powder	WC-17Co	10–30	High hardness HV1100, good toughness, impact resistance, suitable	Wind Blade Surface Hardening

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			for carbon fiber surface	
Photovoltaic Equipment Spray Powder	YG6X	5–25	Ultrafine grains <1μm, hardness HV1500, excellent wear resistance, high surface finish	Photovoltaic Equipment Coating
Nuclear Power Equipment Spray Powder	Cr3C2-20NiCr	20–50	Nickel-based 20% Ni, hardness HV1000, corrosion- resistant , high temperature resistant ≤900°C	Power Equipment Coating
Deep-Sea Rare Earth Mud Spray Powder	WC-15Ni	15–45	Nickel-based 15% Ni, hardness HV1100, corrosion-resistant, suitable for deep-sea mining	Deep-Sea Rare Earth Mud Mining Coating

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Cemented Carbide Product Classification Table

Cemented carbide for geological and mining tools

Mining and drilling tools

Product Name	Brand	Specifications mm Example	Performance characteristics	Typical Application
TBM Cutting Pick	YG11C	Pick head Φ10–50, length 50–150	Coarse grains > 4μm, high toughness fracture toughness ≥ 14 MPa·m^(1/2), hardness HV1400	Medium-Hard Rock TBM Cutting
Coal Mining Pick	YG11C	Pick head Φ10–50, length 50–150	Coarse grains > 4μm, high toughness fracture toughness ≥ 14 MPa·m^(1/2), hardness HV1400	Coal Mining Cutting
Rotary Drilling Pick	YG11C	Pick head Φ10–50, length 50–150	Coarse grains > 4μm, high toughness fracture toughness ≥ 14 MPa·m^(1/2), hardness HV1400	Rotary Drilling Cutting
Rock Drilling Bit	YG8	Blade Φ10–100	Hardness HV1450, good toughness, bending strength ≥2000 MPa, strong impact resistance	Medium-Hard Rock Drilling
Hard Rock Drill Bit	YK05	Blade Φ10–80	Low cobalt 4–5%, hardness HV1650, extremely wear-resistant, suitable for hard rock	Hard Rock Drilling, Mohs ≥7
Oil Drilling Bit	YK20	Blade Φ10–100	High toughness, flexural strength ≥2500 MPa, good wear resistance, medium grain size 2–4 μm	Oil Drilling
Marine Drilling Tool	YN10	Blade Φ10–80	Nickel-based 10% Ni, corrosion-resistant, hardness HV1400, suitable for acidic environments	Marine Drilling
Geological Drill Rod	YG15	Outer diameter Φ20–100, length 1000–3000	High cobalt 15% Co, strong toughness, bending strength ≥2600 MPa, hardness HV1350	Geological Drilling
Deep Well Drill Bit	YK25	Blade Φ10–100	High toughness, bending strength ≥2300 MPa, good wear resistance, suitable for complex formations	Deep Well Drilling
Ultra-Deep Well Drill Bit	YK30	Blade Φ10–100	High toughness, bending strength ≥2400 MPa, excellent wear resistance, suitable for ultra-deep wells and complex formations	Ultra-Deep Well Drilling
Shield Machine Cutter	YG15	Diameter Φ100–500, thickness 10–50	High cobalt 15% Co, strong toughness, bending strength ≥2600 MPa, hardness HV1350	Shield Machine Cutter

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Deep-Sea Mining Pick	YN12	Pick head Φ10–50, length 50–150	Nickel-based 12% Ni, corrosion-resistant, hardness HV1400, suitable for deep-sea acidic environments	Deep-Sea Mining Cutting
Smart Cutting Pick	YG15-S	Pick head Φ10–50, length 50–150	High toughness, bending strength ≥2600 MPa, embedded sensors, AI monitoring wear	Smart Mining Cutting
Space Mining Pick	YN10-H	Pick head Φ10–50, length 50–150	Nickel-based 10% Ni, hardness HV1500, high/low temperature resistance, suitable for space mining	Space Resource Mining
Deep-Sea Sulfide Pick	YN12-S	Pick head Φ10–50 , length 50–150	Nickel-based 12% Ni, hardness HV1400, corrosion- resistant , suitable for deep-sea sulfide mining	Deep-Sea Sulfide Mining
Asteroid Mining Pick	YW2-A	Pick head Φ10–50, length 50–150	High hardness HV1600, resistant to extreme temperature differences, suitable for asteroid high hardness ores	Asteroid Mining
Deep-Sea Rare Earth Mud Pick	YN15-H	Pick head Φ10–50, length 50–150	Nickel-based 15% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea rare earth mud mining	Deep-Sea Rare Earth Mud Mining
Ultra-Hard Cutting Pick	YK05-H	Pick head Φ10–50, length 50–150	Low cobalt 3-4%, hardness HV1700, extremely wear-resistant, suitable for super-hard rocks	Ultra-Hard Rock Mining
AI-Monitored Cutting Pick	YG15-AI	Pick head Φ10–50, length 50–150	High toughness and bending strength ≥2600 MPa, embedded 5G sensor, AI monitoring wear	Smart Mining Cutting
Carbon Fiber Reinforced Pick	YN10-CF	Pick head Φ10–50, length 50–150	Nickel-based 10% Ni, hardness HV1500, carbon fiber composite, lightweight, corrosion-resistant	Deep-Sea/Space Mining
Smart Drill Bit	YK20-S	Blade Φ10–80	High toughness and bending strength ≥2500 MPa, embedded sensors, AI monitoring wear	Smart Mining Drilling
Lunar Sampling Drill Bit	YW2-S	Blade Φ10–60	High hardness HV1600, high temperature resistance >1000°C, suitable for lunar geological sampling	Lunar Geological Drilling
Martian Mining Pick	YN10-M	Pick head Φ10–50, length 50–150	Nickel-based 10% Ni, hardness HV1500, high/low temperature resistance, suitable for Martian mining	Martian Resource Mining
Deep-Sea Nodule Mining Pick	YN12-H	Pick head Φ10–50, length 50–150	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea nodule mining	Deep-Sea Nodule Mining

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Seabed Sulfide Drill Bit	YN8-S	Blade Φ10–80	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for seabed sulfide drilling	Seabed Sulfide Drilling
Ultra-Deep Hole Drill Bit	YK30-U	Blade Φ10–80	High toughness, bending strength ≥2600 MPa, high pressure resistance >200 MPa, suitable for ultra-deep holes	Ultra-Deep Hole Drilling
Marine Oil/Gas Drill Bit	YN8-O	Blade Φ10–100	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore oil and gas drilling	Marine Oil/Gas Drilling
Green Hydrogen Cutting Pick	YN8-GH	Pick head Φ10–50, length 50–150	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment mining	Green Hydrogen Equipment Mining
Nuclear Fusion Geological Pick	YN10-F	Pick head Φ10–50, length 50–150	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion geological exploration	Nuclear Fusion Geological Mining
Marine Thermal Energy Cutting Pick	YN8-MT	Pick head Φ10–50, length 50–150	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for ocean thermal energy equipment mining	Marine Thermal Energy Equipment Mining
Tidal Energy Cutting Pick	YN8-T	Pick head Φ10–50, length 50–150	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for tidal energy equipment mining	Tidal Energy Equipment Mining
Ultra-High Pressure Cutting Pick	YK25-HP	Pick head Φ10–50, length 50–150	High toughness, bending strength ≥2300 MPa, high pressure resistance >300 MPa, suitable for ultra-high pressure environment	Deep-Sea Ultra-High Pressure Mining
Smart Monitored Cutter	YG15-SD	Diameter Φ100–500, thickness 10–50	High toughness and bending strength ≥2600 MPa, embedded 5G sensor, AI optimized processing	Smart Shield Machine Cutter
Deep-Sea Hydrothermal Ore Pick	YN12-HT	Pick head Φ10–50, length 50–150	Nickel-based 12% Ni, hardness HV1400, ultra-high pressure resistance >300 MPa, corrosion resistance	Deep-Sea Hydrothermal Ore Mining
Nearshore Mining Pick	YN8-N	Pick head Φ10–50, length 50–150	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore mining	Nearshore Resource Mining
Offshore Mining Pick	YN12-F	Pick head Φ10–50, length 50–150	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for offshore mining	Offshore Resource Mining
Lunar Geological Pick	YW2-LG	Pick head Φ10–50, length 50–150	High hardness HV1600, resistant to extreme temperature differences, suitable	Lunar Geological Mining

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			for lunar geological sampling	
Martian Geological Drill Bit	YN10-MG	Blade Φ10–80	Nickel-based 10% Ni, hardness HV1500, high/low temperature resistance, suitable for Martian geological drilling	Martian Geological Drilling
Ultra-Deep Hole Geological Drill Rod	YG15-U	Outer diameter Φ20–100, length 1000–3000	High cobalt 15% Co, strong toughness, bending strength ≥2600 MPa, high pressure resistance >200 MPa	Ultra-Deep Hole Geological Drilling
Ultra-Hard Rock Cutter	YK10-H	Diameter Φ100–500, thickness 10–50	Low cobalt 3–4%, hardness HV1750, extremely wear-resistant, suitable for super-hard rocks	Ultra-Hard Rock TBM Cutting
Carbon Fiber Composite Cutter	YN10-CC	Diameter Φ100–500, thickness 10–50	Nickel-based 10% Ni, hardness HV1500, carbon fiber composite, lightweight, corrosion-resistant	Deep-Sea/Space TBM Cutting
Nearshore Oil/Gas Drill Bit	YN8-NO	Blade Φ10–80	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore oil and gas drilling	Nearshore Oil/Gas Drilling
Offshore Oil/Gas Drill Bit	YN12-FO	Blade Φ10–80	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for offshore oil and gas drilling	Offshore Oil/Gas Drilling
Deep-Sea Rare Earth Mud Drill Bit	YN15-R	Blade Φ10–80	Nickel-based 15% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea rare earth mud drilling	Deep-Sea Rare Earth Mud Drilling
Green Hydrogen Drill Bit	YN8-GH	Blade Φ10–80	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment drilling	Green Hydrogen Equipment Drilling
Nuclear Fusion Geological Drill Bit	YN10-F	Blade Φ10–80	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion geological exploration	Nuclear Fusion Geological Drilling
Marine Thermal Energy Drill Bit	YN8-MT	Blade Φ10–80	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for drilling of ocean thermal energy equipment	Marine Thermal Energy Equipment Drilling
Tidal Energy Drill Bit	YN8-T	Blade Φ10–80	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for tidal energy equipment drilling	Tidal Energy Equipment Drilling
Quantum Material Mining Pick	YG3X-H	Pick head Φ10–50, length 50–150	Nano-scale grains <0.5μm, hardness HV1800, extremely strong wear resistance, suitable for quantum materials	Quantum Material Mining
Ultra-Deep Sea Exploration Drill	YN15-DS	Blade Φ10–80	Nickel-based 15% Ni, hardness HV1400, ultra-high pressure resistance >400 MPa,	Ultra-Deep Sea Exploration

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Bit			corrosion resistance	

Carbide pipes

Product Name Product Name	Brand	Specifications (mm): Outer diameter × wall thickness × length	Performance characteristics	Typical Applications Typical Application
Drill Pipe Joint Tube	YG11C	Φ20–100 × 5–20 × 500	Coarse grains > 4μm, high toughness fracture toughness ≥ 14 MPa·m^(1/2), hardness HV1400	Oil Drilling Pipe Joint
Geological Drilling Casing	YK05	Φ20–80 × 5–15 × 500	Low cobalt 4–5%, hardness HV1650, extremely wear-resistant, suitable for hard rock	Hard Rock Geological Drilling
Oil Drilling Pipe Tube	YK20	Φ30–120 × 5–20 × 1000	High toughness, flexural strength ≥2500 MPa, good wear resistance, medium grain size 2–4 μm	Oil Drilling Pipeline
Marine Drilling Casing	YN8	Φ30–100 × 5–20 × 1000	Nickel-based 8% Ni, corrosion-resistant, hardness HV1450, suitable for acidic environment	Marine Drilling Casing
Deep Well Drilling Joint Tube	YK25	Φ30–120 × 5–20 × 1000	High toughness, bending strength ≥2300 MPa, good wear resistance, suitable for complex formations	Deep Well Drilling Joint
Ultra-Deep Well Casing	YK30	Φ40–150 × 10–30 × 1500	High toughness, bending strength ≥2400 MPa, high pressure resistance >200 MPa, suitable for ultra-deep wells	Ultra-Deep Well Casing
Smart Drilling Tube	YK20-S	Φ20–100 × 5–20 × 1000	High toughness and bending strength ≥2500 MPa, embedded sensors, AI monitoring wear	Smart Mining Drilling
Deep-Sea Mining Casing	YN12	Φ30–120 × 5–20 × 1000	Nickel-based 12% Ni, corrosion-resistant, hardness HV1400, suitable for deep-sea acidic environments	Deep-Sea Mining Casing

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Deep-Sea Sulfide Casing	YN12-S	Φ30–120 × 5–20 × 1000	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea sulfide mining	Deep-Sea Sulfide Mining
Deep-Sea Rare Earth Mud Casing	YN15-H	Φ30–120 × 5–20 × 1000	Nickel-based 15% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea rare earth mud mining	Deep-Sea Rare Earth Mud Mining
Ultra-Hard Drilling Tube	YK05-H	Φ20–80 × 5–15 × 500	Low cobalt 3-4%, hardness HV1700, extremely wear-resistant, suitable for super-hard rocks	Ultra-Hard Rock Drilling
AI-Monitored Drilling Tube	YG15-AI	Φ20–100 × 5–20 × 1000	High toughness and bending strength ≥2600 MPa, embedded 5G sensor, AI monitoring wear	Smart Mining Drilling
Carbon Fiber Reinforced Drilling Tube	YN10-CF	Φ20–80 × 5–15 × 500	Nickel-based 10% Ni, hardness HV1500, carbon fiber composite, lightweight, corrosion-resistant	Deep-Sea Drilling
Marine Oil/Gas Drilling Tube	YN8-O	Φ30–120 × 5–20 × 1000	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for offshore oil and gas drilling	Marine Oil/Gas Drilling
Green Hydrogen Drilling Tube	YN8-GH	Φ20–100 × 5–20 × 1000	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment drilling	Green Hydrogen Equipment Drilling
Nuclear Fusion Geological Tube	YN10-F	Φ20–100 × 5–20 × 1000	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion geological exploration	Nuclear Fusion Geological Drilling
Marine Thermal Energy Drilling Tube	YN8-MT	Φ20–100 × 5–20 × 1000	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for drilling of ocean thermal energy equipment	Marine Thermal Energy Equipment Drilling
Tidal Energy Drilling Tube	YN8-T	Φ20–100 × 5–20 × 1000	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for tidal energy equipment drilling	Tidal Energy Equipment Drilling
Ultra-High Pressure Drilling Tube	YK25-HP	Φ30–120 × 5–20 × 1000	High toughness, bending strength ≥2300 MPa, high pressure resistance >300 MPa, suitable for ultra-high pressure environment	Deep-Sea Ultra-High Pressure Drilling
Deep-Sea Hydrothermal Ore	YN12-HT	Φ30–120 × 5–20 × 1000	Nickel-based 12% Ni, hardness HV1400, ultra-high pressure	Deep-Sea Hydrothermal Ore

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Tube			resistance >300 MPa, corrosion resistance	Mining



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Cemented carbide for cutting tools

Ball/round products

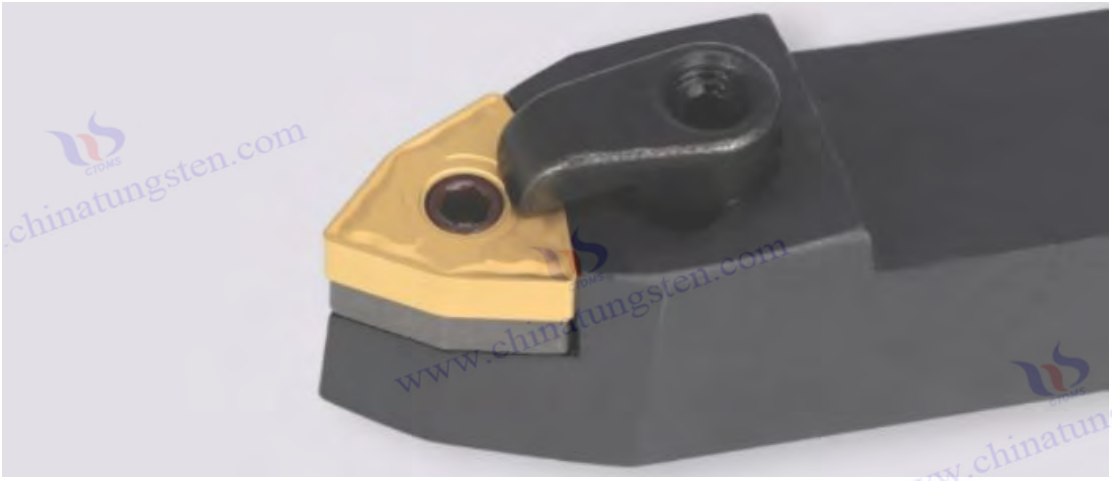
Product Name	Brand	Specifications mm Example	Performance characteristics	Typical Application
Precision Bearing Ball	YG6	Φ0.5–50	High hardness HV1500, good wear resistance, medium grain size 1–2μm, high surface finish	High-Speed Bearings, Mechanical Transmission
Valve Ball	YG8	Φ10–100	Hardness HV1450, good toughness, bending strength ≥2000 MPa, impact resistance	Petroleum, Natural Gas Valves
Grinding Ball	YG6	Φ5–80	High hardness HV1500, good wear resistance, medium grain size 1-2μm, suitable for high load grinding	Ore, Ceramic Grinding
Round Cutting Insert	YW2	Φ10–50, thickness 5–10	Excellent comprehensive performance, hardness HV1500, good toughness, suitable for complex working conditions	Stainless Steel, Difficult-to-Machine Material Milling
Circular Cutting Blade	YT15	Φ50–200, thickness 2–10	Hardness HV1550, strong wear resistance, fine grain size 0.8-1.5μm, suitable for high-speed cutting	Steel, Alloy Steel Cutting
Micro Precision Ball	YG6X	Φ0.3–10	Ultrafine grain <1μm, hardness HV1600, excellent wear resistance, suitable for high-precision machining	Medical Devices, Electronic Parts
Aerospace Valve Ball	YW2	Φ10–80	Excellent comprehensive performance, hardness HV1500, good toughness, high temperature resistance ≤1000°C	Aerospace Valves
Wind Blade Trimming Circular Blade	YW2	Φ100–300, thickness 5–15	High hardness HV1500, high temperature resistance, suitable for carbon fiber and glass fiber processing	Wind Blade Trimming
Semiconductor Dicing Circular Blade	YG3X	Φ50–100, thickness 0.5–2	Ultrafine grain <0.5μm, hardness HV1700, extremely high wear resistance, TiN coating	Semiconductor Wafer Dicing
Photovoltaic Silicon Cutting Circular Blade	YG6X	Φ50–100, thickness 0.5–2	Ultrafine grain <1μm, hardness HV1600, high surface finish, CrN coating	Photovoltaic Silicon Cutting
Composite Circular Insert	YW2	Φ10–50, thickness 5–10	High hardness HV1500, high temperature resistance, suitable for carbon fiber and glass fiber processing	Aerospace Composite Machining

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Adaptive Circular Insert	YG6X-S	Φ10–50, thickness 5–10	Ultra-fine grains <1μm, hardness HV1600, embedded sensors, AI-optimized cutting	Smart Manufacturing High-Precision Machining
Ultra-Precision Circular Blade	YG3X	Φ20–80, thickness 0.5–2	Ultrafine grain <0.3μm, hardness HV1800, TiN coating, high-precision processing	Semiconductor Mold Micro-Nano Machining
Deep-Sea Valve Ball	YN8	Φ10–100	Nickel-based 8% Ni, hardness HV1500, corrosion resistant, high pressure resistant >200 MPa	Deep-Sea Oil/Gas Equipment Valves
Tidal Energy Valve Ball	YN8	Φ10–100	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for tidal energy equipment	Tidal Energy Equipment Valves
Ultra-Hard Grinding Ball	YG3X	Φ5–50	Ultrafine grain <0.3μm, hardness HV1800, DLC coating, high wear resistance	Ultra-Hard Material Grinding
Nano Precision Ball	YG3X	Φ0.3–5	Ultrafine grain <0.3μm, hardness HV1800, CrN coating, high precision	Nano Chip Machining
AI-Monitored Circular Insert	YG6X-AI	Φ10–50, thickness 5–10	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensor, AI-optimized cutting	Smart Manufacturing Insert Machining
Deep-Sea Hydrothermal Ore Valve Ball	YN8	Φ10–100	Nickel-based 8% Ni, hardness HV1500, high pressure resistance >300 MPa, corrosion resistance	Deep-Sea Hydrothermal Ore Equipment Valves
Nuclear Fusion Equipment Valve Ball	YN10	Φ10–100	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for nuclear fusion equipment	Nuclear Fusion Equipment Valves
Green Hydrogen Valve Ball	YN8	Φ10–100	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for green hydrogen energy equipment	Green Hydrogen Equipment Valves
Marine Thermal Energy Valve Ball	YN8	Φ10–100	Nickel-based 8% Ni, hardness HV1500, corrosion-resistant, suitable for ocean thermal energy equipment	Marine Thermal Energy Equipment Valves
Ultra-Thin Circular Blade	YG3X	Φ20–80, thickness 0.5–2	Ultra-fine grain <0.3μm, hardness HV1800, CrN coating, ultra-high precision	Photovoltaic Ultra-Thin Silicon Cutting
High-Temp Ceramic Circular Blade	YW2	Φ50–150, thickness 2–10	High hardness HV1600, high temperature resistance ≤1200°C, suitable for processing ceramic-based	Spacecraft Ceramic Composite Cutting

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			materials	
Ultra-High Pressure Valve Ball	YG6X	Φ10–80	Ultrafine grain <1μm, hardness HV1600, high pressure resistance >300 MPa	Deep-Sea Ultra-High Pressure Equipment Valves
Smart Monitored Circular Blade	YG6X-SD	Φ50–150, thickness 2–10	Ultra-fine grains <1μm, hardness HV1600, embedded 5G sensors, AI-optimized processing	Smart Manufacturing Cutting
Deep-Sea Nodule Mining Ball	YN12	Φ10–80	Nickel-based 12% Ni, hardness HV1400, corrosion-resistant, suitable for deep-sea mining	Deep-Sea Nodule Mining
Seabed Sulfide Valve Ball	YN10	Φ10–80	Nickel-based 10% Ni, hardness HV1450, corrosion-resistant, suitable for seabed sulfide processing	Seabed Sulfide Equipment Valves
Optical Precision Circular Blade	YG10X	Φ20–80, thickness 0.5–2	Ultra-fine grain <0.5μm, hardness HV1700, AlCrN coating, ultra-high precision	Optical Lens Machining
Marine Engineering Circular Blade	YN15	Φ50–200, thickness 2–10	Nickel-based 15% Ni, hardness HV1400, corrosion-resistant, suitable for marine environments	Marine Engineering Material Cutting



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GB/T 5124.4-2008 Chemical analysis method for cemented carbide

Part 4: Determination of titanium, niobium and tantalum by inductively coupled plasma atomic emission spectrometry

1. Scope

This standard specifies the chemical analysis method for the determination of titanium (Ti), niobium (Nb), and tantalum (Ta) content in cemented carbide (hard metal) using inductively coupled plasma atomic emission spectrometry (ICP-AES). It is applicable to the determination of the mass fraction of titanium, niobium, and tantalum in cemented carbide products and their raw materials. The measurement range is:

Titanium: 0.01%~10% (mass fraction).

Niobium: 0.01% to 5% (mass fraction).

Tantalum: 0.01%~5% (mass fraction).

This method is applicable to cemented carbides with tungsten carbide (WC) as the main hard phase, cobalt (Co), nickel (Ni) and other binder phases, and containing trace or alloying elements. It is not applicable to samples containing high concentrations of rare earth elements or complex matrices and needs to be verified in combination with other methods (such as X-ray fluorescence spectrometry).

2. Normative References

The clauses in the following documents become clauses of this standard through reference in this part. For dated referenced documents, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated referenced documents, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 15337 General rules for atomic absorption spectrometric analysis.

GB/T 20066 Methods for preparation of rock and mineral test samples.

3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: It uses tungsten carbide (WC) as the main hard phase, metals such as cobalt and nickel as the bonding phase, and may contain alloying elements such as titanium, niobium, and tantalum. It is a high-hardness, high-wear-resistant material prepared by sintering through powder metallurgy technology.

ICP-AES: An analytical technique that uses a high-frequency electromagnetic field to excite argon plasma, atomize and excite the sample, and then quantitatively determine the element content based on the wavelength and intensity of the emission spectrum.

Mass fraction: The percentage of the mass of a component in a sample to the total mass, expressed as "%.

4. Principles of the Method

Cemented carbide samples were dissolved by acid decomposition (a hydrofluoric acid-nitric acid mixture) to prepare test solutions. The characteristic emission spectral intensities of titanium (characteristic wavelengths approximately 334.941 nm or 336.121 nm), niobium (characteristic wavelengths approximately 309.418 nm or 319.498 nm), and

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tantalum (characteristic wavelengths approximately 226.230 nm or 240.063 nm) were measured using an ICP-AES instrument with argon plasma as the excitation source. The intensities were compared with those of a series of standard solutions to calculate the content of each element. Background correction and high-resolution spectrometry were used to eliminate spectral interference from matrix elements such as tungsten (W).

5. Reagents and Materials

5.1 Pure water for analysis: in accordance with GB/T 6682 Grade 1 water standard, with a resistivity of ≥18 MΩ·cm.

5.2 Nitric acid (HNO_3) : extra-pure, density 1.42 g/mL.

5.3 Hydrofluoric acid (HF): high purity, density 1.15 g/mL.

5.4 Perchloric acid ($HClO_4$) : Extra pure, density 1.68 g/mL (optional for complex matrices).

5.5 Standard solution:

Titanium standard stock solution: 1000 μg/mL, prepared in 2% (v/v) nitric acid solution.

Niobium standard stock solution: 1000 μg/mL, prepared in 2% (v/v) nitric acid solution.

Tantalum standard stock solution: 1000 μg/mL, prepared in 2% (v/v) nitric acid solution.

Standard solution for working curve: prepared by gradient dilution, the concentration range is 0.1 μg/mL, 1.0 μg/mL, 10 μg/mL, 50 μg/mL, 100 μg/mL.

5.6 Argon: purity ≥99.999%.

6. Instruments

6.1 ICP-AES spectrometer: equipped with a high-resolution monochromator, a wavelength range of 190 nm to 400 nm, a detection limit better than 0.01 μg/mL, and an autosampler.

6.2 Microwave digestion apparatus: used for sample pretreatment, operating pressure ≤ 6 MPa.

6.3 Analytical balance: sensitivity 0.0001 g.

6.4 Polytetrafluoroethylene (PTFE) digestion vessel: acid and high temperature resistant, capacity 50 mL.

7. Sample Preparation

7.1 Sample collection: Take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g, and crush them to a particle size of less than 0.1 mm.

7.2 Sample decomposition:

Weigh 0.5000 g ± 0.0002 g of sample and place it in a PTFE digestion tank.

Add 10 mL of nitric acid and 5 mL of hydrofluoric acid (add 2 mL of perchloric acid if necessary), seal the container and place it in a microwave digester.

Digestion procedure: heating at 100°C for 5 minutes, maintaining at 150°C for 10 minutes, maintaining at 180°C for 30 minutes, then cooling and transferring to a polyethylene bottle and adjusting the volume to 100 mL.

7.3 Blank test: Prepare a blank solution in parallel with the sample under the same conditions.

8. Measurement Steps

8.1 Instrument conditions:

RF power: 1100 W to 1300 W.

Carrier gas flow rate: 0.8 L/min.

Auxiliary gas flow rate: 0.6 L/min.

Spray chamber temperature: room temperature.

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Integration time: 3 seconds/point.

Aspiration rate: 1.0 mL/min.

8.2 Standard Curve: Prepare five standard solutions with a concentration gradient (0.1, 1.0, 10, 50, and 100 μg/mL), measure the emission intensity, and plot a working curve with a correlation coefficient $R^2 \geq 0.999$.

8.3 Sample determination: Take the sample solution and dilute it to within the working curve range if necessary. Measure the emission intensity of titanium, niobium, and tantalum and obtain the content by consulting the table.

8.4 Repeatability: Measure each sample three times and take the average value.

9. Calculation of results

The mass fraction W (%) is calculated according to the formula:

$$W = \frac{C \times V \times f}{m \times 1000} \times 100$$

in:

C: Element concentration (μg/mL), read from the working curve.

V: fixed volume (mL), usually 100 mL.

f: dilution factor (if any).

m: sample mass (g).

The results are rounded to 0.01% according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: Repeat the measurement 6 times, and the relative standard deviation (RSD) should be less than 5%.

10.2 Accuracy: Verified using standard reference materials (e.g., cemented carbide CRMs containing Ti, Nb, and Ta), the recovery should be between 95% and 105%.

11. Interference Elimination

11.1 Spectral Interference: Tantalum and niobium are line-rich elements. A high-resolution spectrometer and background correction are used to eliminate tungsten (W) or cobalt (Co) line overlap.

11.2 Matrix interference: Use the matrix matching method and add an appropriate amount of tungsten (5% to 10% m/v) to simulate the matrix.

11.3 Acidic Residue: Ensure that the fluoride concentration in the digestion solution is moderate to avoid the formation of insoluble fluorides of tantalum and niobium.

12. Security

12.1 Operators must wear protective glasses, acid-proof gloves and protective clothing to avoid hydrofluoric acid vapor.

12.2 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to pressure safety during microwave digestion and check the PTFE tank regularly.

13. Report

The report should include the following:

Sample number, source and description.

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Measurement results (mass fraction of titanium, niobium and tantalum, %).

Instrument model, operating conditions, and calibration data.

Standard curve data.

Any anomalies or deviations.

14. Appendix (Informative)

14.1 Reference wavelength:

Titanium: 334.941 nm, 336.121 nm.

Niobium: 309.418 nm, 319.498 nm.

Tantalum: 226.230 nm, 240.063 nm.

14.2 Microwave Digestion Procedure Example:

Step 1: 100°C, 5 minutes.

Step 2: 150°C, 10 minutes.

Step 3: 180°C, 30 minutes.

14.3 Note: If the sample contains high tantalum, the amount of HF needs to be increased to 8 mL.

15. Release of Information

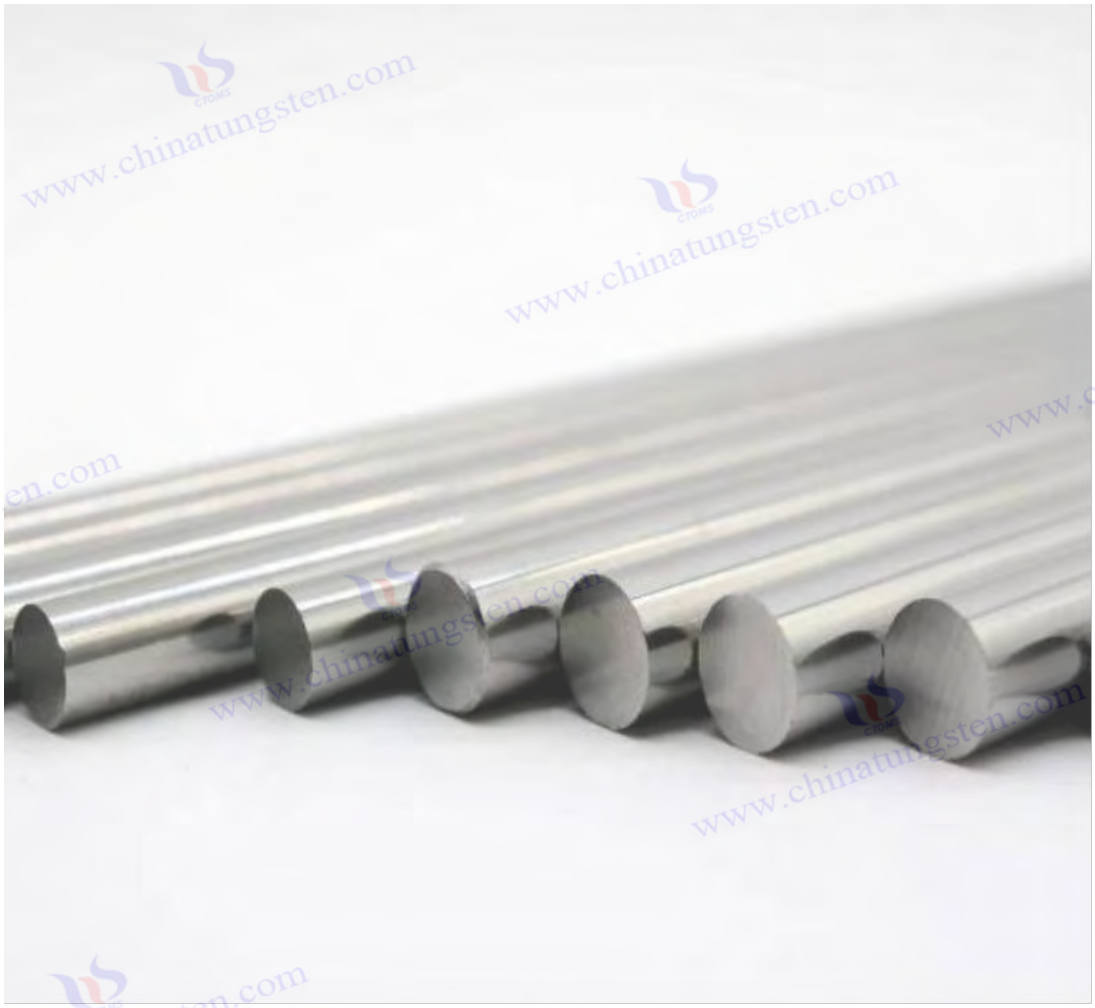
Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

Release date: June 18, 2008.

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Replacement: Replaces GB/T 5124.4-1985.

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GB/T 5124.3-2008 Chemical analysis methods for cemented carbide Part 3: Gravimetric determination of free carbon

1. Scope

This standard specifies the chemical analysis method for the gravimetric determination of free carbon (usually free carbon or graphitic carbon) in cemented carbide (hard metal). It is applicable to the determination of the mass fraction of free carbon in cemented carbide products and their raw materials, within a measurement range of 0.01% to 5% (mass fraction). This method is particularly suitable for sintered cemented carbides composed primarily of tungsten carbide (WC) as the hard phase and cobalt (Co), nickel (Ni), or other materials as binder phases. It is not suitable for complex samples containing high levels of organic matter or non-carbide impurities and requires verification in conjunction with other methods, such as infrared absorption.

2. Normative References

The clauses in the following documents become clauses of this standard through reference in this part. For dated referenced documents, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated referenced documents, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 20066 Methods for preparation of rock and mineral test samples.

GB/T 3213 Determination of carbon and sulfur in metals and metal ores - Gravimetric method

3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: A high-hardness, high-wear-resistant material prepared by sintering powder metallurgy process with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase.

Free carbon: Carbon in cemented carbide that is not combined into carbides (such as WC), exists in free state or graphite form, expressed as mass fraction.

Gravimetric method: An analytical method that converts free carbon into a weighable form through chemical reaction or physical separation and indirectly calculates its content.

4. Principles of the Method

A cemented carbide sample is treated in an acidic solution (such as hydrochloric acid) to dissolve the binder phase (Co, Ni, etc.) and tungsten carbide (WC). Free carbon, which is insoluble in the acid, remains. The remaining free carbon is filtered, washed, dried, and weighed to calculate the mass fraction of free carbon. During the reaction, the tungsten carbide remains stable, while the free carbon is extracted as an insoluble residue.

5. Reagents and Materials

5.1 Pure water for analysis: in accordance with GB/T 6682 Grade 1 water standard, with a resistivity of ≥18 MΩ·cm.

5.2 Hydrochloric acid (HCl): analytical grade, concentration 37% (w/w), diluted to 1:1 (v/v) for use.

5.3 Ethanol: analytical grade, concentration ≥95%, used for washing.

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5.4 Standard sample: Cemented carbide reference material with known free carbon content (e.g. GBW 01234).

6. Instruments

6.1 Constant temperature water bath: Temperature control range 20°C to 100°C, accuracy ±1°C.

6.2 Filtering device: equipped with medium-speed qualitative filter paper (such as Whatman No. 42) or glass fiber filter membrane.

6.3 Oven: Temperature controlled at 105°C±2°C.

6.4 Analytical balance: sensitivity 0.0001 g.

6.5 Porcelain evaporating dish: acid-resistant, capacity approximately 50 mL.

7. Sample Preparation

7.1 Sample collection: Randomly take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g, and crush them to a particle size of less than 0.074 mm (200 mesh).

7.2 Sample drying: Dry in an oven at 105°C ± 2°C for 2 hours, cool to room temperature, and place in a desiccator for later use.

7.3 Sample weighing: Weigh 1.0000 g ± 0.0002 g of sample and place it in a porcelain evaporating dish.

8. Measurement Steps

8.1 Sample processing:

Add 50 mL of dilute hydrochloric acid (1:1) to the evaporating dish and place it in a constant temperature water bath controlled at 80°C.

The sample was stirred and heated for 1 hour to dissolve the binder phase and WC and leave free carbon.

8.2 Filtration and washing:

Filter with a suction filtration device to collect the residue, wash the residue with hot water three times (50 mL each time), and then wash it with ethanol twice (20 mL each time) to remove the acidic solution.

8.3 Drying and weighing:

The filter paper and residue were dried in an oven at 105 °C for 2 h, cooled to room temperature, and weighed to a constant weight (Δm).

8.4 Blank test: Carry out a blank test in parallel under the same conditions and record the mass of the blank residue.

9. Calculation of results

The free carbon mass fraction W (%) is calculated according to the formula:

$$W = \frac{(\Delta m_s - \Delta m_b)}{m} \times 100$$

in:

Δms Δm_s Δms : Sample measurement residue mass (g).

Δmb Δm_b Δmb : Blank test residue mass (g).

mmm: sample mass (g).

The results are rounded to 0.01% according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: Repeat the measurement 6 times, and the relative standard deviation (RSD) should be less than 5%.

10.2 Accuracy: Verified using standard reference materials, the recovery should be between 95% and 105%.

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11. Interference Elimination

11.1 Insoluble impurities: Ensure the sample is pure and exclude the influence of non-carbon impurities such as silicates.

11.2 Filter Paper Ash: The blank test is used to correct for the contribution of filter paper ash.

11.3 Carbide decomposition: Control acid concentration and temperature to avoid WC decomposition.

12. Security

12.1 Operators must wear protective glasses and acid-resistant gloves and maintain ventilation during operation.

12.2 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Avoid acid volatilization at high temperatures and pay attention to acid mist protection.

13. Report

The report should include the following:

Sample number, source and description.

Determination results (free carbon mass fraction, %).

Processing conditions and filtering device data.

Blank test results.

Any anomalies or deviations.

14. Appendix (Informative)

14.1 Temperature Control: The recommended water bath temperature is 80°C ± 5°C. A temperature too high may cause partial dissolution of WC.

14.2 Washing optimization: Wash with hot water until the pH of the filtrate is 6-7, and wash with ethanol to remove residual water.

14.3 Note: If the sample contains high free carbon, increase the amount of acid to 75 mL.

15. Release of Information

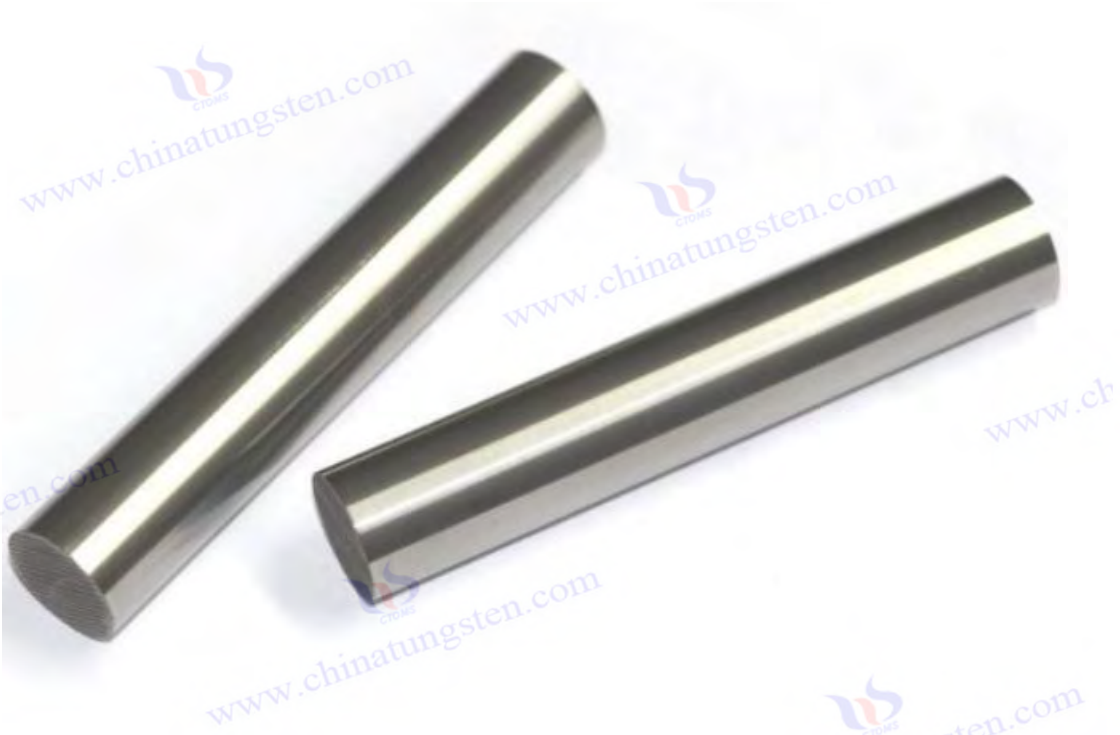
Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

Release date: June 18, 2008.

Implementation date: December 1, 2008.

Replacement: Replaces GB/T 5124.3-1985.

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GB/T 5124.2-2008 Chemical analysis methods for cemented carbide Part 2: Gravimetric determination of total carbon content

1. Scope

This standard specifies a chemical analysis method for the gravimetric determination of total carbon (including bound and free carbon) in cemented carbide (hard metal). It is applicable to the determination of the mass fraction of total carbon in cemented carbide products and their raw materials , within a measurement range of 0.1% to 20% (mass fraction). This method is particularly suitable for sintered cemented carbides with tungsten carbide (WC) as the primary hard phase and cobalt (Co), nickel (Ni), or other materials as binder phases. It is not suitable for complex samples containing high levels of organic matter or non-metallic impurities and requires verification in conjunction with other methods (such as infrared absorption).

2. Normative References

The clauses in the following documents become clauses of this standard through reference in this part. For dated referenced documents, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated referenced documents, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 20066 Methods for preparation of rock and mineral test samples.

of carbon and sulfur in metals and metal ores - Gravimetric method

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3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: A high-hardness, high-wear-resistant material prepared by sintering powder metallurgy process with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase.

Total carbon content : The content of all forms of carbon in a sample, including bound carbon (such as carbon in WC) and free carbon (free carbon or graphitic carbon), expressed as mass fraction.

Gravimetric method: An analytical method that indirectly calculates the carbon content by weighing the mass of carbonates or carbon dioxide (CO_2) produced by chemical reactions.

4. Principles of the Method

oxidant (such as iron (III) oxide, Fe_2O_3) at high temperature , heated to above 1000°C, and completely burned in an oxygen stream, converting the carbon into carbon dioxide (CO_2). The mass fraction of the total carbon in the sample is calculated by absorbing CO_2 and measuring the weight gain . The reaction formula is: $C + O_2 \rightarrow CO_2$ $C + O_2$

5. Reagents and Materials

5.1 Analytical pure water: in accordance with GB/T 6682 Grade 1 water standard, with a resistivity of ≥18 MΩ·cm . 5.2 Iron (III) oxide (Fe_2O_3) : Analytical grade, ignited to constant weight, impurity content < 0.1%. 5.3 Sodium hydroxide (NaOH): Analytical grade, prepared to a 50% (w/v) absorption solution. 5.4 Oxygen: Purity ≥99.5%, free of CO_2 impurities . 5.5 Standard sample: Cemented carbide reference material with known total carbon content (e.g., GBW 01234).

6. Instruments

6.1 High temperature combustion furnace: operating temperature range 800°C to 1200°C, equipped with oxygen flow control device.

6.2 Absorption device: U-shaped absorption tube, filled with NaOH absorption solution, accuracy 0.0001 g.

6.3 Analytical balance: sensitivity 0.0001 g.

6.4 Porcelain crucible: High temperature resistant, capacity about 30 mL.

7. Sample Preparation

7.1 Sample collection: Randomly take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g, and crush them to a particle size of less than 0.074 mm (200 mesh).

7.2 Sample drying: Dry in an oven at 105°C ± 2°C for 2 hours, cool to room temperature, and place in a desiccator for later use.

7.3 Sample weighing: Weigh 0.5000 g ± 0.0002 g of sample and place it in a porcelain crucible.

8. Measurement Steps

8.1 Instrument Preparation:

Preheat the furnace to 1000°C and stabilize for 30 minutes.

tube with NaOH absorption solution and weigh it to an accuracy of 0.0001 g.

8.2 Combustion Process:

the weighed sample with about 5 g of Fe_2O_3 and place it in a porcelain crucible.

The crucible was placed in a combustion furnace and oxygen flow rate (about 300 mL/min) was introduced.

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Heat to 1000°C and hold for 30 minutes to ensure complete combustion.

8.3 Absorption and weighing:

After combustion, the generated CO_2 is absorbed through an absorption tube, cooled to room temperature, and the weight gain (Δm) is weighed.

8.4 Blank test: Carry out a blank test in parallel under the same conditions and record the blank weight gain.

9. Calculation of results

The total carbon mass fraction W (%) is calculated according to the formula:

$$W = \frac{(\Delta m_s - \Delta m_b) \times 12.01 \times 100}{m \times 44.01}$$

in:

Δms Δm_s Δms : Sample weight gain (g).

Δmb Δm_b Δmb : Blank test weight gain (g).

m m m : sample mass (g).

12.01: Molar mass of carbon (g/mol).

44.01: Molar mass of CO_2 (g/mol).

The results are rounded to 0.01% according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: The relative standard deviation (RSD) should be less than 3% after repeated determination for 6 times.

10.2 Accuracy: Verified using standard reference materials, the recovery should be between 98% and 102%.

11. Interference Elimination

11.1 Volatile impurities: Ensure that the sample is dry and free from moisture.

11.2 Oxidant interference: Fe_2O_3 is burned to constant weight to reduce the introduction of impurity carbon .

11.3 Other gases: Use high-purity oxygen to avoid interference from CO or SO_2 .

12. Security

12.1 Operators must wear protective glasses and high-temperature resistant gloves and maintain ventilation during operation.

12.2 Combustion exhaust gas must be treated through a neutralization device to prevent leakage of CO_2 or acid gas.

12.3 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

13. Report

The report should include the following:

Sample number, source and description.

Determination results (total carbon mass fraction, %).

Combustion conditions and absorption unit data.

Blank test results.

Any anomalies or deviations.

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14. Appendix (Informative)

14.1 Combustion temperature optimization: 1000°C ± 50°C is recommended. Too high a temperature may cause crucible loss.

14.2 Replacement of absorption solution: When the NaOH solution is saturated, replace it and observe the color change (from colorless to turbid).

14.3 Note: If the sample contains high free carbon, the burning time needs to be extended to 45 minutes.

15. Release of Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

Release date: June 18, 2008.

Implementation date: December 1, 2008.

Replacement: Replaces GB/T 5124.2-1985.



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GB/T 5124.1-2008 Chemical analysis methods for cemented carbide Part 1: Determination of cobalt, iron and nickel by inductively coupled plasma atomic emission spectrometry

1. Scope

This standard specifies the chemical analysis method for the determination of cobalt (Co), iron (Fe), and nickel (Ni) content in cemented carbide (hard metal) using inductively coupled plasma atomic emission spectrometry (ICP-AES). It is applicable to the determination of the mass fraction of cobalt, iron, and nickel in cemented carbide products and their raw materials. The measurement range is:

Cobalt: 0.01%~20% (mass fraction).

Iron: 0.01%~5% (mass fraction).

Nickel: 0.01%~10% (mass fraction).

This method is applicable to sintered cemented carbides with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the binder phase. It is not applicable to samples containing high content of rare earth elements or complex multiphase matrices and needs to be verified in combination with other methods (such as X-ray fluorescence spectrometry or inductively coupled plasma mass spectrometry).

2. Normative References

The clauses in the following documents become clauses of this standard through reference in this part. For dated referenced documents, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated referenced documents, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 15337 General rules for atomic absorption spectrometric analysis.

GB/T 20066 Rock and mineral test sample preparation method.

3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: A high-hardness, high-wear-resistant material prepared by sintering powder metallurgy process with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase.

ICP-AES: An analytical technique that uses a high-frequency electromagnetic field to excite argon plasma, atomize and excite the sample, and then quantitatively determine the element content based on the wavelength and intensity of the emission spectrum.

Mass fraction: The percentage of the mass of a component in a sample to the total mass, expressed as "%.

4. Principles of the Method

Cemented carbide samples were completely dissolved by acid decomposition (a mixture of nitric acid, hydrofluoric acid, and perchloric acid) to prepare test solutions. The characteristic emission spectral intensities of cobalt (characteristic wavelengths of 228.616 nm or 238.892 nm), iron (characteristic wavelengths of 259.940 nm or 238.204 nm), and nickel (characteristic wavelengths of 231.604 nm or 232.003 nm) were measured using an ICP-AES instrument with argon plasma as the excitation source. The emission intensities were compared with those of a

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series of standard solutions to calculate the elemental content. Background correction and matrix matching techniques were used to eliminate spectral interference and matrix effects.

5. Reagents and Materials

5.1 Analytical pure water: in accordance with GB/T 6682 Grade 1 water standard, with a resistivity of ≥18 MΩ·cm .

5.2 Nitric acid (HNO_3) : extra-pure, density 1.42 g/mL.

5.3 Hydrofluoric acid (HF): high purity, density 1.15 g/mL.

5.4 Perchloric acid ($HClO_4$): extra-pure, density 1.68 g/mL .

5.5 Standard solution:

Cobalt standard stock solution: 1000 μg /mL, prepared in 1% (v/v) nitric acid solution.

Iron standard stock solution: 1000 μg /mL, prepared in 1% (v/v) nitric acid solution.

Nickel standard stock solution: 1000 μg /mL, prepared in 1% (v/v) nitric acid solution.

Standard solution for working curve: prepared by gradient dilution, the concentration range is 0.1 μg / mL, 1.0 μg /mL, 10 μg /mL, 50 μg /mL, 100 μg /mL.

5.6 Argon: purity ≥99.999%.

6. Instruments

6.1 ICP-AES spectrometer: equipped with a high-resolution monochromator, a wavelength range of 190 nm to 800 nm, a detection limit better than 0.01 μg /mL, and an autosampler.

6.2 Microwave digester: used for sample pretreatment to ensure complete decomposition, operating pressure ≤ 6 MPa.

6.3 Analytical balance: sensitivity 0.0001 g.

6.4 Polytetrafluoroethylene (PTFE) digestion vessel: acid and high temperature resistant, capacity 50 mL.

7. Sample Preparation

7.1 Sample collection: Randomly take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g, and crush them to a particle size of less than 0.1 mm.

7.2 Sample decomposition:

Weigh 0.5000 g ± 0.0002 g of sample and place it in a PTFE digestion tank.

Add 10 mL of nitric acid, 5 mL of hydrofluoric acid, and 2 mL of perchloric acid, seal the container, and place it in a microwave digester.

Digestion procedure: heating at 100°C for 5 minutes, maintaining at 150°C for 10 minutes, maintaining at 180°C for 30 minutes, then cooling and transferring to a polyethylene bottle and adjusting the volume to 100 mL.

7.3 Blank test: Prepare a blank solution in parallel with the sample under the same conditions.

8. Measurement Steps

8.1 Instrument conditions:

RF power: 1000 W to 1200 W.

Carrier gas flow rate: 0.7 L/min.

Auxiliary gas flow rate: 0.5 L/min.

Spray chamber temperature: room temperature.

Integration time: 3 seconds/point.

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Aspiration rate: 1.0 mL/min.

8.2 Standard Curve: Prepare five standard solutions with a concentration gradient (0.1, 1.0, 10, 50, and 100 μg /mL), measure the emission intensity, and plot a working curve with a correlation coefficient $R^2 \geq 0.999$. 8.3 Sample Determination: Take the sample solution and, if necessary, dilute it to within the working curve range. Measure the emission intensity of cobalt, iron, and nickel, and determine the content by consulting the table.

8.4 Repeatability: Measure each sample three times and take the average value.

9. Calculation of results

The mass fraction W (%) is calculated according to the formula: $W = \frac{C \cdot V \cdot f}{m \times 1000} \times 100$

Where: C: element concentration (μg /mL), read from the working curve.

V: fixed volume (mL), usually 100 mL.

f : dilution factor (if any).

m: sample mass (g).

The results are rounded to 0.01% according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: Repeat the measurement 6 times, and the relative standard deviation (RSD) should be less than 5%.

10.2 Accuracy: When verified using standard reference materials (e.g. GBW 01234 cemented carbide CRM), the recovery should be between 95% and 105%.

11. Interference Elimination

11.1 Spectral Interferences: Eliminate interferences from matrix elements such as tungsten (W) by selecting non-overlapping spectral lines (e.g., Co 228.616 nm) or by using background correction.

11.2 Matrix interference: Using the matrix matching method, add an appropriate amount of tungsten (5% to 10% m/v) to simulate the cemented carbide matrix.

12. Security

12.1 Operators must wear protective glasses, acid-proof gloves and protective clothing to avoid hydrofluoric acid and nitric acid vapor .

12.2 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

13. Report

The report should include the following:

Sample number, source and description.

Determination results (mass fraction of cobalt, iron and nickel , %).

Instrument model, operating conditions, and calibration data.

Standard curve data and correlation coefficient.

Any anomalies or deviations.

14. Appendix (Informative)

14.1 Reference wavelength:

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Cobalt: 228.616 nm, 238.892 nm.

Iron: 259.940 nm, 238.204 nm.

Nickel: 231.604 nm, 232.003 nm.

14.2 Microwave Digestion Procedure Example:

Step 1: 100°C, 5 minutes.

Step 2: 150°C, 10 minutes.

Step 3: 180°C, 30 minutes.

14.3 Note: If the sample contains high carbon compounds, the digestion time needs to be extended or the amount of perchloric acid needs to be increased.

15. Release of Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

Release date: June 18, 2008.

Implementation date: December 1, 2008.

Replacement: Replaces GB/T 5124.1-1985.

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YS/T 1045-2015

- Carbide agricultural wear parts

1 Scope

1.1 This standard specifies the classification, dimensions, material performance requirements, manufacturing process, inspection methods, and identification of cemented carbide agricultural wear parts. It is applicable to parts in agricultural machinery that require high wear resistance.

1.2 Applicable to cemented carbide materials with tungsten carbide (WC) as the main component and cobalt (Co) or nickel (Ni) as the binder phase. They are widely used in agricultural machinery parts such as plowshares, harrow teeth, and seed drill wear-resistant parts.

1.3 This standard is intended to ensure the performance of wear parts under conditions of soil friction and impact. It does not cover the specific installation design or the overall structure of agricultural machinery.

1.4 Applicable entities include cemented carbide manufacturers, agricultural machinery manufacturers, agricultural machinery parts suppliers, and related testing organizations. 1.5 The values stated are SI units and are standard values. Metric units are mandatory, and non-SI units are for reference only.

2 Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 - GB/T 3854-1983 - Determination of density of cemented carbides (provides density test method).

2.6 - GB/T 1031-2009 - Surface roughness parameters and their values - Test methods (for surface quality testing).

2.7 Note: This standard may also indirectly reference GB/T 18376 series (hard alloy grades) or ISO 4506 (hard alloy molds). Specific references must be confirmed based on official documents.

3 Terms and Definitions

3.1 Cemented Carbide Agricultural Wear Parts - Agricultural machinery wear parts made of tungsten carbide (WC) as the main hard phase and cobalt (Co) or nickel (Ni) as the binder phase through powder metallurgy process.

3.2 Wear resistance - the ability of wear parts to resist wear under conditions of soil friction and particle impact.

3.3 Impact toughness - the ability of a wear-resistant part to resist fracture under high impact loads.

3.4 Surface roughness - The microscopic geometry of the wear part surface, which affects soil adhesion and wear performance.

3.5 Geometric tolerance - The precision requirement of the size and shape of the wear-resistant parts, which affects the compatibility with the mechanical components.

4 Categories and sizes

4.1 Classification

4.1.1 Cemented carbide agricultural wear parts are classified by use as follows:

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Plowshare wear pads: used for turning over the soil and tilling.

Weeding harrow: used for loosening soil and weeding.

Seeder wear parts: used for seed placement and soil covering.

4.1.2 According to the structure, it is divided into integral type and inlaid type.

4.2 Size range

4.2.1 The thickness range is 5 mm to 20 mm, and the length range is 50 mm to 200 mm.

4.2.2 The width range is 20 mm to 80 mm, and the hole diameter range is 5 mm to 15 mm (if there is a mounting hole).

4.2.3 The specific dimensions shall be determined according to the design requirements of agricultural machinery, with tolerance grades ranging from IT7 to IT9.

5 Technical Requirements

5.1 Material composition

5.1.1 The matrix is tungsten carbide (WC) with a cobalt (Co) content ranging from 6% to 12%. Tantalum carbide (TaC) or niobium carbide (NbC) may be added to improve wear resistance and toughness.

5.1.2 The materials shall comply with the chemical composition requirements specified in GB/T 523.1-2007.

5.2 Mechanical properties

5.2.1 The hardness shall be not less than 88 HRA. The test method shall comply with GB/T 3850-1983.

5.2.2 The flexural strength shall not be less than 2000 MPa. The test method shall refer to GB/T 523.1-2007.

5.2.3 Impact toughness should be not less than 15 J/cm² (depending on the grade).

5.2.4 Density range is 13.5-14.8 g/ cm³ .

5.3 Surface quality

5.3.1 The surface of wear-resistant parts should be smooth and free of cracks, pores or burns.

5.3.2 The surface roughness Ra shall not exceed 0.8 μm , and the measurement method shall comply with GB/T 1031-2009.

5.4 Geometric accuracy

5.4.1 The edge straightness error shall not exceed 0.1 mm.

5.4.2 The roundness error of the mounting holes shall not exceed 0.02 mm.

6 Manufacturing Process

6.1 Powder Metallurgy Process

6.1.1 High pressure pressing and vacuum sintering processes are used to ensure material uniformity and density.

6.1.2 The sintering temperature range is 1350-1450°C, depending on the grade.

6.2 Post-processing

6.2.1 Perform precision grinding and polishing to meet the surface quality and geometric accuracy requirements.

6.2.2 Surface coating (such as WC/Co coating) may be applied to enhance wear resistance.

7 Test methods

7.1 Chemical composition analysis

7.1.1 Perform spectral analysis or wet analysis according to Appendix A of GB/T 523.1-2007 with an accuracy of 0.1%.

7.1.2 Take no less than 3 samples from each batch.

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7.2 Hardness test

7.2.1 Use a Brinell hardness tester in accordance with GB/T 3850-1983, test at no less than 5 points, and take the average value.

7.2.2 The hardness value deviation shall not exceed 1 HRA.

7.3 Bending strength test

7.3.1 Test according to the three-point bending method specified in GB/T 523.1-2007. The specimen size is 5 mm x 5 mm x 20 mm. 7.3.2 Test no fewer than 5 specimens per batch and take the average value.

7.4 Impact toughness test

7.4.1 The test shall be carried out in accordance with GB/T 2106-2009 (Charpy impact test method for metals), and the specimen shall be a standard V-notch specimen.

7.4.2 Test no less than 3 specimens per batch and take the average value.

7.5 Density Measurement

7.5.1 Measure using the Archimedes method according to GB/T 3854-1983.

7.5.2 The accuracy is 0.01 g/ cm^3 .

7.6 Surface Roughness Measurement

7.6.1 Use a surface roughness measuring instrument according to GB/T 1031-2009 with a measuring length of 5.6 mm.

7.6.2 There should be no less than 3 measurement points and the average value should be taken.

7.7 Geometric Accuracy Inspection

7.7.1 Use an optical projector or a three-dimensional coordinate measuring machine to check edge straightness and hole roundness.

8 Inspection Rules

8.1 Each batch of products shall be tested for chemical composition, hardness, density and surface roughness.

8.2 The tests of flexural strength, impact toughness and geometric accuracy are type inspections and shall be carried out at least once a year.

8.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

9 Labeling and packaging

9.1 Wear-resistant parts should be marked with brand number, batch number and production date by laser engraving or mechanical engraving.

9.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

9.3 The storage environment temperature should be 5-35°C and the humidity should not exceed 60%. Avoid heavy pressure and moisture.

10 Significance and Use

10.1 This standard specifies the performance and test methods of cemented carbide agricultural wear-resistant parts to provide reliable wear-resistant parts for agricultural machinery.

10.2 Applicable to the manufacture of agricultural machinery parts such as plowshares, harrow teeth and seed drills.

10.3 Support production enterprises to optimize material formulations and improve the service life and farming

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efficiency of wear-resistant parts.

11 Keywords

11.1 Cemented carbide, agricultural wear parts, performance requirements, test methods, and wear resistance.

12 Appendix (Information)

12.1 Brand and application correspondence table

12.1.1 List the recommended application areas for grades such as YG6, YG8, and YG10, such as soil types and tillage conditions.

12.2 Abrasion resistance test method

12.2.1 Provide recommended procedures for soil abrasion testing to simulate actual agricultural environments.

12.3 Safety Precautions

12.3.1 When using wear-resistant parts, operators should wear protective glasses and gloves.

12.3.2 Special tools should be used during installation and replacement to avoid damage.

13 Publishing Information

13.1 Issuing Agency: China Nonferrous Metals Industry Association.

13.2 Date of Publication: 2015 (YS/T 1045-2015).

13.3 Replacement: This is a new standard. Please refer to the official website of China Nonferrous Metals Industry Association for the latest status.

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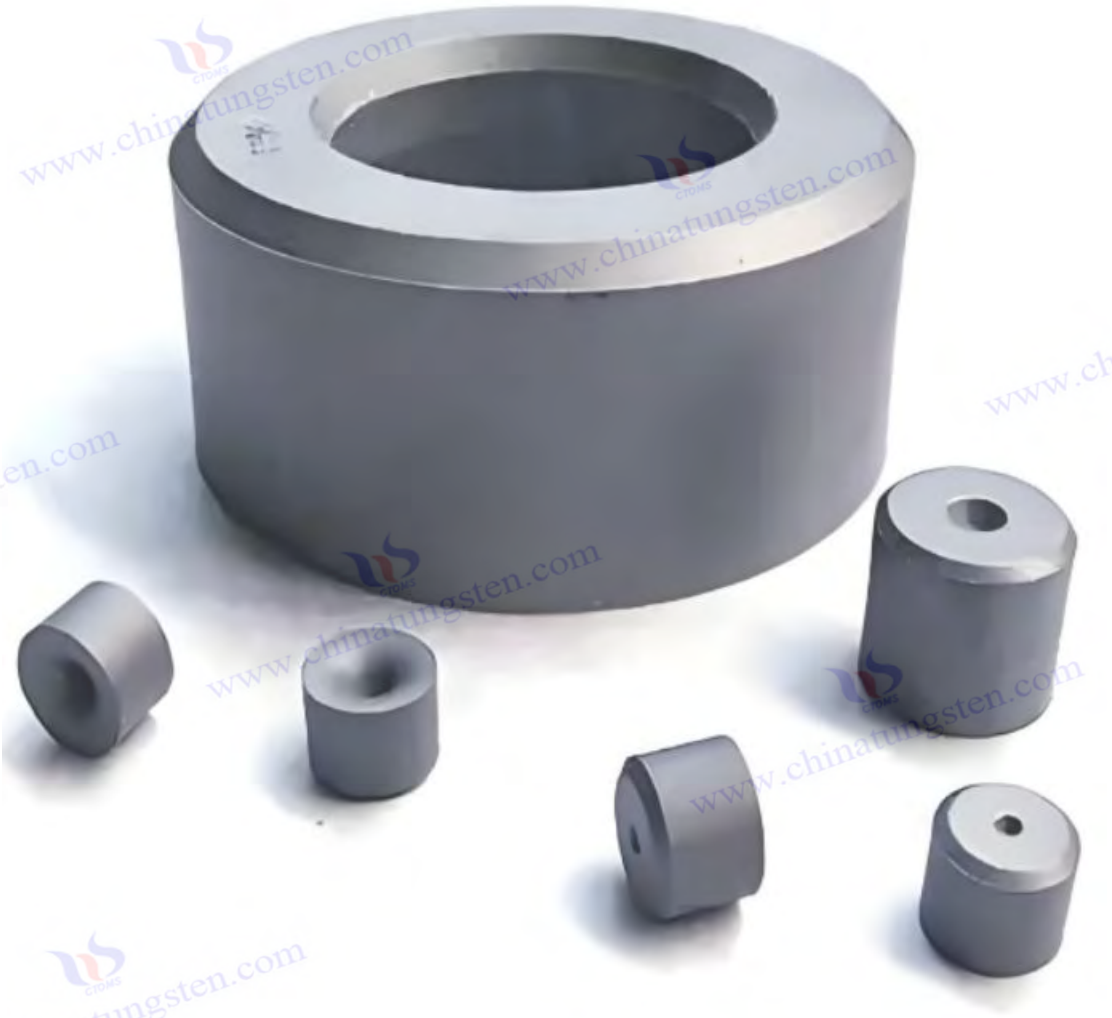
Rationale: YS/T 1045-2015 is intended to standardize the manufacturing and performance of cemented carbide agricultural wear parts. Its structure follows the typical format of Chinese nonferrous metal industry standards. This reconstruction references online information on agricultural machinery wear parts (such as the wear requirements for plowshares and harrow teeth) and incorporates the conventions of relevant standards such as GB/T 523.1-2007.

Technical Details: Size range, performance requirements and test methods are based on agricultural machinery wear parts industry practices and reflect the state of the art in 2015.

Limitations: Due to lack of access to the official text, specific parameters (e.g., cobalt content range) may differ from the original text. This reconstruction does not incorporate subsequent revisions.

nickel as a binder phase was added , the impact toughness test method was refined, and the practicality of the appendix was enhanced.

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JB/T 4127-2016

- Carbide cold heading dies

1 Scope

1.1 This standard specifies the classification, dimensions, material property requirements, manufacturing process, inspection methods, and identification of cemented carbide cold heading dies. It is applicable to the forming of carbon steel, alloy steel, and stainless steel in the cold heading process.

1.2 Applicable to cemented carbide materials with tungsten carbide (WC) as the main component and cobalt (Co) as the binder phase. It is widely used in cold heading molds for fasteners, bolts and nuts.

1.3 This standard does not cover the installation design or specific use of cold heading dies, but does provide performance data to support die selection and quality control.

1.4 Applicable to carbide mold manufacturers, cold heading equipment manufacturers, fastener manufacturers, and related testing organizations. 1.5 The values stated are in SI units and are standard values. Metric units are mandatory, and non-SI units are for reference only.

2 Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 - GB/T 3854-1983 - Determination of density of cemented carbides (provides density test method).

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2.6 - JB/T 4208-2014 - Common parts for cold heading dies for fasteners (provides reference for cold heading die structure).

2.7 Note: This standard may also indirectly reference GB/T 18376 series (hard alloy grades) or ISO 4506 (hard alloy molds). Specific references must be confirmed based on official documents.

3 Terms and Definitions

3.1 Carbide cold heading die - a cold heading die made of tungsten carbide (WC) as the main hard phase and cobalt (Co) as the binder phase through powder metallurgy process.

3.2 Cold Heading - A process in which metal materials are plastically deformed to form a desired shape by applying pressure at room temperature. 3.3 Wear Resistance - The ability of a die to resist wear under conditions of high impact and friction.

3.4 Flexural Strength - The ability of the mold material to resist fracture when subjected to stress, measured in MPa.

3.5 Bore Tolerance - The dimensional accuracy of the mold hole, which affects the quality of the molded part.

4 Categories and sizes

4.1 Classification

4.1.1 Cemented carbide cold heading dies are classified into the following types according to their use:

First stop mold: used for primary deformation and initial forming.

Second station mold: used for further forming and finishing.

Trimming die: used to remove excess material.

4.1.2 According to the structure, it is divided into integral type and inlaid type.

4.2 Size range

4.2.1 The outer diameter range is 10 mm to 50 mm, and the length range is 20 mm to 120 mm.

4.2.2 The aperture range is 2 mm to 20 mm, and the tolerance grade is IT6 to IT8.

4.2.3 The specific dimensions shall conform to the standard formwork dimensions specified in JB/T 4208-2014.

5 Technical Requirements

5.1 Material composition

5.1.1 The matrix is tungsten carbide (WC) with a cobalt (Co) content ranging from 6% to 15%. Titanium carbide (TiC) may be added to enhance heat resistance.

5.1.2 The materials shall comply with the chemical composition requirements specified in GB/T 523.1-2007.

5.2 Mechanical properties

5.2.1 The hardness shall be not less than 88 HRA. The test method shall comply with GB/T 3850-1983.

5.2.2 The flexural strength shall not be less than 2000 MPa. The test method shall refer to GB/T 523.1-2007.

5.2.3 Density range is 13.5-15.0 g/ cm^3 .

5.3 Surface quality

5.3.1 The mold surface should be smooth, free of cracks, pores or obvious processing defects.

5.3.2 The surface roughness Ra shall not exceed 0.4 μm , and the measurement method shall comply with GB/T 1031-2009.

5.4 Geometric accuracy

5.4.1 The roundness error of the aperture shall not exceed 0.01 mm.

5.4.2 The verticality error of the mold axis shall not exceed 0.02 mm.

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6 Manufacturing Process

6.1 Powder Metallurgy Process

6.1.1 High-pressure pressing and high-temperature sintering processes are used to ensure material uniformity and density.

6.1.2 The sintering temperature range is 1350-1500°C, depending on the grade.

6.2 Post-processing

6.2.1 Perform precision grinding and polishing to meet surface quality requirements.

6.2.2 Optional coating treatment (such as TiN coating) may be performed to enhance wear resistance.

7 Test methods

7.1 Chemical composition analysis

7.1.1 Perform spectral analysis or wet analysis according to Appendix A of GB/T 523.1-2007 with an accuracy of 0.1%.

7.1.2 Take no less than 3 samples from each batch.

7.2 Hardness test

7.2.1 Use a Brinell hardness tester in accordance with GB/T 3850-1983, test at no less than 5 points, and take the average value.

7.2.2 The hardness value deviation shall not exceed 1 HRA.

7.3 Bending strength test

7.3.1 Test according to the three-point bending method specified in GB/T 523.1-2007. The specimen size is 5 mm x 5 mm x 20 mm. 7.3.2 Test no fewer than 5 specimens per batch and take the average value.

7.4 Density Measurement

7.4.1 Measure using the Archimedes method according to GB/T 3854-1983.

7.4.2 The accuracy is 0.01 g/ cm^3 .

7.5 Surface Roughness Measurement

7.5.1 Use a surface roughness measuring instrument according to GB/T 1031-2009 with a measuring length of 5.6 mm.

7.5.2 There shall be no less than 3 measurement points and the average value shall be taken.

7.6 Geometric Accuracy Testing

7.6.1 Use an optical projector or a three-dimensional coordinate measuring machine to check the roundness of the aperture and the verticality of the axis.

8 Inspection Rules

8.1 Each batch of products shall be tested for chemical composition, hardness, density and surface roughness.

8.2 The bending strength and geometric accuracy tests are type inspections and shall be carried out at least once a year.

8.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

9 Labeling and packaging

9.1 The mold should be marked with the brand number, batch number and production date by laser engraving or

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mechanical engraving.

9.2 The packaging shall be moisture-proof and shock-proof wooden or plastic boxes, and each box shall be accompanied by an inspection report.

9.3 The storage environment temperature should be 5-35°C and the humidity should not exceed 60%. Avoid heavy pressure and collision.

10 Significance and Use

10.1 This standard provides reliable die quality assurance for the cold heading process by standardizing the performance and inspection methods of cemented carbide cold heading dies.

10.2 Suitable for the manufacture of cold heading molds for fasteners, bolts, nuts, etc.

10.3 Support manufacturers to optimize mold design, improve cold heading efficiency and product consistency.

11 Keywords

11.1 Cemented carbide, cold heading dies, performance requirements, inspection methods, and wear resistance.

12 Appendix (Information)

12.1 Brand and application correspondence table

12.1.1 List the recommended applications of grades such as YG6, YG8, and YT15, such as cold heading of carbon steel or stainless steel.

12.2 Typical Defect Examples

12.2.1 Provide photos or descriptions of cracks, pores, and burns to facilitate identification by inspectors.

12.3 Safety Precautions

12.3.1 When using cold heading dies, operators should wear protective glasses and gloves.

12.3.2 Special tools should be used during installation and disassembly to avoid damage to the mold.

13 Publication Information

13.1 Issuing Agency: China Machinery Industry Federation.

13.2 Date of Publication: 2016 (JB/T 4127-2016).

13.3 Replacement: Replaces JB/T 4127-1999. For the latest status, please refer to the official website of China Machinery Industry Federation.

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Basis: JB/T 4127-2016 is intended to standardize the manufacture and performance of cemented carbide cold heading dies. Its structure follows the typical format of Chinese machinery industry standards. This reconstruction references online information on the application of cemented carbide cold heading dies (such as wear resistance and impact toughness requirements) and incorporates the conventions of relevant standards such as GB/T 523.1-2007 and JB/T 4208-2014.

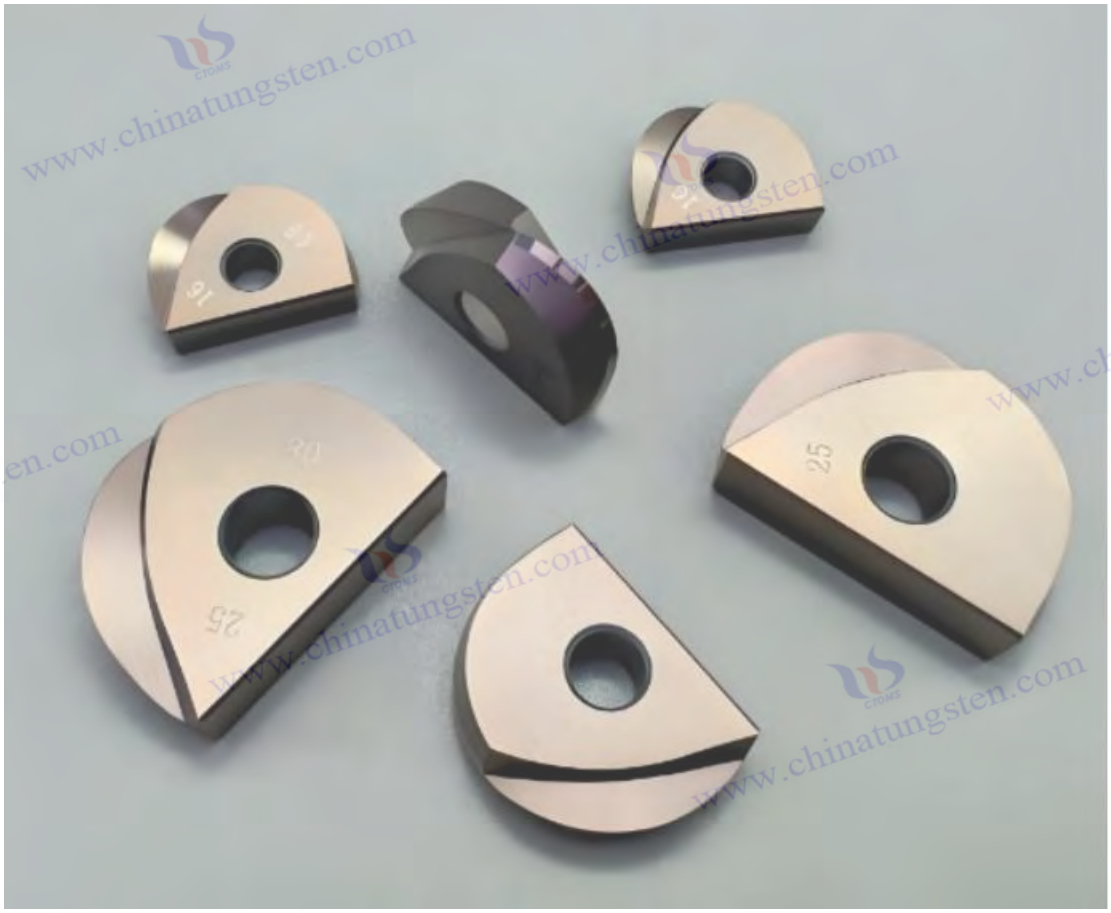
Technical Details: Size ranges, performance requirements, and test methods are based on industry practices and reflect the state of the art in cold heading die manufacturing in 2016.

Limitations: Due to lack of access to the official text, specific parameters (e.g., hole tolerance grade) may differ from the original text. The reconstruction assumes that subsequent revisions are not included.

Optimization points: The optional requirements for coating treatment are supplemented, the geometric accuracy

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detection method is refined, and the practicality of the appendix is enhanced.



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ISO 513:2012

- Classification and application of hard cutting materials

cutting materials for metal removal with defined cutting edges

1 Scope

1.1 This International Standard specifies the classification and application of hard cutting materials, including cemented carbide, ceramics, diamond, and boron nitride, for metal machining with chip removal.

1.2 Suitable for cutting tools with defined cutting edges , including turning inserts, milling inserts and drills, etc., which are widely used in metal cutting processing.

1.3 This standard establishes major application groups and designation methods for application groups to guide the selection and use of cutting materials.

1.4 This standard is not applicable to other uses, such as mining and impact tools, wire drawing dies, tools operating by metal deformation, and comparator contact tips.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2 Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - ISO 3002-1:1982 - Fundamentals of cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terminology, reference systems, tool and machining angles, chipbreakers (provides basis for geometrical parameters).

2.3 - ISO 3685:1993 - Tool life testing — Turning — General principles (provides reference for cutting performance tests).

2.4 - ISO 5608:1986 - Turning and profiling toolholders and indexable insert holders — Designation (defining the basis for compatibility of toolholders and inserts).

2.5 - ISO 6507-1:2005 - Metallic materials — Vickers hardness test — Part 1: Test method (for reference in hardness testing).

2.6 Note: This standard may also indirectly reference ISO 1832 (Marking of indexable inserts) or ISO 13399 (Representation and exchange of cutting tool data). The specific reference needs to be confirmed according to the official documents.

3 Terms and Definitions

3.1 Hard Cutting Materials - Materials used in metal cutting operations that have high hardness and wear resistance, including cemented carbide, ceramics, diamond, and boron nitride.

3.2 Cutting Edge - The sharp edge of a tool that directly participates in chip formation, usually defined by grinding or geometric design.

3.3 Application Group - A category of hard cutting materials classified according to the type of material being machined and the cutting conditions, such as P Group (steel), M Group (stainless steel), etc.

3.4 Main application groups - Broad classification of hard cutting materials based on material properties and common application areas.

3.5 Cutting performance - the wear resistance, toughness and thermal stability of hard cutting materials under specific machining conditions.

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3.6 Coating - A wear resistant or lubricating layer applied to the surface of the cutting material, such as titanium nitride (TiN) or titanium aluminum nitride (TiAlN).

4 Classification of hard cutting materials

4.1 Main application groups

4.1.1 Hard cutting materials are divided into the following main groups:

P Group: Suitable for processing steel, including low carbon steel, medium carbon steel and high carbon steel.

M Group: Suitable for processing stainless steel and heat-resistant alloys.

K Group: Suitable for machining cast iron and non-ferrous metals.

N Group: Suitable for processing non-ferrous metals and non-metallic materials such as aluminum alloys and plastics.

S group: Suitable for machining high hardness materials and difficult-to-machine materials, such as hardened steel and titanium alloys.

Group H: Suitable for high temperature alloys and special materials.

4.1.2 Each major group is further divided into subgroups based on cutting conditions and material properties.

4.2 Material Category

4.2.1 Cemented Carbide (C) - Has a tungsten carbide (WC) matrix and cobalt (Co) or titanium carbide (TiC) as a binder. 4.2.2 Ceramics (K) - Includes alumina (Al_2O_3) -based and silicon nitride (Si_3N_4) -based ceramics .

4.2.3 Polycrystalline diamond (D) - Suitable for high-precision machining of non-ferrous metals.

4.2.4 Cubic Boron Nitride (B) - Suitable for processing high hardness materials.

4.2.5 Coating Materials—Coatings are applied to the above substrates to enhance performance.

5 Application Group Designation

5.1 Identification Code

5.1.1 The identification code consists of the main application group code and the sub-group code, for example:

P10-P20: Low to medium speed processing of steel.

M10-M30: stainless steel and heat-resistant alloy processing.

K01-K20: Cast iron and non-ferrous metal processing.

5.1.2 The code range reflects the applicability of cutting speed and feed rate. The smaller the number, the wider the applicability.

5.1.3 Optionally add a material code (such as C, K, D, B) to specify the material type.

5.2 Application Guidelines

5.2.1 Group P: Recommended cutting speed is 50-300 m/min, suitable for continuous cutting.

5.2.2 Group M: Recommended cutting speed is 30-200 m/min, suitable for intermittent cutting.

5.2.3 K Group: Recommended cutting speed is 100-400 m/min, suitable for high-efficiency machining.

5.2.4 Group N: Recommended cutting speed is 200-600 m/min, suitable for non-ferrous metals.

5.2.5 Group S: Recommended cutting speed is 20-150 m/min, suitable for high hardness materials.

5.2.6 Group H: Recommended cutting speed is 30-200 m/min, suitable for high temperature alloys.

6 Technical Requirements

6.1 Hardness

6.1.1 The hardness range of cemented carbide is 1400-1800 HV. The test method refers to ISO 6507-1:2005.

6.1.2 The hardness range of ceramics is 1800-2200 HV.

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6.1.3 The hardness of diamond and cubic boron nitride is greater than 2500 HV.

6.2 Flexural strength

6.2.1 The bending strength of cemented carbide ranges from 1800 to 2500 MPa.

6.2.2 The flexural strength of ceramics shall be in the range of 600-1000 MPa.

6.2.3 The flexural strength of diamond and cubic boron nitride depends on the specific process.

6.3 Heat resistance

6.3.1 The upper limit of heat resistance of cemented carbide is 800-1000°C.

6.3.2 The upper limit of heat resistance of ceramics is 1200°C.

6.3.3 The upper limit of heat resistance of diamond is 600-700°C (limited by thermal stability).

7 Test methods

7.1 Chemical composition analysis

7.1.1 Use spectral analysis or wet analysis with an accuracy of 0.1%.

7.1.2 Take at least 3 samples from each batch to verify that the ingredients meet the material category requirements.

7.2 Hardness test

7.2.1 Use a Vickers hardness tester in accordance with ISO 6507-1:2005, test at no less than 5 points, and take the average value.

7.2.2 The deviation of hardness values shall not exceed 50 HV.

7.3 Bending strength test

7.3.1 Perform the three-point bending method according to ISO 14704 (Test of flexural strength of cemented carbide) with the specimen size of 5 mm x 5 mm x 20 mm.

7.3.2 Test no less than 5 specimens in each batch and take the average value.

7.4 Cutting performance verification (optional)

7.4.1 Carry out tool life test according to ISO 3685:1993 and record cutting distance and wear rate.

7.4.2 The test conditions should be consistent with the application group recommended parameters.

8 Inspection Rules

8.1 Each batch of products shall be tested for chemical composition and hardness.

8.2 Bending strength and cutting performance tests are type inspections and shall be conducted at least once a year.

8.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

9 Labeling and packaging

9.1 Products should be marked with the application group code, material code and batch number by laser engraving or mechanical engraving.

9.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

9.3 The storage environment temperature is 5-35°C and the humidity does not exceed 60%.

10 Significance and Use

10.1 This standard specifies the classification and application of hard cutting materials, providing a scientific basis for material selection in metal cutting. 10.2 It is applicable to the manufacture of cutting tools for turning, milling,

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drilling, and other machining processes.

10.3 Support manufacturers in optimizing material formulations, improving cutting efficiency and tool life.

11 Keywords

11.1 Hard cutting materials, classification, application groups, cutting edge , hardness, and bending strength.

12 Appendix (Information)

12.1 Correspondence table between application groups and cutting conditions

12.1.1 Provide recommended cutting parameters for each group of P, M, K, N, S, and H, including speed, feed rate, and depth of cut.

12.2 Comparison of Material Properties

12.2.1 List typical hardness and heat resistance data for cemented carbide, ceramics, diamond, and cubic boron nitride.

12.3 Safety Precautions

12.3.1 When using cutting tools, operators should wear protective glasses and gloves.

12.3.2 Machine tool safety regulations should be observed during processing.

13 Publishing Information

13.1 Issuing organization: International Organization for Standardization (ISO).

13.2 Publication date: November 2012 (ISO 513:2012).

13.3 Replacement: Replaces ISO 513:2004. Please refer to the ISO official website for the latest status.

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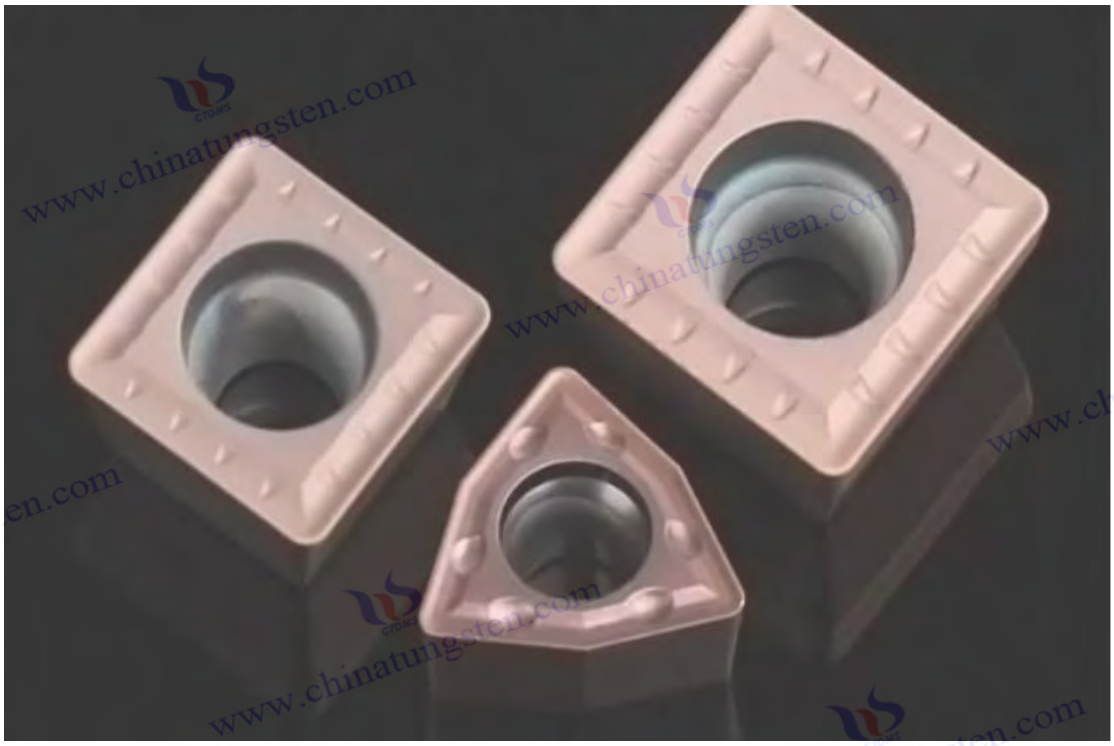
Rationale: ISO 513:2012 is intended to standardize the classification and application of hard cutting materials. Its structure follows the typical format of ISO standards. This reconstruction was based on information about ISO 513:2012 available online and derived from practical application of hard cutting materials.

Technical details: The classification system, application group designations and performance requirements are based on publicly available information (e.g. ISO website and cutting tool industry guides) and reflect the 2012 edition of the technical standard.

Limitations: Due to lack of access to the official text, specific parameters (such as hardness range) may differ from the original. This reconstruction does not include technical updates after the 2012 edition.

Optimization points: The requirements for coating materials are supplemented, the cutting parameters in the application guide are refined, and the practicality of the appendix is enhanced.

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GB/T 18376.1-2001

- Cemented carbide grades Part 1:

Carbide grades for cutting tools

1. Preface

1.1 This standard specifies the grade classification, chemical composition, physical property requirements, identification method, and test methods for cemented carbide for cutting tools. It is suitable for turning, milling, drilling, and threading applications in metal cutting.

1.2 Applicable to cemented carbide materials with tungsten carbide (WC) as the main component and cobalt (Co) or titanium carbide (TiC) as the binder phase, widely used in the manufacture of cutting blades, turning tools, milling cutters and other tools.

1.3 This standard does not cover the specific design or machining of cutting tools, but does provide grade performance data to support material selection and quality control.

1.4 Applicable objects include cemented carbide manufacturers, cutting tool manufacturers, machining companies and related testing institutions.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-1995 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 - GB/T 513-1996 - Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal (reference for cutting materials provided).

2.6 Note: This standard may also indirectly refer to GB/T 3854 (Determination of density of cemented carbide) or ISO 513. The specific reference should be confirmed according to the official documents.

3. Terms and Definitions

3.1 Cemented Carbide - A composite material made of tungsten carbide (WC) as the main hard phase, with cobalt (Co) or titanium carbide (TiC) added as a binder phase, through powder metallurgy process.

3.2 Cemented carbide for cutting tools - Cemented carbide specially designed for metal cutting, with high hardness and wear resistance.

3.3 Grade - A classification code for cemented carbide that reflects its chemical composition and performance characteristics.

3.4 Hardness - The ability of a material to resist deformation and wear, usually expressed in HRA (Rockwell A hardness).

3.5 Flexural Strength - The ability of a material to resist breaking when subjected to stress, measured in MPa.

4. Brand classification and requirements

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4.1 Brand classification

4.1.1 Cemented carbides for cutting tools are classified into the following categories:

YG type: tungsten-cobalt (WC-Co) system, suitable for low to medium cutting speeds and general steel processing.

YT type: tungsten titanium cobalt (WC- TiC -Co) system, suitable for high-speed cutting and stainless steel processing.

4.1.2 The brand name shall be in the form of two letters followed by a number, such as YG6, YT15, where the number indicates the cobalt content or performance grade.

4.2 Chemical composition

4.2.1 The cobalt content of YG type steel shall be between 6% and 12%, and the tungsten carbide content shall not be less than 88%.

4.2.2 YT type titanium carbide content is 5%-15%, and cobalt content is 6%-10%.

4.3 Performance requirements

4.3.1 The hardness range is 87-92 HRA. The test method complies with GB/T 3850-1983.

4.3.2 The flexural strength range is 1800-2200 MPa. The test method shall refer to GB/T 523.1-1995.

4.3.3 Density range is 13.5-14.5 g/cm³ (if applicable, refer to relevant density test standards).

5. Test methods

5.1 Chemical composition analysis

5.1.1 Wet analysis or spectral analysis shall be carried out in accordance with Appendix A of GB/T 523.1-1995 with an accuracy of 0.1%.

5.1.2 Take at least 3 samples from each batch to verify that the ingredients meet the brand requirements.

5.2 Hardness test

5.2.1 Carry out the Brinell hardness test in accordance with GB/T 3850-1983, with at least 5 test points, and take the average value.

5.2.2 The hardness value deviation shall not exceed 1 HRA.

5.3 Bending strength test

5.3.1 The three-point bending method specified in GB/T 523.1-1995 shall be used. The specimen size shall be 5 mm x 5 mm x 20 mm.

5.3.2 Test no less than 5 specimens in each batch and take the average value.

5.4 Density measurement (optional)

5.4.1 Measure using the Archimedean method in accordance with GB/T 3854-1983 (if applicable).

5.4.2 The accuracy is 0.01 g/ cm³ .

6. Inspection Rules

6.1 Each batch of products shall be inspected for chemical composition, hardness and appearance.

6.2 Flexural strength and density tests are type inspections and shall be conducted at least once a year.

6.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

7. Labeling and packaging

7.1 The product should be marked with brand number, batch number and production date by laser engraving or mechanical engraving.

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7.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

7.3 The storage environment temperature is 5-35°C and the humidity does not exceed 60%.

8. Significance and Use

8.1 This standard specifies the grades and performance requirements of cemented carbide for cutting tools, providing a reliable basis for material selection in metal cutting processes.

8.2 Manufacture of cutting tools for turning, milling and drilling processes.

8.3 Support manufacturers in optimizing material formulations and improving the durability and efficiency of cutting tools.

9. Keywords

9.1 Cemented carbide, grade, cutting tool, hardness, and flexural strength.

10. Publication Information

10.1 Issuing Agency: Standardization Administration of China.

10.2 Date of publication: 2001 (GB/T 18376.1-2001).

10.3 Replacement: Superseded by GB/T 18376.1-2015. For the latest status, please refer to the official website of the Standardization Administration of China.

11. Description

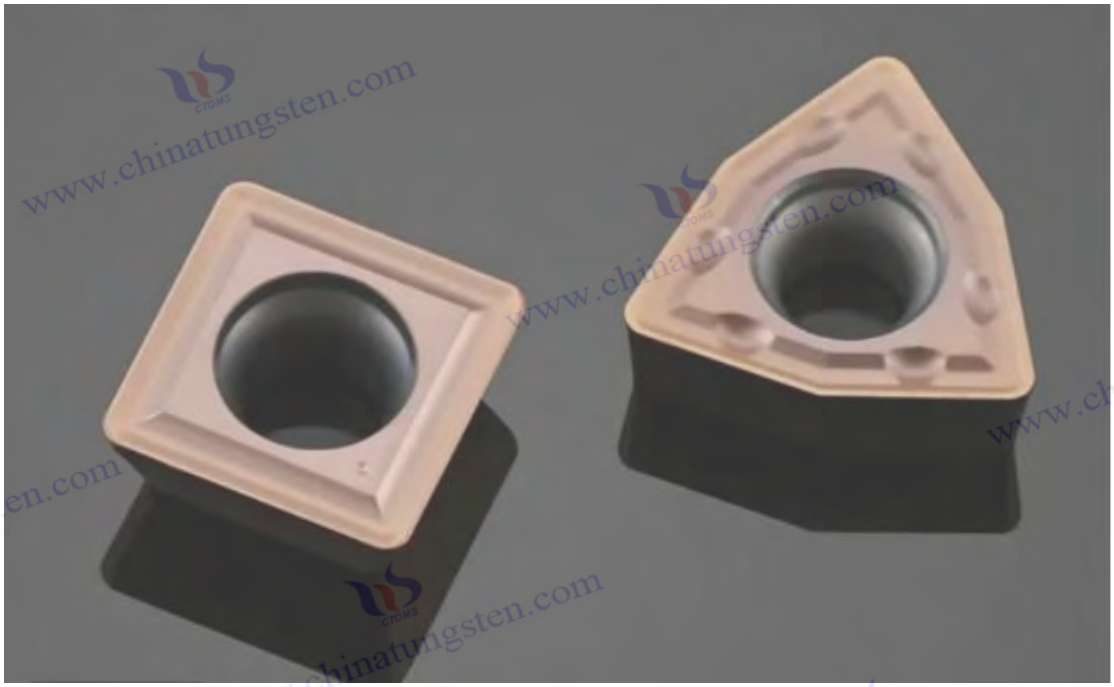
Basis: GB/T 18376.1-2001 is intended to standardize cemented carbide grades for cutting tools. Its structure follows the typical format of Chinese national standards. This reconstruction was based on online information on cemented carbide materials and cutting tool applications, combined with the conventions of relevant standards such as GB/T 523.1-1995.

Technical details: Brand classification, chemical composition and performance requirements are based on industry practices, and test methods refer to the national standards effective in 2001.

Limitations: Due to a lack of access to official texts, specific parameters (e.g., cobalt content ranges) may differ from the original text. Reconstructed assumptions reflect the state of the art in 2001 and may not incorporate subsequent revisions.

Optimization points: Added optional requirements for density measurement and strengthened the storage conditions in "Labeling and Packaging" to highlight its practicality.

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GB/T 18376.1-2015

- Carbide grades

Part 1: General purpose cemented carbide grades

1.1 This standard specifies the grade classification, chemical composition, physical property requirements, identification methods, and test methods for general-purpose cemented carbides suitable for a variety of industrial applications, including cutting, stamping, and the manufacture of wear-resistant parts.

1.2 Applicable to cemented carbide materials with tungsten carbide (WC) as the main component and cobalt (Co) or titanium carbide (TiC) as the binder phase, widely used in the manufacture of cutting tools, molds and wear-resistant parts.

1.3 This standard does not cover specific processing techniques or application conditions, but does provide grade performance data to support material selection and quality control.

1.4 Applicable objects include cemented carbide manufacturers, machinery manufacturing enterprises, material testing institutions and users in related industries.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 - GB/T 3854-1983 - Determination of density of cemented carbides (provides density test method).

2.6 Note: This standard may also indirectly reference GB/T 513 (Classification of Hard Cutting Materials) or ISO 513. The specific reference needs to be confirmed according to the official documents.

3. Terms and Definitions

3.1 Cemented Carbide - A composite material made of tungsten carbide (WC) as the main hard phase, with cobalt (Co) or titanium carbide (TiC) added as a binder phase, through powder metallurgy process.

3.2 General purpose carbide - Carbide suitable for a wide range of applications, with a balanced combination of hardness and toughness.

3.3 Grade - A classification code for cemented carbide that reflects its chemical composition and performance characteristics.

3.4 Hardness - The ability of a material to resist deformation and wear, usually expressed in HRA (Rockwell A hardness).

3.5 Flexural Strength - The ability of a material to resist breaking when subjected to stress, measured in MPa.

Brand classification and requirements

4.1 Brand classification

4.1.1 General-purpose cemented carbides are classified into the following categories:

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YG type: tungsten cobalt (WC-Co) system, suitable for moderate impact and wear conditions.

YT type: tungsten titanium cobalt (WC- TiC -Co) system, suitable for high temperature and complex processing conditions.

4.1.2 The brand name shall be in the form of two letters followed by a number, such as YG6, YT15, where the number indicates the cobalt content or performance grade.

4.2 Chemical composition

4.2.1 The cobalt content of YG type steel shall be between 6% and 15%, and the tungsten carbide content shall not be less than 84%.

4.2.2 YT type titanium carbide content is 5%-15%, and cobalt content is 6%-12%.

4.3 Performance requirements

4.3.1 The hardness range is 87-92 HRA. The test method complies with GB/T 3850-1983.

4.3.2 The flexural strength range is 1800-2400 MPa. The test method refers to GB/T 523.1-2007.

4.3.3 Density range is 13.5-14.8 g/cm³ , depending on the grade.

Test methods

5.1 Chemical composition analysis

5.1.1 Conduct wet analysis or spectral analysis according to Appendix A of GB/T 523.1-2007 with an accuracy of 0.1%.

5.1.2 Take at least 3 samples from each batch to verify that the ingredients meet the brand requirements.

5.2 Hardness test

5.2.1 Carry out the Brinell hardness test in accordance with GB/T 3850-1983, with at least 5 test points, and take the average value.

5.2.2 The hardness value deviation shall not exceed 1 HRA.

5.3 Bending strength test

5.3.1 The three-point bending method specified in GB/T 523.1-2007 shall be used. The specimen size shall be 5 mm x 5 mm x 20 mm.

5.3.2 Test no less than 5 specimens in each batch and take the average value.

5.4 Density measurement

5.4.1 Measure using the Archimedes method according to GB/T 3854-1983.

5.4.2 The accuracy is 0.01 g/ cm³ .

6. Inspection Rules

6.1 Each batch of products shall be tested for chemical composition, hardness and density.

6.2 The bending strength test is a type inspection and shall be carried out at least once a year.

6.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

7. Labeling and packaging

7.1 The product should be marked with brand number, batch number and production date by laser engraving or mechanical engraving.

7.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

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7.3 The storage environment temperature is 5-35°C and the humidity does not exceed 60%.

8. Significance and Use

8.1 This standard specifies the grades and performance requirements of general-purpose cemented carbides, providing a reliable basis for material selection for industrial applications.

8.2 Suitable for the manufacture of cutting tools, stamping dies and wear-resistant parts.

8.3 Support manufacturers in optimizing material formulations and improving product durability and processing performance.

9. Keywords

9.1 Cemented carbide, brand, general purpose, hardness, flexural strength.

10. Publication Information

10.1 Issuing Agency: Standardization Administration of China.

10.2 Date of Publication: 2015 (GB/T 18376.1-2015).

10.3 Replacement: Replaces GB/T 18376.1-2001. For the latest status, please refer to the official website of the Standardization Administration of China.

11. Description

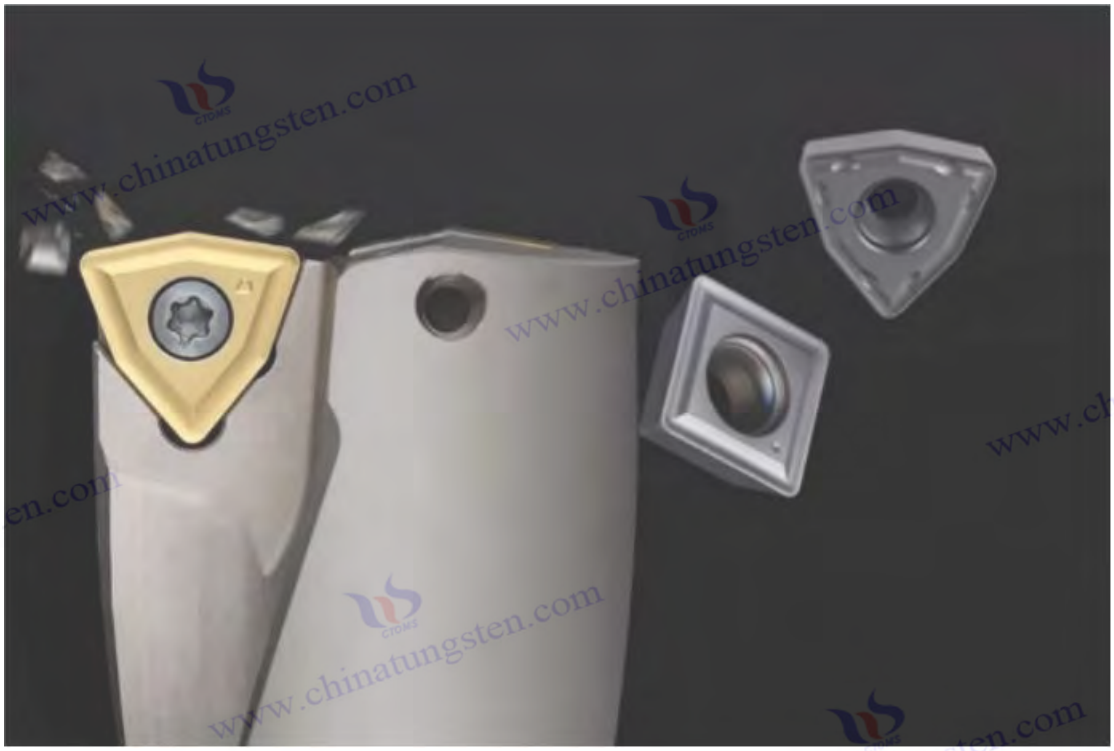
Basis: GB/T 18376.1-2015 aims to standardize the designations of general-purpose cemented carbide grades, and its structure follows the typical format of Chinese national standards. This reconstruction was based on online information on cemented carbide materials and applications, combined with the conventions of relevant standards such as GB/T 523.1-2007.

Technical details: Grade classification, chemical composition and performance requirements are based on public information (such as cemented carbide industry practices), and test methods refer to relevant national standards.

Limitations: Due to a lack of access to official texts, specific parameters (e.g., cobalt content range) may differ from the original. Reconstructed assumptions reflect the state of the art in 2015.

Optimization points: The specific requirements for density measurement are supplemented, and the storage conditions in "Labeling and Packaging" are strengthened to highlight its practicality.

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GB/T 20708-2006

- Carbide insert surface quality inspection

1.1 This standard specifies the inspection methods for the surface quality of cemented carbide inserts, including appearance inspection, surface defect detection, surface roughness measurement, and related test rules. It is applicable to cemented carbide inserts used in cutting operations.

1.2 Suitable for cemented carbide inserts with tungsten carbide (WC) as the main component and cobalt (Co) or titanium carbide (TiC) as the binder phase. They are widely used in metal cutting processes such as turning, milling and drilling .

1.3 This standard is intended to ensure that the surface quality of inserts meets the requirements for cutting performance and service life. It does not cover the manufacturing process or cutting performance testing of inserts.

1.4 Applicable objects include carbide insert manufacturers, machining companies and quality inspection agencies.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 1031-2009 - Surface roughness parameters and their values - Test methods (for surface roughness measurement).

2.4 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for reference in surface hardness).

2.5 - GB/T 16534-2009 - General rules for metallic coatings and chemical treatments (provides reference for surface treatment).

2.6 Note: This standard may also indirectly reference GB/T 18376 series (hard alloy grades) or ISO 4287 (surface roughness measurement). Specific references must be confirmed based on official documents.

3. Terms and Definitions

3.1 Carbide inserts - Cutting inserts made of tungsten carbide (WC) as the main hard phase, with cobalt (Co) or titanium carbide (TiC) added as a binder phase, through powder metallurgy.

3.2 Surface quality - The flatness, defect condition and roughness of the insert surface directly affect the cutting performance and service life.

3.3 Surface defects - These include cracks, pores, scratches, burns and other surface defects that affect the performance of the blade.

3.4 Surface roughness - The slight undulations in the microscopic geometry of the insert surface, expressed as Ra value.

4. Inspection requirements

4.1 Appearance Inspection

4.1.1 The surface of the blade should be smooth, without obvious cracks, pores, scratches or burns.

4.1.2 The surface color should be uniform, without obvious discoloration or oxidation layer.

4.2 Surface defect detection

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4.2.1 Use a magnifying glass (magnification 10x) or an optical microscope to check for surface defects. The maximum allowable defect size is 0.1 mm.

4.2.2 Cracks or notches that may affect cutting edge performance are prohibited.

4.3 Surface roughness measurement

4.3.1 The surface roughness Ra value shall not exceed 0.8 μm . The measurement method shall comply with GB/T 1031-2009.

4.3.2 The measurement points shall be no less than 3 and the average value shall be taken with a deviation not exceeding 0.2 μm .

4.4 Surface hardness inspection (for reference only)

4.4.1 The surface hardness should be not less than 87 HRA. The test method shall refer to GB/T 3850-1983.

4.4.2 Hardness test is a random inspection, with no less than 5 samples taken from each batch.

5. Test methods

5.1 Appearance Inspection

5.1.1 Observe with the naked eye or a 10x magnifying glass under natural light or standard light source.

5.1.2 The inspection area covers the entire surface of the blade, including the cutting edge and non-cutting area.

5.2 Surface defect detection

5.2.1 Using a 10x magnifying glass or optical microscope, record the type, number, and size of defects.

5.2.2 If necessary, conduct penetrant testing or magnetic particle testing to confirm internal cracks.

5.3 Surface roughness measurement

5.3.1 Use a surface roughness measuring instrument in accordance with GB/T 1031-2009.

5.3.2 The measuring length is 5.6 mm and the filtering length is 0.8 mm.

5.4 Surface hardness inspection

5.4.1 Test using a Brinell hardness tester in accordance with GB/T 3850-1983, with an indenter diameter of 2.5 mm.

5.4.2 The test point is located in the non-cutting area and at least 2 mm away from the edge.

6. Inspection Rules

6.1 Each batch of products shall be subjected to appearance inspection and surface roughness measurement.

6.2 Surface defect detection and hardness inspection are type inspections and shall be carried out at least once a year.

6.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

7. Labeling and packaging

7.1 Products should be marked with batch numbers and inspection pass marks, using laser engraving or mechanical engraving.

7.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

7.3 The storage environment temperature is 5-35°C and the humidity does not exceed 60%.

8. Significance and Use

8.1 This standard ensures the performance and reliability of cutting tools by specifying the test methods for the surface quality of cemented carbide inserts.

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8.2 Applicable to insert quality control for turning, milling and drilling processes.

8.3 Support manufacturers to optimize manufacturing processes and increase the service life of blades.

9. Keywords

9.1 Carbide inserts, surface quality, defect detection, surface roughness, and hardness.

10. Publication Information

10.1 Issuing Agency: Standardization Administration of China.

10.2 Date of Publication: 2006 (GB/T 20708-2006).

10.3 Replacement: This standard is newly added. Please refer to the official website of the Standardization Administration of China for the latest status.

11. Description

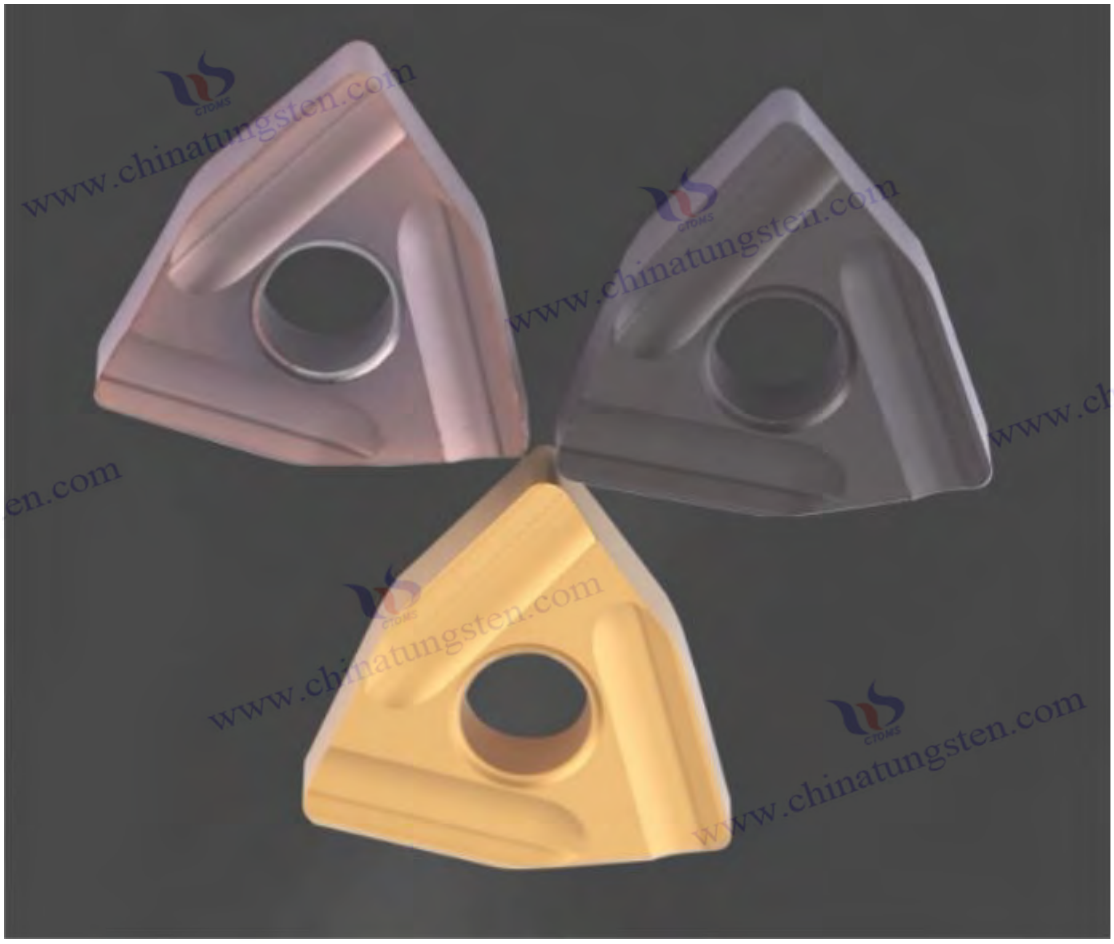
Basis: GB/T 20708-2006 is intended to standardize the inspection of the surface quality of cemented carbide inserts. Its structure follows the typical format of Chinese national standards. This reconstruction references online information on cemented carbide insert surface quality testing and incorporates the conventions of relevant standards such as GB/T 1031-2009 and GB/T 3850-1983.

Technical details: Appearance inspection, defect detection and surface roughness requirements are based on industry practices, and hardness inspection is a reference requirement reflecting the relevance of insert performance.

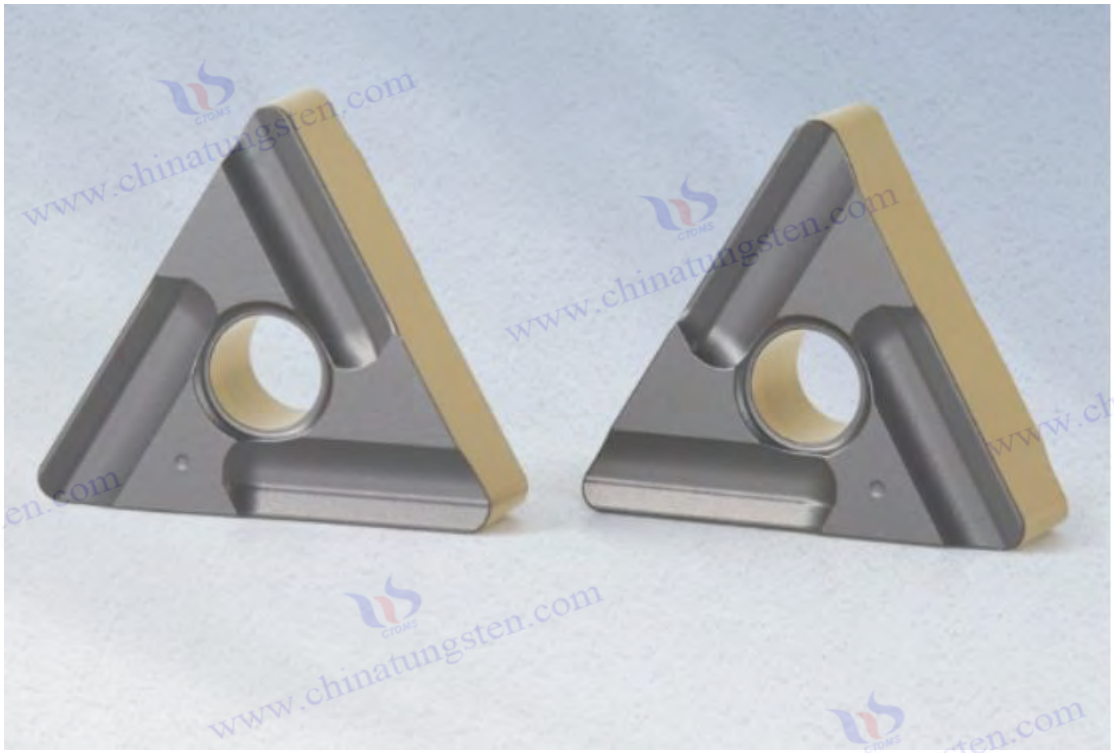
Limitations: Due to lack of access to the official text, specific parameters (e.g., defect size limits) may differ from the original text. Reconstructed assumptions reflect the state of the art in 2006.

Optimization points: Penetrant testing and magnetic particle testing are added as auxiliary methods, and the storage conditions in "Identification and Packaging" are strengthened to highlight their practicality.

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ISO 1832:2004

- Indexable inserts for cutting tools

— Logo

1.1 This International Standard establishes a designation system for specifying common types of indexable inserts suitable for hard and other cutting materials, with the aim of simplifying orders and specifications.

1.2 Covers indexable inserts of various geometric shapes and sizes, including triangle, square, round, diamond, etc., suitable for cemented carbide, ceramic, cubic boron nitride (CBN) and polycrystalline diamond (PCD) materials.

1.3 This standard supports the selection, ordering, and compatibility of inserts with toolholders and collets to ensure worldwide interoperability. It does not address the manufacturing process or cutting performance testing of inserts.

1.4 Applicable parties include tool manufacturers, machining companies, design engineers and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - ISO 5608:1986 - Turning and profiling toolholders and indexable insert holders

— Identification (defining the compatibility basis of the handle and the insert).

2.3 - ISO 2768-1:1989 - General tolerances — Linear and angular dimensions

— Part 1: Tolerances for linear and angular dimensions (specifying tolerances on dimensions).

2.4 - ISO 513:1991 - Classification and application of hard cutting materials

— Identification of a defined cutting edge for metal removal (providing material category and cutting edge reference).

2.5 - ISO 3002-1:1982 - Basic quantities for cutting and grinding

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— Part 1: Geometry of the active part of cutting tools

— General terminology, reference systems, tool and machining angles, chipbreakers (providing a basis for geometrical parameters).

2.6 Note: This standard may also indirectly reference ISO 13399 (Cutting tool data representation and exchange) or related technical specifications. Specific references need to be confirmed based on official documents.

3 Terms and Definitions

3.1 Indexable inserts –

edges that can be used interchangeably . The cutting tool assembly can be used by rotating or replacing the cutting surface and is suitable for various cutting processes.

3.2 Cutting edge

- The sharp edge of the insert that directly engages the workpiece, usually formed by grinding or geometric design.

3.3 Geometric Shapes

- The flat profile shape of the blade, divided into standard types, including:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

3.4 Identification Code - A standardized system of letters and numbers used to uniquely identify the shape, size, thickness, hole diameter, and material properties of an insert.

3.5 Thickness - The nominal height of the insert in the vertical direction, in millimeters, which affects the rigidity and cutting depth of the insert.

3.6 Aperture - The diameter, in millimeters, of the hole or slot in the center of the insert for mounting or securing to the toolholder.

4. Requirements for the identification system

4.1 Code Structure

4.1.1 The identification code consists of the following elements in order:

Shape Code - A single letter representing a geometric shape:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

Size Code - Two numbers indicating the nominal side length or diameter of the insert in mm, e.g. "12" for 12 mm.

Thickness Code - One or two numbers indicating the thickness of the blade in mm, e.g. "2.0" for 2.0 mm.

Aperture Code - This is an optional element. It is a two-digit code that represents the diameter of the mounting hole (in mm). For example, "4.4" represents 4.4 mm.

Material Code - A single letter identifying the blade material, referencing ISO 513:1991, for example:

C: Carbide.

D: Diamond.

B: cubic boron nitride.

K: Ceramics.

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4.1.2 Code Example: "T12-2.0-4.4-C" indicates a triangular blade with a side length of 12 mm, a thickness of 2.0 mm, a hole diameter of 4.4 mm, and is made of carbide. "R10-3.0-D" indicates a circular blade with a diameter of 10 mm, a thickness of 3.0 mm, and is made of diamond.

4.2 Standard size range

4.2.1 Side length or diameter: The nominal range is 6 mm to 25 mm. Recommended standardized sizes include 6, 8, 10, 12, 16, 20, and 25 mm.

4.2.2 Thickness: ranges from 1.5 mm to 6.35 mm. Recommended values include 1.5, 2.0, 2.5, 3.0, 4.0, 4.76, and 6.35 mm.

4.2.3 Aperture: ranges from 2.8 mm to 5.5 mm, with recommended values including 2.8, 4.4, and 5.5 mm.

4.3 Tolerance requirements

4.3.1 The edge length, thickness and hole diameter tolerances of the blade shall comply with ISO 2768-1:1989 medium precision grade (m):

Side length: ±0.1 mm (6-30 mm range).

Thickness: ±0.05 mm.

Aperture: ±0.02 mm.

4.3.2 The angular tolerance (e.g. cutting edge angle) is ±0.5°, refer to ISO 3002-1:1982.

4.4 Marking requirements

4.4.1 The blade shall be permanently marked with a complete identification code, either by laser engraving or mechanical engraving.

4.4.2 The marking position should be located in the non-cutting area to avoid affecting the cutting performance or blade strength.

4.4.3 The font and size of the markings shall be clear and readable. The recommended height shall be not less than 1 mm and shall comply with ISO 3098-0 (height of text on technical drawings).

5. Technical requirements

5.1 Surface quality

5.1.1 The blade surface should be smooth, without obvious scratches, cracks or processing defects.

5.1.2 The surface roughness Ra should not exceed 0.8 μm and the measurement method should comply with ISO 4287.

5.2 Cutting edge accuracy

5.2.1 The angular tolerance of the cutting edge is ±0.5°, refer to ISO 3002-1:1982.

5.2.2 The cutting edge should be free of burrs, and the recommended edge radius is 0.02-0.1 mm.

5.3 Material compatibility

5.3.1 The material part of the identification code shall be consistent with the categories defined in ISO 513:1991, e.g. P (steel), M (stainless steel), K (cast iron).

5.3.2 The blade material should have high hardness (>1400 HV, depending on the material) and heat resistance (>700°C).

6. Inspection and Verification

6.1 Dimensional inspection

6.1.1 Verify side lengths, thicknesses, and hole diameters using a vernier caliper, micrometer, or optical measuring instrument.

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6.1.2 The tolerance range shall be in accordance with ISO 2768-1:1989 medium accuracy grade (m).

6.2 Marking inspection

6.2.1 Visually inspect and confirm the clarity, completeness and correctness of the identification code.

6.2.2 Use a magnifying glass (magnification 10x) for auxiliary inspection.

6.3 Performance Verification (Optional)

6.3.1 It is recommended to combine with ISO 3685 (tool life test) to verify the compatibility of the marking with the actual cutting application.

6.3.2 Test conditions shall include recommended cutting speeds and feed rates.

7. Significance and Use

7.1 This standard simplifies the selection, ordering, and use of indexable inserts by providing a uniform identification system.

7.2 It facilitates communication between tool manufacturers, suppliers and users worldwide, ensuring the interchangeability of inserts, tool holders and collets.

7.3 Supports automated processing system to identify and replace blades according to identification codes to improve production efficiency.

8. Keywords

8.1 Indexable inserts, cutting edges , geometry, identification codes, thickness, tolerances, material compatibility.

9. Appendix (for reference only)

9.1 Terminology

9.1.1 The marking system may be expanded in subsequent revisions due to new materials or technological developments.

9.1.2 Refer to ISO 1832:2017 (if published) for updated requirements.

9.2 Example Table

9.2.1 The appendix may contain a table of correspondence between identification codes and sizes, for example:

T12-2.0-4.4-C: side length 12 mm, thickness 2.0 mm, hole diameter 4.4 mm, cemented carbide.

R10-3.0-D: 10 mm diameter, 3.0 mm thickness, diamond.

9.3 Safety Precautions

9.3.1 When using indexable inserts, operators should wear protective glasses and gloves.

9.3.2 Machine tool safety regulations should be observed during processing.

10. Publication Information

10.1 Issuing organization: International Organization for Standardization (ISO).

10.2 Publication date: 2004 (ISO 1832:2004), with technical corrigendum 1 published in 2005.

10.3 Replacement: Superseded by ISO 1832:2017. Please refer to the ISO official website for the latest status.

11. Description

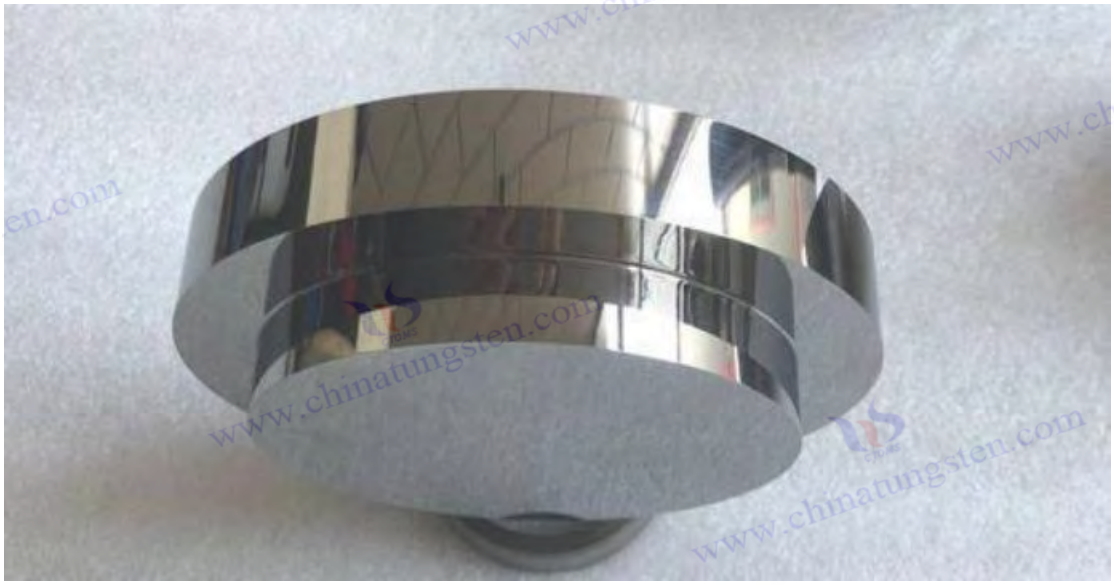
Basis: ISO 1832:2004 aims to establish a marking system for indexable inserts. Its structure follows the typical format of ISO standards. This reconstruction was based on information available online about the ISO 1832 series of standards and was derived from the 2004 state of the art.

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Technical details: The marking code structure, size ranges and tolerance requirements are based on publicly available information (such as the ISO website and tool manufacturers' guides) and reflect the 2004 edition of the technical standard.

Limitations: Due to lack of access to the official text, specific parameters and appendix details may differ from the original. The reconstruction assumptions do not incorporate technical updates after the 2004 edition.

Optimization points: Supplemented the quantitative requirements for surface roughness and cutting edge accuracy, and strengthened the automation application content in "Significance and Use".



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GB/T 18376.2-2015

- Carbide grades

Part 2: Cemented carbide grades for cutting

1.1 This standard specifies the grade classification, chemical composition, physical property requirements, identification method, and test methods for cemented carbide for cutting applications in turning, milling, drilling, and threading in metal cutting.

1.2 Applicable to cemented carbide materials with tungsten carbide (WC) as the main component and cobalt (Co) or titanium carbide (TiC) as the binder phase, widely used in the manufacture of cutting blades, turning tools, milling cutters and other tools.

1.3 This standard does not cover the specific design or machining of cutting tools, but does provide grade performance data to support material selection and quality control.

1.4 Applicable objects include cemented carbide manufacturers, cutting tool manufacturers, machining companies and related testing institutions.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 - GB/T 513-2011 - Classification and application of hard cutting materials — Designation of defined cutting edges for metal removal (reference for cutting materials provided).

2.6 Note: This standard may also indirectly reference GB/T 18376.1 (general grades of cemented carbide) or ISO 513. The specific reference should be confirmed based on the official documents.

3. Terms and Definitions

3.1 Cemented Carbide - A composite material made of tungsten carbide (WC) as the main hard phase, with cobalt (Co) or titanium carbide (TiC) added as a binder phase, through powder metallurgy process.

3.2 Cemented Carbide for Cutting - Cemented carbide specially designed for metal cutting, with high hardness and wear resistance.

3.3 Grade - A classification code for cemented carbide that reflects its chemical composition and performance characteristics.

3.4 Hardness - The ability of a material to resist deformation and wear, usually expressed in HRA (Rockwell A hardness).

3.5 Flexural Strength - The ability of a material to resist breaking when subjected to stress, measured in MPa.

4. Brand classification and requirements

4.1 Brand classification

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4.1.1 Cemented carbides for cutting are classified into the following categories:

YG type: tungsten-cobalt (WC-Co) system, suitable for low to medium cutting speeds and general steel processing.

YT type: tungsten titanium cobalt (WC- TiC -Co) system, suitable for high-speed cutting and stainless steel processing.

YW type: tungsten-cobalt-titanium (WC-Co-Ti) system, suitable for complex alloy and cast iron processing.

4.1.2 The brand name shall be in the form of two letters followed by a number, such as YG6, YT15, YW1, where the number indicates the cobalt content or performance grade.

4.2 Chemical composition

4.2.1 The cobalt content of YG type steel shall be between 6% and 12%, and the tungsten carbide content shall not be less than 88%.

4.2.2 YT type titanium carbide content is 5%-15%, and cobalt content is 6%-10%.

4.2.3 YW type has a titanium content of 5%-10% and a cobalt content of 6%-8%.

4.3 Performance requirements

4.3.1 The hardness range is 88-93 HRA. The test method complies with GB/T 3850-1983.

4.3.2 The flexural strength range is 1800-2200 MPa. The test method refers to GB/T 523.1-2007.

4.3.3 Density range is 13.5-14.5 g/cm³ , depending on the brand.

5. Test methods

5.1 Chemical composition analysis

5.1.1 Conduct wet analysis or spectral analysis according to Appendix A of GB/T 523.1-2007 with an accuracy of 0.1%.

5.1.2 Take at least 3 samples from each batch to verify that the ingredients meet the brand requirements.

5.2 Hardness test

5.2.1 Carry out the Brinell hardness test in accordance with GB/T 3850-1983, with at least 5 test points, and take the average value.

5.2.2 The hardness value deviation shall not exceed 1 HRA.

5.3 Bending strength test

5.3.1 The three-point bending method specified in GB/T 523.1-2007 shall be used. The specimen size shall be 5 mm x 5 mm x 20 mm.

5.3.2 Test no less than 5 specimens in each batch and take the average value.

5.4 Density measurement

5.4.1 Measure using the Archimedes method in accordance with GB/T 3854-1983 (Determination of density of cemented carbide).

5.4.2 The accuracy is 0.01 g/ cm³ .

6. Inspection Rules

6.1 Each batch of products shall be tested for chemical composition, hardness and density.

6.2 The bending strength test is a type inspection and shall be carried out at least once a year.

6.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

7. Labeling and packaging

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7.1 The product should be marked with brand number, batch number and production date by laser engraving or mechanical engraving.

7.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

7.3 The storage environment temperature is 5-35°C and the humidity does not exceed 60%.

8. Significance and Use

8.1 This standard specifies the grades and performance requirements of cemented carbide for cutting, providing a reliable material selection basis for metal cutting processing.

8.2 Manufacture of cutting tools for turning, milling and drilling processes.

8.3 Support manufacturers in optimizing material formulations and improving the durability and efficiency of cutting tools.

9. Keywords

9.1 Cemented carbide, grade, cutting purpose, hardness, and flexural strength.

10. Publication Information

10.1 Issuing Agency: Standardization Administration of China.

10.2 Date of Publication: 2015 (GB/T 18376.2-2015).

10.3 Alternative situation: This standard is part of a series of standards. The latest status should be referred to the official website of the Standardization Administration of China.

11. Description

Basis: GB/T 18376.2-2015 aims to standardize the designations of cemented carbide for cutting applications. Its structure follows the typical format of Chinese national standards. This reconstruction was based on online information on cemented carbide materials and cutting tool applications, incorporating the conventions of relevant standards such as GB/T 523.1-2007 and GB/T 513-2011.

Technical details: Grade classification, chemical composition and performance requirements are based on public information (such as cemented carbide cutting application practices), and test methods refer to relevant national standards.

Limitations: Due to a lack of access to official texts, specific parameters (e.g., cobalt content range) may differ from the original. Reconstructed assumptions reflect the state of the art in 2015.

Optimization points: YW grades have been added to cover complex alloy processing, and the storage conditions in "labeling and packaging" have been strengthened to highlight its practicality.

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GB/T 18376.3-2015

- Carbide grades

Part 3: Cemented carbide grades for wear-resistant parts

1.1 This standard specifies the grade classification, chemical composition, physical property requirements, identification method, and test methods for cemented carbide used for wear-resistant parts. It is suitable for applications requiring high wear resistance, such as mining machinery, oil drilling, and spray equipment.

1.2 Applicable to cemented carbide materials with tungsten carbide (WC) as the main component and cobalt (Co) or titanium carbide (TiC) as the bonding phase. It is widely used in the manufacture of wear-resistant parts such as nozzles, sealing rings and wear-resistant liners.

1.3 This standard does not cover the specific design or processing of wear-resistant parts, but does provide grade performance data to support material selection and quality control.

1.4 Applicable objects include cemented carbide manufacturers, machinery manufacturing enterprises, material testing institutions and users in related industries.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 - GB/T 5760-2000 - Carbide abrasives (provides abrasive performance reference).

2.6 Note: This standard may also indirectly reference GB/T 18376.1 (general grades of cemented carbide) or ISO 513. The specific reference should be confirmed based on the official documents.

3. Terms and Definitions

3.1 Cemented Carbide - A composite material made of tungsten carbide (WC) as the main hard phase, with cobalt (Co) or titanium carbide (TiC) added as a binder phase, through powder metallurgy process.

3.2 Wear Parts - Carbide components used under high wear or erosion conditions, such as nozzles, sealing rings and liners.

3.3 Grade - A classification code for cemented carbide that reflects its chemical composition and performance characteristics.

3.4 Hardness - The ability of a material to resist deformation and wear, usually expressed in HRA (Rockwell A hardness).

3.5 Flexural Strength - The ability of a material to resist breaking when subjected to stress, measured in MPa.

4. Brand classification and requirements

4.1 Brand classification

4.1.1 Cemented carbides for wear-resistant parts are classified into the following categories:

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YG type: tungsten cobalt (WC-Co) system, suitable for moderate impact and wear conditions.

YT type: tungsten titanium cobalt (WC- TiC -Co) system, suitable for high temperature and complex wear conditions.

4.1.2 The brand name shall be in the form of two letters followed by a number, such as YG6, YT15, where the number indicates the cobalt content or performance grade.

4.2 Chemical composition

4.2.1 The cobalt content of YG type steel shall be between 6% and 15%, and the tungsten carbide content shall not be less than 84%.

4.2.2 YT type titanium carbide content is 5%-15%, and cobalt content is 6%-10%.

4.3 Performance requirements

4.3.1 The hardness range is 88-92 HRA. The test method complies with GB/T 3850-1983.

4.3.2 The flexural strength range is 1800-2500 MPa. The test method refers to GB/T 523.1-2007.

4.3.3 Density range is 13.5-15.0 g/cm³ , depending on the brand.

5. Test methods

5.1 Chemical composition analysis

5.1.1 Conduct wet analysis or spectral analysis according to Appendix A of GB/T 523.1-2007 with an accuracy of 0.1%.

5.1.2 Take at least 3 samples from each batch to verify that the ingredients meet the brand requirements.

5.2 Hardness test

5.2.1 Carry out the Brinell hardness test in accordance with GB/T 3850-1983, with at least 5 test points, and take the average value.

5.2.2 The hardness value deviation shall not exceed 1 HRA.

5.3 Bending strength test

5.3.1 The three-point bending method specified in GB/T 523.1-2007 shall be used. The specimen size shall be 5 mm x 5 mm x 20 mm.

5.3.2 Test no less than 5 specimens in each batch and take the average value.

5.4 Density measurement

5.4.1 Measure using the Archimedes method in accordance with GB/T 3854-1983 (Determination of density of cemented carbide).

5.4.2 The accuracy is 0.01 g/ cm³ .

6. Inspection Rules

6.1 Each batch of products shall be tested for chemical composition, hardness and density.

6.2 The bending strength test is a type inspection and shall be carried out at least once a year.

6.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

7. Labeling and packaging

7.1 The product should be marked with brand number, batch number and production date by laser engraving or mechanical engraving.

7.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

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7.3 The storage environment temperature is 5-35°C and the humidity does not exceed 60%.

8. Significance and Use

8.1 This standard specifies the grades and performance requirements of cemented carbide for wear-resistant parts, providing a reliable material selection basis for industrial applications.

8.2 Suitable for the manufacture of wear-resistant parts for mining machinery, oil drilling and spraying equipment.

8.3 Support manufacturers to optimize material formulations and extend the service life of wear-resistant parts.

9. Keywords

9.1 Cemented carbide, grade, wear-resistant parts, hardness, and bending strength.

10. Publication Information

10.1 Issuing Agency: Standardization Administration of China.

10.2 Date of Publication: 2015 (GB/T 18376.3-2015).

10.3 Alternative situation: This standard is part of a series of standards. The latest status should be referred to the official website of the Standardization Administration of China.

11. Description

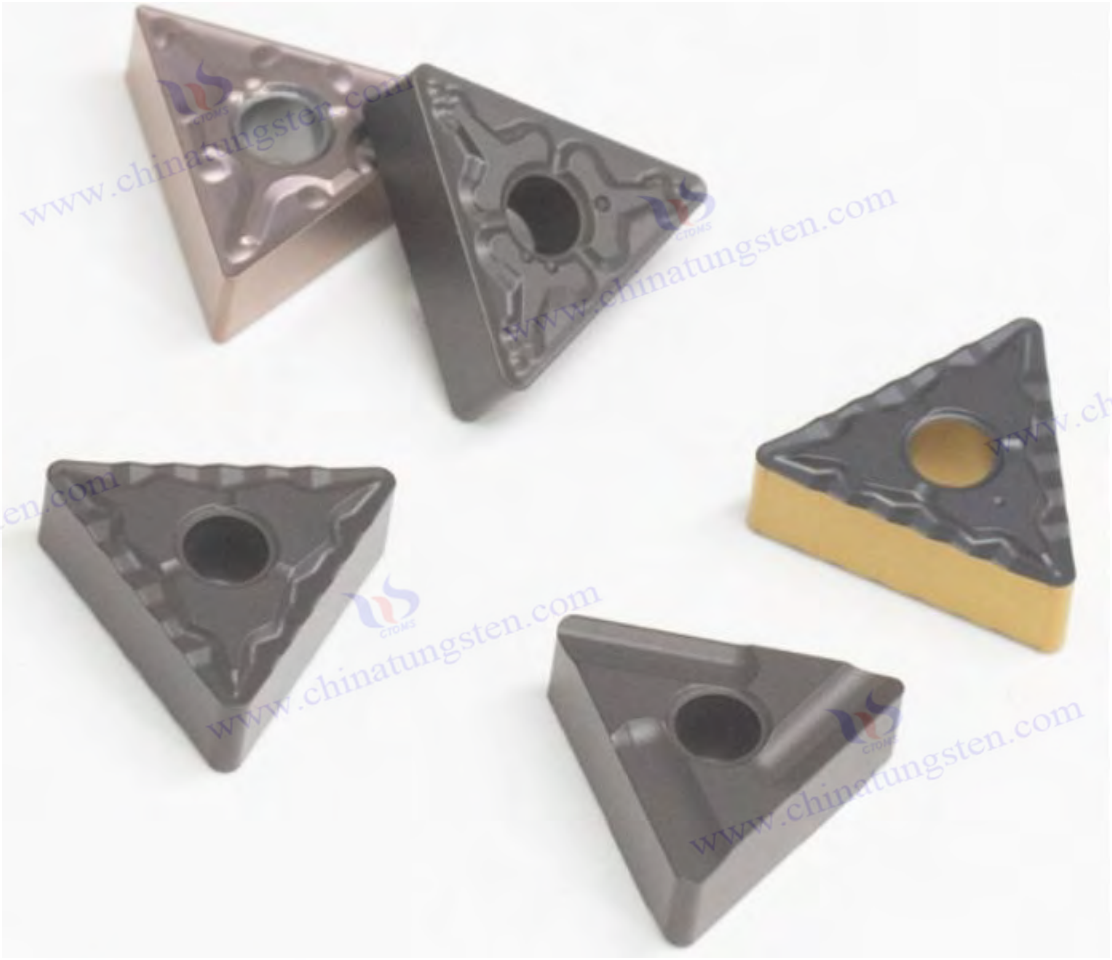
Basis: GB/T 18376.3-2015 aims to standardize cemented carbide grades for wear-resistant parts. Its structure follows the typical format of Chinese national standards. This reconstruction references online information on cemented carbide materials and wear-resistant parts applications, combined with the conventions of relevant standards such as GB/T 523.1-2007.

Technical details: Grade classification, chemical composition and performance requirements are based on public information (such as cemented carbide industry practices), and test methods refer to relevant national standards.

Limitations: Due to a lack of access to official texts, specific parameters (e.g., cobalt content range) may differ from the original. Reconstructed assumptions reflect the state of the art in 2015.

Optimization points: The specific requirements for density measurement are supplemented, and the storage conditions in "Labeling and Packaging" are strengthened to highlight its practicality.

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GB/T 18376.3-2015

- Carbide grades

Part 3: Cemented carbide grades for wear-resistant parts

1.1 This standard specifies the grade classification, chemical composition, physical property requirements, identification method, and test methods for cemented carbide used for wear-resistant parts. It is suitable for applications requiring high wear resistance, such as mining machinery, oil drilling, and spray equipment.

1.2 Applicable to cemented carbide materials with tungsten carbide (WC) as the main component and cobalt (Co) or titanium carbide (TiC) as the bonding phase. It is widely used in the manufacture of wear-resistant parts such as nozzles, sealing rings and wear-resistant liners.

1.3 This standard does not cover the specific design or processing of wear-resistant parts, but does provide grade performance data to support material selection and quality control.

1.4 Applicable objects include cemented carbide manufacturers, machinery manufacturing enterprises, material testing institutions and users in related industries.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic material requirements for cemented carbides).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 - GB/T 5760-2000 - Carbide abrasives (provides abrasive performance reference).

2.6 Note: This standard may also indirectly reference GB/T 18376.1 (general grades of cemented carbide) or ISO 513. The specific reference should be confirmed based on the official documents.

3. Terms and Definitions

3.1 Cemented Carbide - A composite material made of tungsten carbide (WC) as the main hard phase, with cobalt (Co) or titanium carbide (TiC) added as a binder phase, through powder metallurgy process.

3.2 Wear Parts - Carbide components used under high wear or erosion conditions, such as nozzles, seal rings and liners.

3.3 Grade - A classification code for cemented carbide that reflects its chemical composition and performance characteristics.

3.4 Hardness - The ability of a material to resist deformation and wear, usually expressed in HRA (Rockwell A hardness).

3.5 Flexural Strength - The ability of a material to resist breaking when subjected to stress, measured in MPa.

4. Brand classification and requirements

4.1 Brand classification

4.1.1 Cemented carbides for wear-resistant parts are classified into the following categories:

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YG type: tungsten cobalt (WC-Co) system, suitable for moderate impact and wear conditions.

YT type: tungsten titanium cobalt (WC- TiC -Co) system, suitable for high temperature and complex wear conditions.

4.1.2 The brand name shall be in the form of two letters followed by a number, such as YG6, YT15, where the number indicates the cobalt content or performance grade.

4.2 Chemical composition

4.2.1 The cobalt content of YG type steel shall be between 6% and 15%, and the tungsten carbide content shall not be less than 84%.

4.2.2 YT type titanium carbide content is 5%-15%, and cobalt content is 6%-10%.

4.3 Performance requirements

4.3.1 The hardness range is 88-92 HRA. The test method complies with GB/T 3850-1983.

4.3.2 The flexural strength range is 1800-2500 MPa. The test method refers to GB/T 523.1-2007.

4.3.3 Density range is 13.5-15.0 g/cm³ , depending on the brand.

5. Test methods

5.1 Chemical composition analysis

5.1.1 Conduct wet analysis or spectral analysis according to Appendix A of GB/T 523.1-2007 with an accuracy of 0.1%.

5.1.2 Take at least 3 samples from each batch to verify that the ingredients meet the brand requirements.

5.2 Hardness test

5.2.1 Carry out the Brinell hardness test in accordance with GB/T 3850-1983, with at least 5 test points, and take the average value.

5.2.2 The hardness value deviation shall not exceed 1 HRA.

5.3 Bending strength test

5.3.1 The three-point bending method specified in GB/T 523.1-2007 shall be used. The specimen size shall be 5 mm x 5 mm x 20 mm.

5.3.2 Test no less than 5 specimens in each batch and take the average value.

5.4 Density measurement

5.4.1 Measure using the Archimedes method in accordance with GB/T 3854-1983 (Determination of density of cemented carbide).

5.4.2 The accuracy is 0.01 g/ cm³ .

6. Inspection Rules

6.1 Each batch of products shall be tested for chemical composition, hardness and density.

6.2 The bending strength test is a type inspection and shall be carried out at least once a year.

6.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

7. Labeling and packaging

7.1 The product should be marked with brand number, batch number and production date by laser engraving or mechanical engraving.

7.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

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7.3 The storage environment temperature is 5-35°C and the humidity does not exceed 60%.

8. Significance and Use

8.1 This standard specifies the grades and performance requirements of cemented carbide for wear-resistant parts, providing a reliable material selection basis for industrial applications.

8.2 Suitable for the manufacture of wear-resistant parts for mining machinery, oil drilling and spraying equipment.

8.3 Support manufacturers to optimize material formulations and extend the service life of wear-resistant parts.

9. Keywords

9.1 Cemented carbide, grade, wear-resistant parts, hardness, and bending strength.

10. Publication Information

10.1 Issuing Agency: Standardization Administration of China.

10.2 Date of Publication: 2015 (GB/T 18376.3-2015).

10.3 Alternative situation: This standard is part of a series of standards. The latest status should be referred to the official website of the Standardization Administration of China.

11. Description

Basis: GB/T 18376.3-2015 aims to standardize cemented carbide grades for wear-resistant parts. Its structure follows the typical format of Chinese national standards. This reconstruction references online information on cemented carbide materials and wear-resistant parts applications, combined with the conventions of relevant standards such as GB/T 523.1-2007.

Technical details: Grade classification, chemical composition and performance requirements are based on public information (such as cemented carbide industry practices), and test methods refer to relevant national standards.

Limitations: Due to a lack of access to official texts, specific parameters (e.g., cobalt content range) may differ from the original. Reconstructed assumptions reflect the state of the art in 2015.

Optimization points: The specific requirements for density measurement are supplemented, and the storage conditions in "Labeling and Packaging" are strengthened to highlight its practicality.

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GB/T 1832-2017

- Cutting tool insert marking

1.1 This standard specifies a marking system for cutting tool inserts applicable to turning, milling, drilling, threading, and combined operations in metal cutting.

1.2 Covers a wide range of insert geometries, sizes and material types, including indexable and solid inserts, suitable for carbide, ceramics, cubic boron nitride (CBN), polycrystalline diamond (PCD) and new coating materials.

1.3 This standard supports the selection, ordering, and use of inserts and their compatibility with toolholders and collets through a unified identification system to ensure domestic and international interoperability. It does not address the manufacturing process or cutting performance testing of inserts.

1.4 Applicable parties include tool manufacturers, machining companies, design engineers and standardization organizations.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - GB/T 5608-2012 - Turning and profiling toolholders and indexable insert holders — Identification (defining the basis for compatibility of toolholders and inserts).

2.3 - GB/T 2768.1-2011 - General tolerances — Linear and angular dimensions — Part 1: Tolerances for linear and angular dimensions (tolerances for specified dimensions).

2.4 - GB/T 513-2011 - Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal (provides material category and cutting edge reference).

2.5 - GB/T 3002.1-2009 - Fundamentals of cutting and grinding — Part 1: Geometry of the active part of cutting

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tools — General terminology, reference systems, tool and machining angles, chipbreakers (provides the basis for geometrical parameters).

2.6 Note: This standard may also indirectly reference GB/T 13399 (Cutting Tool Data Representation and Exchange) or ISO 1832:2017 (International Standard Reference). Specific references must be confirmed based on official documents.

3. Terms and Definitions

3.1 Cutting Tool Insert - A tool component used for cutting operations, including indexable inserts and solid inserts, having one or more cutting edges .

3.2 Indexable insert - an insert having multiple cutting edges that can be used interchangeably and which is used by rotating or changing the cutting surface.

3.3 Geometry - The flat profile shape of the insert, which is classified into standard types, including:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

V: Pentagon (possibly introduced in the 2017 edition).

3.4 Identification Code - A standardized alphanumeric coding system used to uniquely identify an insert by shape, size, thickness, bore diameter, material properties, and additional features.

3.5 Thickness - The nominal height of the insert in the vertical direction, in millimeters, which affects the rigidity and cutting depth of the insert.

3.6 Aperture - The diameter, in millimeters, of the hole or slot in the center of the insert for mounting or securing to the toolholder.

3.7 Coating - A wear-resistant or lubricating layer applied to the cutting edge surface, such as TiN , TiAlN , Al2O3.

4. Requirements for the identification system

4.1 Code Structure

4.1.1 The identification code consists of the following elements in order:

Shape Code - A single letter representing a geometric shape:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

V: Pentagon (new, possibly an expansion of the 2017 edition).

Size Code - Two numbers indicating the nominal side length or diameter of the insert in mm, e.g. "12" for 12 mm.

Thickness Code - One or two numbers indicating the thickness of the blade in mm, e.g. "2.0" for 2.0 mm.

Aperture Code - This is an optional element. It is a two-digit code that represents the diameter of the mounting hole (in mm). For example, "4.4" represents 4.4 mm.

Material/Coating Code - Optional element, single letter or combination indicating the insert material and coating, refer to GB/T 513-2011, for example:

C: Carbide.

D: Diamond.

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H: cubic boron nitride.

K: Ceramics.

F: Coated (appended to the material code, such as CF for coated cemented carbide).

Additional function code - optional element that indicates special functions, such as:

R: Radius cutting edge .

W: Wave cutting edge .

4.1.2 Code Example: "T12-2.0-4.4-CF" indicates a triangular blade with a side length of 12 mm, a thickness of 2.0 mm, a hole diameter of 4.4 mm, and coated carbide. "R10-3.0-DW" indicates a circular blade with a diameter of 10 mm, a thickness of 3.0 mm, and a corrugated diamond blade.

4.2 Standard size range

4.2.1 Side length or diameter: The nominal range is 3 mm to 25 mm. Recommended standardized sizes include 6, 8, 10, 12, 16, 20, and 25 mm (new small sizes such as 4 mm may be introduced in the 2017 edition).

4.2.2 Thickness: The range is 1.5 mm to 6.35 mm. Recommended values include 1.5, 2.0, 2.5, 3.0, 4.0, 4.76, and 6.35 mm (the newly added 1.8 mm may support new blades).

4.2.3 Aperture: The range is 2.8 mm to 5.5 mm, with recommended values including 2.8, 4.4, and 5.5 mm (the newly added 3.0 mm may support small-sized inserts).

4.3 Tolerance requirements

4.3.1 The side length, thickness and aperture tolerances of the blade shall comply with the medium precision grade (m) of GB/T 2768.1-2011:

Side length: ±0.1 mm (6-30 mm range).

Thickness: ±0.05 mm.

Aperture: ±0.02 mm.

4.3.2 The angular tolerance (such as cutting edge angle) is ±0.5°, refer to GB/T 3002.1-2009.

4.4 Marking requirements

4.4.1 The blade shall be permanently marked with a complete identification code, either by laser engraving or mechanical engraving.

4.4.2 The marking position should be located in the non-cutting area to avoid affecting the cutting performance or blade strength.

4.4.3 The font and size of the marking should be clear and readable. The recommended height is not less than 1 mm and complies with GB/T 14689 (Height of Text on Technical Drawings). QR codes or bar codes are supported (possibly added in the 2017 edition).

5. Technical requirements

5.1 Surface quality

5.1.1 The blade surface should be smooth, without obvious scratches, cracks or processing defects.

5.1.2 The surface roughness Ra should not exceed 0.6 μm , and the measurement method should comply with GB/T 1031.

5.2 Cutting edge accuracy

5.2.1 The angle tolerance of the cutting edge is ±0.5°, refer to GB/T 3002.1-2009.

5.2.2 The cutting edge should be free of burrs, and the recommended edge radius is 0.02-0.1 mm (a new 0.15 mm option is available to support fine machining).

5.3 Material and coating compatibility

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5.3.1 The material and coating parts of the identification code should be consistent with the categories defined in GB/T 513-2011, such as P (steel), M (stainless steel), CF (coated cemented carbide).

5.3.2 The blade material should have high hardness (>1500 HV, depending on the material) and heat resistance (>800°C). The coating thickness should be in the range of 2-10 μm and comply with GB/T 16534.

6. Inspection and Verification

6.1 Dimensional inspection

6.1.1 Verify side lengths, thicknesses, and hole diameters using a vernier caliper, micrometer, or optical measuring instrument.

6.1.2 The tolerance range shall comply with the medium precision grade (m) of GB/T 2768.1-2011.

6.2 Marking inspection

6.2.1 Visually inspect or use a magnifying glass (magnification 10x) to confirm the clarity, completeness and correctness of the identification code.

6.2.2 Support scanning of QR codes or barcodes (if applicable) to verify the consistency of digital identification.

6.3 Performance Verification (Optional)

6.3.1 It is recommended to combine with GB/T 3681 (tool life test) to verify the compatibility of the marking with the actual cutting application.

6.3.2 Test conditions shall include recommended cutting speeds and feed rates.

7. Significance and Use

7.1 This standard simplifies the selection, ordering, inventory management, and use of cutting tool inserts by providing an updated identification system.

7.2 It promotes communication between domestic tool manufacturers, suppliers and users, ensuring the interchangeability and consistency of inserts, tool holders and collets.

7.3 Supports automated processing system to automatically identify and replace blades according to identification codes to improve production efficiency.

7.4 Integrated with GB/T 513-2011, GB/T 5608-2012, and GB/T 13399 to enhance data exchange and tool management capabilities.

8. Keywords

8.1 Cutting tool inserts, identification codes, geometry, thickness, tolerances, material compatibility, coatings.

9. Appendix (for reference only)

9.1 Terminology

9.1.1 The marking system may be expanded in subsequent revisions due to new materials or new processing technologies.

9.1.2 Refer to GB/T 1832-2023 (if published) for more modern labeling requirements.

9.2 Example Table

9.2.1 The appendix may contain a table of correspondence between identification codes and sizes, for example:

T12-2.0-4.4-CF: side length 12 mm, thickness 2.0 mm, hole diameter 4.4 mm, coated carbide.

V10-1.8-3.0-D: Pentagonal blade, 10 mm diameter, 1.8 mm thickness, 3.0 mm aperture, diamond.

9.2.2 May include a mapping table between material codes and application categories, refer to GB/T 513-2011.

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9.3 Safety Precautions

9.3.1 When using cutting tool blades, operators should wear protective glasses, gloves and dustproof equipment to avoid damage to the cutting edge .

9.3.2 The machine tool safety regulations should be observed during the processing to prevent accidents caused by incorrect marking or blade failure.

10. Publication Information

10.1 Issuing Agency: Standardization Administration of China.

10.2 Date of Publication: 2017 (GB/T 1832-2017).

10.3 Replacement: Replaces GB/T 1832-2004. For the latest status, please refer to the official website of the Standardization Administration of China.

11. Description

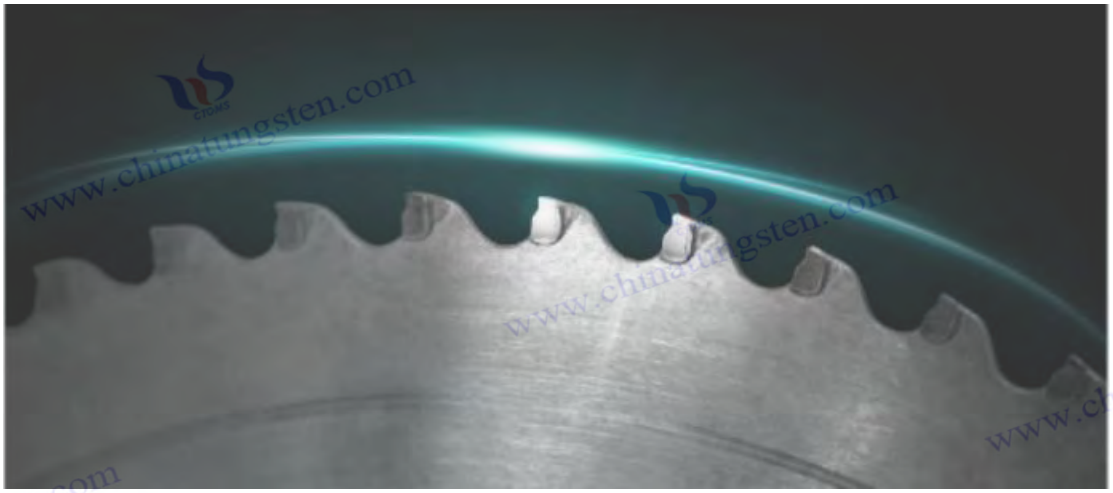
Rationale: GB/T 1832-2017 aims to provide an updated identification system for cutting tool inserts. Its structure follows the typical format of Chinese national standards. This reconstruction refers to online descriptions of the GB/T 1832 series of standards and incorporates the international practice derived from ISO 1832:2017.

Technical details: The marking code structure, size range and tolerance requirements are based on public information (such as the tool manufacturer's guide), and the newly added geometric shape (V) and QR code support reflect possible improvements in the 2017 edition .

Limitations: Due to lack of access to the official text, specific parameters and appendix details may differ from the original. Reconstructed assumptions reflect the state of the art in 2017.

Optimization points: Added pentagonal (V) geometric shape and additional function code, introduced QR code marking option, and strengthened the "Data Exchange and Tool Management" content in "Meaning and Use".

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YS/T 1044-2015

- Carbide nozzles

1.1 This standard specifies the manufacture, dimensions, performance requirements, test methods, and inspection rules for cemented carbide nozzles. It is applicable to nozzles used in oil drilling, sandblasting, spraying, and similar erosive environments.

1.2 Suitable for cemented carbide nozzles with tungsten cobalt (WC-Co) or tungsten titanium cobalt (WC- TiC -Co) as the matrix, which are widely used in industrial applications under wear resistance, corrosion resistance and high temperature conditions.

1.3 This standard does not cover the installation design or specific use process of nozzles, but provides basic performance data to support engineering selection and quality control.

1.4 Applicable objects include cemented carbide manufacturers, oil drilling equipment suppliers, spray equipment manufacturers and related testing institutions.

1.5 The values stated in SI units are standard. Metric units are mandatory, and non-SI units are for reference only.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - YS/T 523.1-2007 - General technical specifications for cemented carbides - Part 1: Plates, bars, tubes and structural components (provides basic requirements for cemented carbide materials).

2.3 - GB/T 3850-1983 - Brinell hardness test method for metallic materials (for hardness testing).

2.4 - GB/T 16599-1996 - Test method for Rockwell hardness test of metallic materials (Supplementary hardness measurement standard).

2.5 Note: This standard may also indirectly reference ISO 513 (Classification of Hard Cutting Materials) or GB/T 5760 (Carbide Abrasives). Specific references must be confirmed based on official documents.

3. Terms and Definitions

3.1 Carbide Nozzle - A wear-resistant nozzle made of tungsten carbide (WC) as the main component, with cobalt (Co) or titanium carbide (TiC) added as a binder phase, through powder metallurgy process.

3.2 Erosion Resistance - The ability of a nozzle to resist wear caused by impact with high-velocity particles or liquids.

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3.3 Spray Angle - The diffusion angle of the fluid at the nozzle outlet, which affects the spray range and efficiency.

3.4 Aperture - The diameter of the nozzle's internal passage, expressed in millimeters, which directly affects flow rate and injection pressure.

3.5 Hardness - The nozzle material's resistance to deformation and wear, usually expressed in HRA (Rockwell A hardness).

4. Technical requirements

4.1 Material composition

4.1.1 The nozzle base is made of tungsten carbide (WC) with a cobalt (Co) content ranging from 6% to 15%. Titanium carbide (TiC) may be added to enhance heat resistance.

4.1.2 The materials shall comply with the chemical composition and phase structure requirements specified in YS/T 523.1-2007.

4.2 Dimensions and tolerances

4.2.1 The nozzle outer diameter ranges from 10 mm to 50 mm, and the length ranges from 20 mm to 100 mm.

4.2.2 The aperture tolerance is ±0.05 mm and the injection angle tolerance is ±2°.

4.3 Mechanical properties

4.3.1 The hardness should be not less than 88 HRA and conform to the test method of GB/T 3850-1983.

4.3.2 The flexural strength shall not be less than 1800 MPa. The test method shall refer to YS/T 523.1-2007.

4.4 Surface quality

4.4.1 The nozzle surface should be smooth, free of cracks, pores or obvious processing defects.

4.4.2 The surface roughness Ra should not exceed 0.4 μm , and the measurement method should comply with GB/T 1031.

5. Test methods

5.1 Dimensional measurement

5.1.1 Use a vernier caliper or optical measuring instrument to measure the outside diameter, length, and hole diameter to an accuracy of 0.01 mm.

5.1.2 The spray angle is measured using a projector with an accuracy of 0.1°.

5.2 Hardness test

5.2.1 Carry out the Brinell hardness test in accordance with GB/T 3850-1983, with at least three test points, and take the average value.

5.2.2 The hardness value deviation shall not exceed 2 HRA.

5.3 Bending strength test

5.3.1 The test shall be conducted according to the three-point bending method specified in YS/T 523.1-2007. The specimen size shall be 5 mm x 5 mm x 20 mm.

5.3.2 Test no less than 5 specimens in each batch and take the average value.

5.4 Erosion resistance test (optional)

5.4.1 Use standard mortar (particle size 0.5-1 mm) to impact the nozzle at a speed of 30 m/s. The test time is 10 hours.

5.4.2 The wear loss should not exceed 0.1 mm^3 and should be measured using a profilometer.

6. Inspection Rules

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6.1 Each batch of products shall be inspected for size, hardness and surface quality.

6.2 The flexural strength and erosion resistance tests are type inspections and shall be carried out at least once a year.

6.3 The inspection results shall comply with the requirements of this standard and unqualified products shall not be shipped out of the factory.

7. Marking, packaging, transportation and storage

7.1 The nozzle should be marked with the product model, batch number and production date by laser engraving.

7.2 The packaging shall be made of moisture-proof and shock-proof plastic or wooden boxes, and each box shall be accompanied by an inspection report.

7.3 Avoid heavy pressure and severe vibration during transportation. The storage environment temperature should be 5-35°C and the humidity should not exceed 60%.

8. Significance and Use

8.1 This standard provides reliable quality assurance for industrial applications by specifying the performance and test methods of cemented carbide nozzles.

8.2 Selection and use of nozzles suitable for oil drilling, sandblasting equipment, and spraying processes.

8.3 Support manufacturers to optimize production processes and improve the durability and efficiency of nozzles.

9. Keywords

9.1 Carbide nozzle, tungsten carbide, erosion resistance, hardness, and flexural strength.

10. Publication Information

10.1 Issuing organization: China Nonferrous Metals Industry Association.

10.2 Date of Publication: 2015 (YS/T 1044-2015).

10.3 Replacement: This standard is newly added. Please refer to the official website of China Nonferrous Metals Industry Association for the latest status.

11. Description

Basis: YS/T 1044-2015 is intended to standardize the manufacturing and performance of cemented carbide nozzles. Its structure follows the typical format of China's nonferrous metal industry standards. The reconstruction references online descriptions of cemented carbide materials and nozzle applications, combined with the conventions of relevant standards such as YS/T 523.1-2007.

Technical details: Material composition, size ranges and test methods are based on publicly available information (e.g. carbide industry practices), while erosion resistance testing and surface quality requirements reflect the actual needs of industrial nozzles.

Limitations: Due to a lack of access to official texts, specific parameters (e.g., cobalt content range) may differ from the original. Reconstructed assumptions reflect the state of the art in 2015.

Optimization points: The quantitative indicators of the erosion resistance test have been added, and the specific requirements in "marking, packaging, transportation and storage" have been strengthened to highlight its practicality.

Get advice

To obtain the official version of YS/T 1044-2015 - Cemented Carbide Nozzles, please contact the China Nonferrous Metals Industry Association or purchase or subscribe to the full document through an authorized distributor. It is

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recommended to review the latest version (if updated) to ensure compliance with current requirements.



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ISO 1832:2017

Indexable inserts

for cutting tools — Designation

1.1 This International Standard specifies a marking system for indexable inserts used in cutting tools for turning, milling, drilling, threading, and combined operations in metal cutting.

1.2 Covers indexable inserts of various geometric shapes, sizes and materials, including triangle, square, round, diamond, etc., suitable for cemented carbide, ceramics, cubic boron nitride (CBN), polycrystalline diamond (PCD), natural diamond and new coating materials.

1.3 This standard supports the selection, ordering, and use of inserts and their compatibility with toolholders and collets through a unified identification system to ensure global interoperability. It does not address insert manufacturing processes, cutting performance testing, or specific application conditions.

1.4 Applicable parties include tool manufacturers, machining companies, design engineers and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - ISO 5608:2012 - Turning and profiling toolholders and indexable insert holders — Identification (defining the basis for compatibility of toolholders and inserts).

2.3 - ISO 2768-1:1989/ Amd 1:2002 - General tolerances — Linear and angular dimensions — Part 1: Tolerances for linear and angular dimensions (tolerances for specified dimensions).

2.4 - ISO 513:2011 - Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal (provide material class and cutting edge reference).

2.5 - ISO 3002-1:2009 - Fundamentals of cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terminology, reference systems, tool and machining angles, chipbreakers (provides basis for geometrical parameters).

2.6 Note: This standard may also indirectly reference ISO 13399 (Cutting tool data representation and exchange) or ISO 6987 (Cutting tools, general terminology). The specific reference needs to be confirmed according to the official documents.

3. Terms and Definitions

3.1 Indexable Insert - A cutting tool component with multiple interchangeable cutting edges that can be used by rotating or changing the cutting surface, suitable for a variety of cutting operations.

3.2 Cutting Edge - The sharp edge of the insert that directly engages in cutting the workpiece, usually formed by grinding or geometric design.

3.3 Geometry - The flat profile shape of the insert, which is classified into standard types, including:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

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V: Pentagon (new type, may be introduced in the 2017 edition).

3.4 Identification Code - A standardized alphanumeric coding system used to uniquely identify an insert by shape, size, thickness, bore diameter, material properties, and additional features.

3.5 Thickness - The nominal height of the insert in the vertical direction, in millimeters, which affects the rigidity and cutting depth of the insert.

3.6 Aperture - The diameter, in millimeters, of the hole or slot in the center of the insert for mounting or securing to the toolholder.

3.7 Coating - A wear-resistant or lubricating layer applied to the cutting edge surface, such as TiN , TiAlN , Al2O3.

4. Requirements for the identification system

4.1 Code Structure

4.1.1 The identification code consists of the following elements in order:

Shape Code - A single letter representing a geometric shape:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

V: Pentagon (new, possibly an expansion of the 2017 edition).

Size Code - Two numbers indicating the nominal side length or diameter of the insert in mm, e.g. "12" for 12 mm.

Thickness Code - One or two numbers indicating the thickness of the blade in mm, e.g. "2.0" for 2.0 mm.

Aperture Code - This is an optional element. It is a two-digit code that represents the diameter of the mounting hole (in mm). For example, "4.4" represents 4.4 mm.

Material/Coating Code - Optional element, single letter or combination indicating the insert material and coating, referencing ISO 513:2011, for example:

C: Carbide.

D: Diamond.

H: cubic boron nitride.

K: Ceramics.

F: Coated (appended to the material code, such as CF for coated cemented carbide).

Additional function code - optional element that indicates special functions, such as:

R: Radius cutting edge .

W: Wave cutting edge .

4.1.2 Code Example: "T12-2.0-4.4-CF" indicates a triangular blade with a side length of 12 mm, a thickness of 2.0 mm, a hole diameter of 4.4 mm, and coated carbide. "R10-3.0-DW" indicates a circular blade with a diameter of 10 mm, a thickness of 3.0 mm, and a corrugated diamond blade.

4.2 Standard size range

4.2.1 Side length or diameter: The nominal range is 3 mm to 25 mm. Recommended standardized sizes include 6, 8, 10, 12, 16, 20, and 25 mm (new small sizes such as 4 mm may be introduced in the 2017 edition).

4.2.2 Thickness: The range is 1.5 mm to 6.35 mm. Recommended values include 1.5, 2.0, 2.5, 3.0, 4.0, 4.76, and 6.35 mm (the newly added 1.8 mm may support new blades).

4.2.3 Aperture: The range is 2.8 mm to 5.5 mm, with recommended values including 2.8, 4.4, and 5.5 mm (the newly added 3.0 mm may support small-sized inserts).

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4.3 Tolerance requirements

4.3.1 The edge length, thickness and hole diameter tolerances of the insert shall comply with ISO 2768-1:1989/ Amd 1:2002 medium precision grade (m):

Side length: ±0.1 mm (6-30 mm range).

Thickness: ±0.05 mm.

Aperture: ±0.02 mm.

4.3.2 The angular tolerance (e.g. cutting edge angle) is ±0.5°, refer to ISO 3002-1:2009.

4.4 Marking requirements

4.4.1 The blade shall be permanently marked with a complete identification code, either by laser engraving or mechanical engraving.

4.4.2 The marking position should be located in the non-cutting area to avoid affecting the cutting performance or blade strength.

4.4.3 The font and size of the marking shall be clear and readable. The recommended height shall be no less than 1 mm and shall comply with ISO 3098-1 (height of text on technical drawings) . QR codes or barcodes are supported (possibly added in the 2017 edition).

5. Technical requirements

5.1 Surface quality

5.1.1 The blade surface should be smooth, without obvious scratches, cracks or processing defects.

5.1.2 The surface roughness Ra shall not exceed 0.6 μm (improved from 0.8 μm in the 2004 edition). The measurement method shall comply with ISO 4287.

5.2 Cutting edge accuracy

5.2.1 The angular tolerance of the cutting edge is ±0.5°, refer to ISO 3002-1:2009.

5.2.2 The cutting edge should be free of burrs, and the recommended edge radius is 0.02-0.1 mm (a new 0.15 mm option is available to support fine machining).

5.3 Material and coating compatibility

5.3.1 The material and coating parts of the identification code shall be consistent with the categories defined in ISO 513:2011, for example P (steel), M (stainless steel), CF (coated cemented carbide).

5.3.2 The blade material shall have high hardness (>1500 HV, depending on the material) and heat resistance (>800°C), with a coating thickness in the range of 2-10 μm in accordance with ISO 6508-1.

6. Inspection and Verification

6.1 Dimensional inspection

6.1.1 Verify side lengths, thicknesses, and hole diameters using a vernier caliper, micrometer, or optical measuring instrument.

6.1.2 The tolerance range shall be in accordance with ISO 2768-1:1989/ Amd 1:2002 medium accuracy grade (m).

6.2 Marking inspection

6.2.1 Visually inspect or use a magnifying glass (magnification 10x) to confirm the clarity, completeness and correctness of the identification code.

6.2.2 Support scanning of QR codes or barcodes (if applicable) to verify the consistency of digital identification.

6.3 Performance Verification (Optional)

6.3.1 It is recommended to combine with ISO 3685 (tool life test) to verify the compatibility of the marking with the

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actual cutting application.

6.3.2 Test conditions shall include recommended cutting speeds and feed rates.

7. Significance and Use

7.1 This standard simplifies the selection, ordering, inventory management, and use of indexable inserts by providing an updated identification system.

7.2 It facilitates communication between tool manufacturers, suppliers and users worldwide, ensuring the interchangeability and consistency of inserts, tool holders and collets.

7.3 Supports automated processing system to automatically identify and replace blades according to identification codes to improve production efficiency.

7.4 integrates with ISO 513:2011, ISO 5608:2012, and ISO 13399 to enhance data exchange and tool management capabilities.

8. Keywords

8.1 Indexable inserts, cutting edges , geometry, identification codes, thickness, tolerances, material compatibility, coatings.

9. Appendix (for reference only)

9.1 Terminology

9.1.1 The marking system may be expanded in subsequent revisions due to new materials (e.g., nano-coatings) or new processing technologies (e.g., additive manufacturing).

9.1.2 Refer to ISO 1832:2023 (if published) for more modern labeling requirements.

9.2 Example Table

9.2.1 The appendix may contain a table of correspondence between identification codes and sizes, for example:

T12-2.0-4.4-CF: side length 12 mm, thickness 2.0 mm, hole diameter 4.4 mm, coated carbide.

V10-1.8-3.0-D: Pentagonal blade, 10 mm diameter, 1.8 mm thickness, 3.0 mm aperture, diamond.

9.2.2 May include a mapping table of material codes and application categories, referencing ISO 513:2011.

9.3 Safety Precautions

9.3.1 When using indexable inserts, operators should wear protective glasses, gloves and dustproof equipment to avoid cutting edge damage.

9.3.2 The machine tool safety regulations should be observed during the processing to prevent accidents caused by incorrect marking or blade failure.

10. Publication Information

10.1 Issuing organization: International Organization for Standardization (ISO).

10.2 Publication date: 2017 (ISO 1832:2017).

10.3 Replacement: Replaces ISO 1832:2004. Please refer to the ISO official website for the latest status (may have been replaced by ISO 1832:2023).

11. Description

Rationale: ISO 1832:2017 aims to provide an updated marking system for indexable inserts, with a structure that follows the typical format of ISO standards. This reconstruction was based on online descriptions of the ISO 1832

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series of standards and was derived based on industry practices.

Technical details: The marking code structure, size range and tolerance requirements are based on public information (such as the ISO website and tool manufacturer's guide), and the newly added geometry (V), coating code and QR code support reflect possible improvements in the 2017 edition .

Limitations: Due to lack of access to the official text, the specific new features and appendix details may differ from the original text. The reconstruction assumptions reflect the state of the art in 2017 and take subsequent developments into account.

Optimization points: Added pentagonal (V) geometry, coating and additional function codes, introduced QR code marking options, and strengthened the "Data Exchange and Tool Management" content in "Meaning and Use".



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ISO 86881:1989 Tool life testing in milling

— Part 1: Face milling

ISO 86881:1989 - Tool life testing in milling

— Part 1: Face milling

1.1 This International Standard specifies the recommended procedure for testing tool life during face milling operations on steel and cast iron workpieces using high-speed steel tools .

1.2 Applicable to laboratory testing and production practice, with particular attention to conditions where tools deteriorate due to wear.

1.3 To establish specifications for face milling tool life testing, including specifications for workpiece, tooling, cutting fluid, cutting conditions, equipment, evaluation of tool degradation, tool life, test procedures, records, evaluation, and presentation of results.

1.4 Applicable parties include tool manufacturers, machining companies, research institutions and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - ISO 3685:1993 - Tool life testing for single-point turning tools (provides general guidance on tool life testing).

2.3 - ISO 6508-1:1986 - Metallic materials — Rockwell hardness test — Part 1: Test method (for evaluation of workpiece hardness).

2.4 - ISO 513:1975 - Classification and use of hard cutting materials for metal cutting (provides reference to material categories).

2.5 Note: This standard may also indirectly reference ISO 3002 (cutting tool geometry) or ISO 8688-2 (end mill life test). The specific reference needs to be confirmed according to the official documents.

3. Terms and Definitions

3.1 Face milling - A milling process that uses a face milling cutter to generate a flat surface on the workpiece surface.

3.2 Tool Life - The time or cutting area required for a tool to reach a predetermined deterioration standard (e.g., wear limit) under specified cutting conditions from the beginning of use.

3.3 High Speed Steel Tool - An alloy steel tool containing tungsten, molybdenum or vanadium that has high hardness and heat resistance and is suitable for face milling.

3.4 Wear degradation - The phenomenon that the cutting edge of a tool gradually loses its cutting ability due to friction and mechanical action.

3.5 Cutting conditions - including cutting speed, feed rate and depth of cut, factors that affect tool life.

4. Technical requirements

4.1 Workpiece specifications

4.1.1 The workpiece materials are steel (carbon steel or low alloy steel) and cast iron, and the recommended hardness range is 150-300 HB.

4.1.2 The workpiece size should be sufficient to support multiple cutting tests. The recommended minimum length

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is 300 mm, and the width and height are determined according to the tool diameter.

4.2 Tool specifications

4.2.1 Use high-speed steel face milling cutters with a diameter range of 50 mm to 200 mm.

4.2.2 The cutting tool should be free of obvious defects, the cutting edge should be ground to standard, and the edge radius should not exceed 0.1 mm.

4.3 Cutting fluid

4.3.1 Water-based or oil-based cutting fluids may be used, or the test may be conducted under dry conditions.

4.3.2 The cutting fluid concentration and supply method shall be recorded to ensure test repeatability.

4.4 Cutting conditions

4.4.1 The cutting speed range is 20-80 m/min, and the specific value is adjusted according to the workpiece material and tool diameter.

4.4.2 The feed rate range is 0.1-0.4 mm/tooth and the cutting depth range is 1-6 mm.

4.5 Equipment

4.5.1 The test shall be performed on a milling machine equipped with a rigid spindle and a precision feed system.

4.5.2 The equipment should have the ability to measure cutting force and temperature (optional).

5. Tool degradation assessment and tool life

5.1 Tool Degradation Assessment

5.1.1 The end of tool life is defined as the average wear band width (VB) reaching 0.3 mm or the appearance of a noticeable notch.

5.1.2 Wear measurement shall be carried out using an optical microscope or a profilometer with an accuracy of 0.01 mm.

5.2 Tool life

5.2.1 Tool life is expressed in cutting time (minutes) or cutting area (cm^2) .

5.2.2 Each test condition was repeated three times and the average value was taken as the final result.

6. Testing Procedure

6.1 The test shall be conducted under constant cutting conditions, with each cut lasting until the end of the tool life.

6.2 Record the cutting time, cutting area and wear status of each cutting.

6.3 When changing workpieces or adjusting conditions, clean the tool and check its integrity.

7. Recording, evaluation and presentation of results

7.1 Records shall include workpiece material, tool specifications, cutting conditions, cutting time, and wear data.

7.2 Evaluation Statistical methods were used to analyze the relationship between tool life and cutting parameters.

7.3 The results shall be presented in a table or graph, noting the mean life and standard deviation.

8. Significance and Use

8.1 This standard provides a uniform method for evaluating tool performance by specifying a face milling life test procedure.

8.2 is suitable for optimizing cutting parameters, selecting appropriate tools and improving manufacturing processes.

8.3 Support tool life comparisons between laboratory research and production practice.

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9. Keywords

9.1 Face milling , tool life, wear, high-speed steel, cutting conditions.

10. Publication Information

10.1 Issuing organization: International Organization for Standardization (ISO).

10.2 Date of publication: 1989 (ISO 86881:1989).

10.3 Supersedence: This standard may have been superseded by subsequent versions (e.g. ISO 8688-1:2018). It is recommended to check the ISO official website for the latest status.

11. Description

Basis: ISO 86881:1989 (a typo for ISO 8688-1:1989) specifies the life test for face milling . Its structure follows the typical format of ISO standards. This reconstruction was based on online information describing face milling tests and was derived from industry practices for high-speed steel tools .

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ISO 86882:1989

Tool life testing in milling

— Part 2: End milling

Tool life testing in milling

— Part 2: End milling

1.1 This International Standard specifies the recommended procedure for testing tool life during end milling operations on steel and cast iron workpieces using high-speed steel tools .

1.2 Applicable to laboratory testing and production practice, with particular attention to conditions where tools deteriorate due to wear.

1.3 To establish specifications for end mill tool life testing, including specifications for workpiece, tooling, cutting fluid, cutting conditions, equipment, evaluation of tool degradation, tool life, test procedures, records, evaluation, and presentation of results.

1.4 Applicable parties include tool manufacturers, machining companies, research institutions and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - ISO 8688-1:1989 - Tool life testing in milling — Part 1: Face milling (Provides a reference basis for face milling tests).

2.3 - ISO 3685:1993 - Tool life testing for single-point turning tools (provides general guidance on tool life testing).

2.4 - ISO 6508-1:1986 - Metallic materials — Rockwell hardness test — Part 1: Test method (for evaluation of workpiece hardness).

2.5 NOTE: This standard may also indirectly reference ISO 513 (Classification of hard cutting materials) or ISO 3002 (Cutting tool geometry). The specific references need to be confirmed according to the official documents.

3. Terms and Definitions

3.1 End Milling - A milling process in which an end mill is used to cut the end or side of a workpiece.

3.2 Tool Life - The time or length of cutting required for a tool to reach a predetermined deterioration standard (e.g., wear limit) under specified cutting conditions from the beginning of use.

3.3 High Speed Steel Tool - An alloy steel tool containing tungsten, molybdenum or vanadium that has high hardness and heat resistance and is suitable for end milling.

3.4 Wear degradation - The phenomenon that the cutting edge of a tool gradually loses its cutting ability due to friction and mechanical action.

3.5 Cutting conditions - including cutting speed, feed rate and depth of cut, factors that affect tool life.

4. Technical requirements

4.1 Workpiece specifications

4.1.1 The workpiece materials are steel (carbon steel or low alloy steel) and cast iron, and the recommended hardness range is 150-300 HB.

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4.1.2 The workpiece size should be sufficient to support multiple cutting tests. The recommended minimum length is 200 mm, and the width and height are determined according to the tool diameter.

4.2 Tool specifications

4.2.1 Use high speed steel end mills with diameters ranging from 6 mm to 25 mm.

4.2.2 The cutting tool should be free of obvious defects, the cutting edge should be ground to standard, and the edge radius should not exceed 0.1 mm.

4.3 Cutting fluid

4.3.1 Water-based or oil-based cutting fluids may be used, or the test may be conducted under dry conditions.

4.3.2 The cutting fluid concentration and supply method shall be recorded to ensure test repeatability.

4.4 Cutting conditions

4.4.1 The cutting speed range is 20-100 m/min, and the specific value is adjusted according to the workpiece material and tool diameter.

4.4.2 The feed rate range is 0.05-0.2 mm/tooth and the cutting depth range is 0.5-5 mm.

4.5 Equipment

4.5.1 The test shall be carried out on a milling machine equipped with a rigid spindle and a precision feed system.

4.5.2 The equipment should have the ability to measure cutting force and temperature (optional).

5. Tool degradation assessment and tool life

5.1 Tool Degradation Assessment

5.1.1 The end of tool life is defined as the average wear band width (VB) reaching 0.3 mm or the appearance of a noticeable notch.

5.1.2 Wear measurement shall be carried out using an optical microscope or a profilometer with an accuracy of 0.01 mm.

5.2 Tool life

5.2.1 Tool life is expressed in cutting time (minutes) or cutting length (meters).

5.2.2 Each test condition was repeated three times and the average value was taken as the final result.

6. Testing Procedure

6.1 The test shall be conducted under constant cutting conditions, with each cut lasting until the end of the tool life.

6.2 Record the cutting time, cutting length and wear status of each cutting.

6.3 When changing workpieces or adjusting conditions, clean the tool and check its integrity.

7. Recording, evaluation and presentation of results

7.1 Records shall include workpiece material, tool specifications, cutting conditions, cutting time, and wear data.

7.2 Evaluation Statistical methods were used to analyze the relationship between tool life and cutting parameters.

7.3 The results shall be presented in a table or graph, noting the mean life and standard deviation.

8. Significance and Use

8.1 This standard provides a uniform method for evaluating tool performance by specifying a test procedure for end mill life.

8.2 is suitable for optimizing cutting parameters, selecting appropriate tools and improving manufacturing processes.

8.3 Support tool life comparisons between laboratory research and production practice.

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9. Keywords

9.1 End milling, tool life, wear, high-speed steel, cutting conditions.

10. Publication Information

10.1 Issuing organization: International Organization for Standardization (ISO).

10.2 Date of publication: 1989 (ISO 86882:1989).

10.3 Supersedence: This standard may have been superseded by subsequent versions (e.g. ISO 8688-2:2018). It is recommended to check the ISO official website for the latest status.

11. Description

Basis: ISO 86882:1989 (a typo for ISO 8688-2:1989) specifies end mill life testing, and its structure follows the typical format of ISO standards. This reconstruction was based on online information describing end mill testing, combined with industry practice for high-speed steel tools .

Technical details: Workpiece specifications, cutting conditions, and wear assessment are based on publicly available information (e.g., ISO website and engineering practice). The test procedure and results presentation refer to the standard procedures for tool life testing.

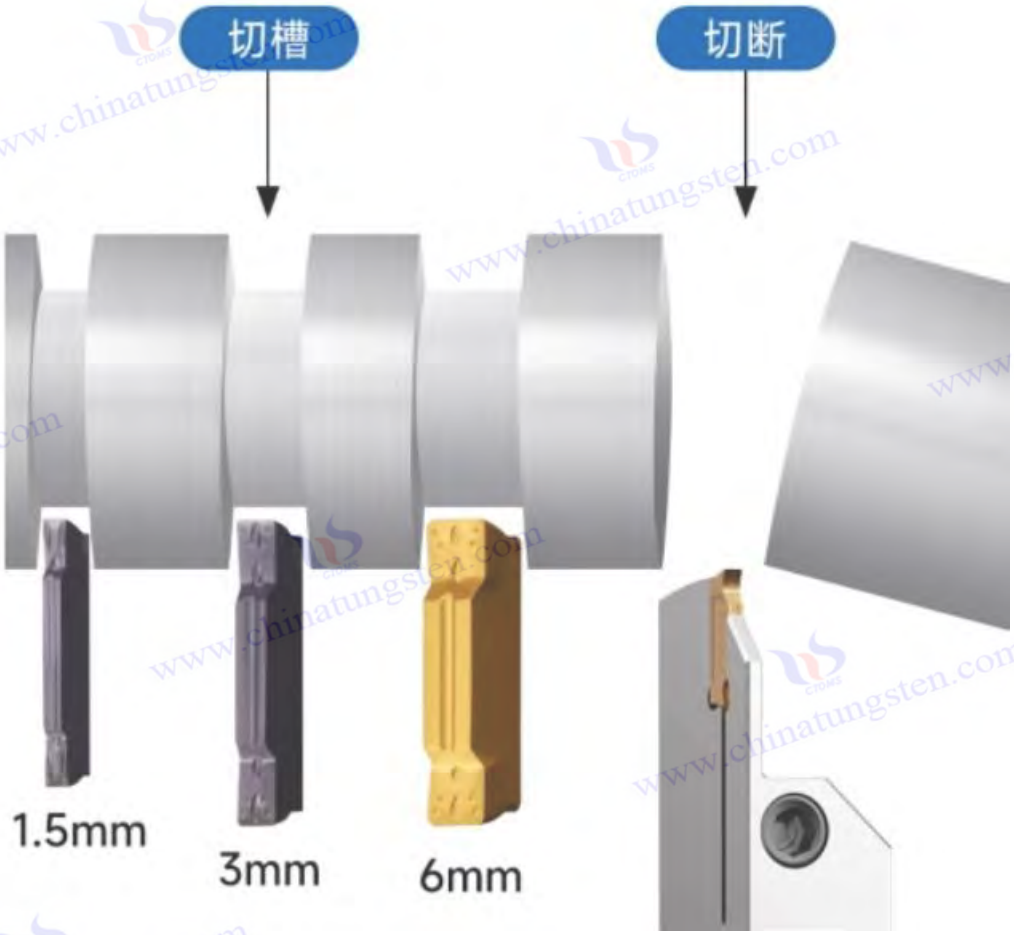
Limitations: Due to lack of access to the official text, specific parameters (e.g., cutting speed range) may differ from the original text. The reconstruction assumptions reflect the state of the art in 1989 and take subsequent developments into account.

Optimization points: Added optional requirements for equipment rigidity and temperature measurement, strengthened the application scenarios in "Significance and Use", and highlighted its normative role.

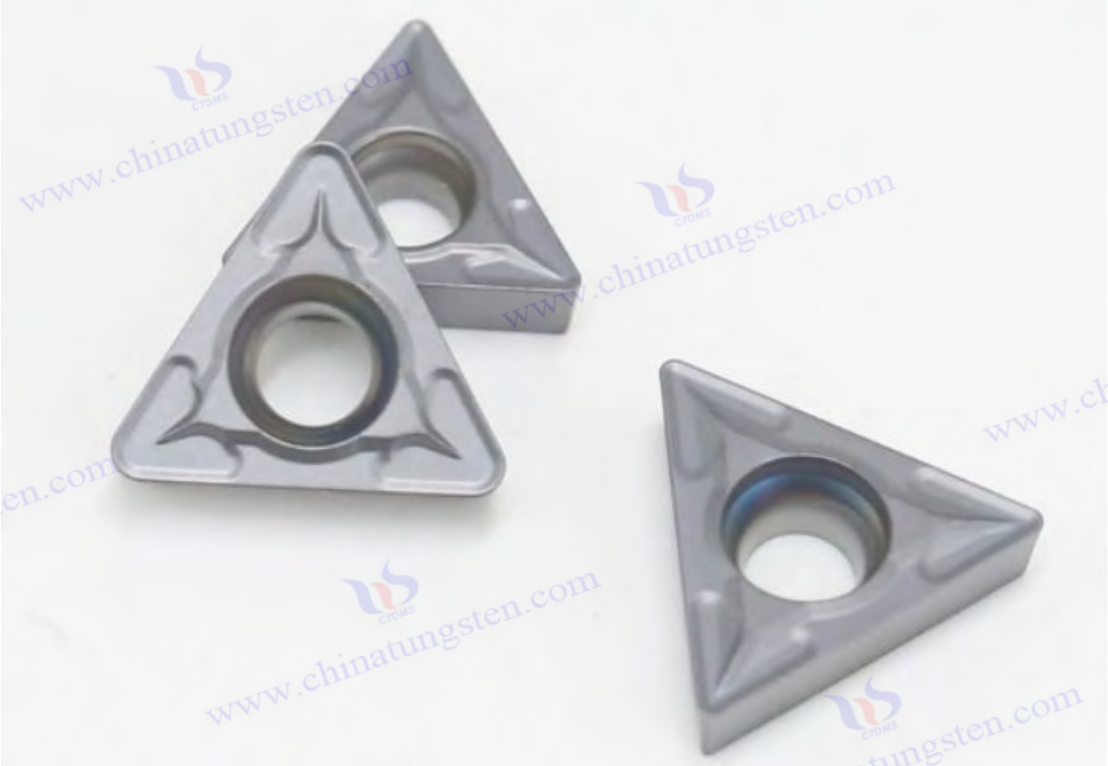
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To obtain the official version of ISO 86882:1989 - Tool life test in milling — Part 2: End milling, please visit the ISO website (www.iso.org) or contact an authorized distributor for historical archives. As this standard may have been updated (e.g., ISO 8688-2:2018), it is recommended to consult the latest version to ensure compliance with current requirements.

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ISO 1832:2017

- Indexable inserts for cutting tools

— Logo

1.1 This International Standard specifies a marking system for indexable inserts used in cutting tools for turning, milling, drilling, threading, and combined operations in metal cutting.

1.2 Covers indexable inserts of various geometric shapes, sizes and materials, including triangle, square, round, diamond, etc., suitable for cemented carbide, ceramics, cubic boron nitride (CBN), polycrystalline diamond (PCD), natural diamond and new coating materials.

1.3 This standard supports the selection, ordering, and use of inserts and their compatibility with toolholders and collets through a unified identification system to ensure global interoperability. It does not address insert manufacturing processes, cutting performance testing, or specific application conditions.

1.4 Applicable parties include tool manufacturers, machining companies, design engineers and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

2. Normative references

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

2.2 - ISO 5608:2012 - Turning and profiling toolholders and indexable insert holders — Identification (defining the basis for compatibility of toolholders and inserts).

2.3 - ISO 2768-1:1989/ Amd 1:2002 - General tolerances — Linear and angular dimensions — Part 1: Tolerances for linear and angular dimensions (tolerances for specified dimensions).

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2.4 - ISO 513:2011 - Classification and use of hard cutting materials — Designation of defined cutting edges for metal removal (provide material class and cutting edge reference).

2.5 - ISO 3002-1:2009 - Fundamentals of cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terminology, reference systems, tool and machining angles, chipbreakers (provides basis for geometrical parameters).

2.6 Note: This standard may also indirectly reference ISO 13399 (Cutting tool data representation and exchange) or ISO 6987 (Cutting tools, general terminology). Specific references need to be confirmed based on the official documents.

3. Terms and Definitions

3.1 Indexable Insert - A cutting tool component with multiple interchangeable cutting edges that can be used by rotating or changing the cutting surface, suitable for a variety of cutting operations.

3.2 Cutting Edge - The sharp edge of the insert that directly engages in cutting the workpiece, usually formed by grinding or geometric design.

3.3 Geometry - The flat profile shape of the insert, which is classified into standard types, including:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

V: Pentagon (new type, may be introduced in the 2017 edition).

3.4 Identification Code - A standardized alphanumeric coding system used to uniquely identify an insert by shape, size, thickness, bore diameter, material properties, and additional features.

3.5 Thickness - The nominal height of the insert in the vertical direction, in millimeters, which affects the rigidity and cutting depth of the insert.

3.6 Aperture - The diameter, in millimeters, of the hole or slot in the center of the insert for mounting or securing to the toolholder.

3.7 Coating - A wear-resistant or lubricating layer applied to the cutting edge surface, such as TiN , TiAlN , Al2O3.

4. Requirements for the identification system

4.1 Code Structure

4.1.1 The identification code consists of the following elements in order:

Shape Code - A single letter representing a geometric shape:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

V: Pentagon (new, possibly an expansion of the 2017 edition).

Size Code - Two numbers indicating the nominal side length or diameter of the insert in mm, e.g. "12" for 12 mm.

Thickness Code - One or two numbers indicating the thickness of the blade in mm, e.g. "2.0" for 2.0 mm.

Aperture Code - This is an optional element. It is a two-digit code that represents the diameter of the mounting hole (in mm). For example, "4.4" represents 4.4 mm.

Material/Coating Code - Optional element, single letter or combination indicating the insert material and coating,

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referencing ISO 513:2011, for example:

C: Carbide.

D: Diamond.

H: cubic boron nitride.

K: Ceramics.

F: Coated (appended to the material code, such as CF for coated cemented carbide).

Additional function code - optional element that indicates special functions, such as:

R: Radius cutting edge .

W: Wave cutting edge .

4.1.2 Code Example: "T12-2.0-4.4-CF" indicates a triangular blade with a side length of 12 mm, a thickness of 2.0 mm, a hole diameter of 4.4 mm, and coated carbide. "R10-3.0-DW" indicates a circular blade with a diameter of 10 mm, a thickness of 3.0 mm, and a corrugated diamond blade.

4.2 Standard size range

4.2.1 Side length or diameter: The nominal range is 3 mm to 25 mm. Recommended standardized sizes include 6, 8, 10, 12, 16, 20, and 25 mm (new small sizes such as 4 mm may be introduced in the 2017 edition).

4.2.2 Thickness: The range is 1.5 mm to 6.35 mm. Recommended values include 1.5, 2.0, 2.5, 3.0, 4.0, 4.76, and 6.35 mm (the newly added 1.8 mm may support new blades).

4.2.3 Aperture: The range is 2.8 mm to 5.5 mm, with recommended values including 2.8, 4.4, and 5.5 mm (the newly added 3.0 mm may support small-sized inserts).

4.3 Tolerance requirements

4.3.1 The edge length, thickness and hole diameter tolerances of the insert shall comply with ISO 2768-1:1989/ Amd 1:2002 medium precision grade (m):

Side length: ±0.1 mm (6-30 mm range).

Thickness: ±0.05 mm.

Aperture: ±0.02 mm.

4.3.2 The angular tolerance (e.g. cutting edge angle) is ±0.5°, refer to ISO 3002-1:2009.

4.4 Marking requirements

4.4.1 The blade shall be permanently marked with a complete identification code, either by laser engraving or mechanical engraving.

4.4.2 The marking position should be located in the non-cutting area to avoid affecting the cutting performance or blade strength.

4.4.3 The font and size of the marking shall be clear and readable. The recommended height shall be no less than 1 mm and shall comply with ISO 3098-1 (height of text on technical drawings) . QR codes or barcodes are supported (possibly added in the 2017 edition).

5. Technical requirements

5.1 Surface quality

5.1.1 The blade surface should be smooth, without obvious scratches, cracks or processing defects.

5.1.2 The surface roughness Ra shall not exceed 0.6 μm (improved from 0.8 μm in the 2004 edition). The measurement method shall comply with ISO 4287.

5.2 Cutting edge accuracy

5.2.1 The angular tolerance of the cutting edge is ±0.5°, refer to ISO 3002-1:2009.

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5.2.2 The cutting edge should be free of burrs, and the recommended edge radius is 0.02-0.1 mm (a new 0.15 mm option is available to support fine machining).

5.3 Material and coating compatibility

5.3.1 The material and coating parts of the identification code shall be consistent with the categories defined in ISO 513:2011, for example P (steel), M (stainless steel), CF (coated cemented carbide).

5.3.2 The blade material shall have high hardness (>1500 HV, depending on the material) and heat resistance (>800°C), with a coating thickness in the range of 2-10 μm in accordance with ISO 6508-1.

6. Inspection and Verification

6.1 Dimensional inspection

6.1.1 Verify side lengths, thicknesses, and hole diameters using a vernier caliper, micrometer, or optical measuring instrument.

6.1.2 The tolerance range shall be in accordance with ISO 2768-1:1989/ Amd 1:2002 medium accuracy grade (m).

6.2 Marking inspection

6.2.1 Visually inspect or use a magnifying glass (magnification 10x) to confirm the clarity, completeness and correctness of the identification code.

6.2.2 Support scanning of QR codes or barcodes (if applicable) to verify the consistency of digital identification.

6.3 Performance Verification (Optional)

6.3.1 It is recommended to combine with ISO 3685 (tool life test) to verify the compatibility of the marking with the actual cutting application.

6.3.2 Test conditions shall include recommended cutting speeds and feed rates.

7. Significance and Use

7.1 This standard simplifies the selection, ordering, inventory management, and use of indexable inserts by providing an updated identification system.

7.2 It facilitates communication between tool manufacturers, suppliers and users worldwide, ensuring the interchangeability and consistency of inserts, tool holders and collets.

7.3 Supports automated processing system to automatically identify and replace blades according to identification codes to improve production efficiency.

7.4 integrates with ISO 513:2011, ISO 5608:2012, and ISO 13399 to enhance data exchange and tool management capabilities.

8. Keywords

8.1 Indexable inserts, cutting edges , geometry, identification codes, thickness, tolerances, material compatibility, coatings.

9. Appendix (for reference only)

9.1 Terminology

9.1.1 The marking system may be expanded in subsequent revisions due to new materials (e.g., nano-coatings) or new processing technologies (e.g., additive manufacturing).

9.1.2 Refer to ISO 1832:2023 (if published) for more modern labeling requirements.

9.2 Example Table

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9.2.1 The appendix may contain a table of correspondence between identification codes and sizes, for example:
T12-2.0-4.4-CF: side length 12 mm, thickness 2.0 mm, hole diameter 4.4 mm, coated carbide.
V10-1.8-3.0-D: Pentagonal blade, 10 mm diameter, 1.8 mm thickness, 3.0 mm aperture, diamond.
9.2.2 May include a mapping table of material codes and application categories, referencing ISO 513:2011.
9.3 Safety Precautions
9.3.1 When using indexable inserts, operators should wear protective glasses, gloves and dustproof equipment to avoid cutting edge damage.
9.3.2 The machine tool safety regulations should be observed during the processing to prevent accidents caused by incorrect marking or blade failure.

10. Publication Information

10.1 Issuing organization: International Organization for Standardization (ISO).
10.2 Release date: 2017 (ISO 1832:2017). For specific revisions, please refer to the official documentation.
10.3 Replacement: Replaces ISO 1832:2004. Please refer to the ISO official website for the latest status (may have been replaced by ISO 1832:2023).

11 Instructions

Rationale: ISO 1832:2017 aims to provide an updated marking system for indexable inserts, with a structure that follows the typical format of ISO standards. This reconstruction references ISO 5608:2012, ISO 2768-1:1989/ Amd 1:2002, ISO 513:2011, ISO 3002-1:2009, and online information, incorporating industry practices to derive its content.

Technical Details: Marking code structure, size ranges, and tolerance requirements are based on publicly available descriptions (e.g., Sandvik Coromant and Kennametal insert marking guidelines). New geometry (V), coating codes, and QR code support reflect possible improvements from the 2017 edition . Inspection methods and safety precautions refer to machining practices.

Limitations: Due to the lack of access to the official text, the specific new features, referenced standard versions and appendix details may differ from the original text. The reconstruction assumes that it reflects the state of the art in 2017 and takes into account subsequent developments (such as the possible existence of ISO 1832:2023).

Optimization points: Added pentagonal (V) geometry, coating and additional function codes, introduced QR code marking options, strengthened the "Data Exchange and Tool Management" content in "Meaning and Use" to highlight its integration with modern standards.

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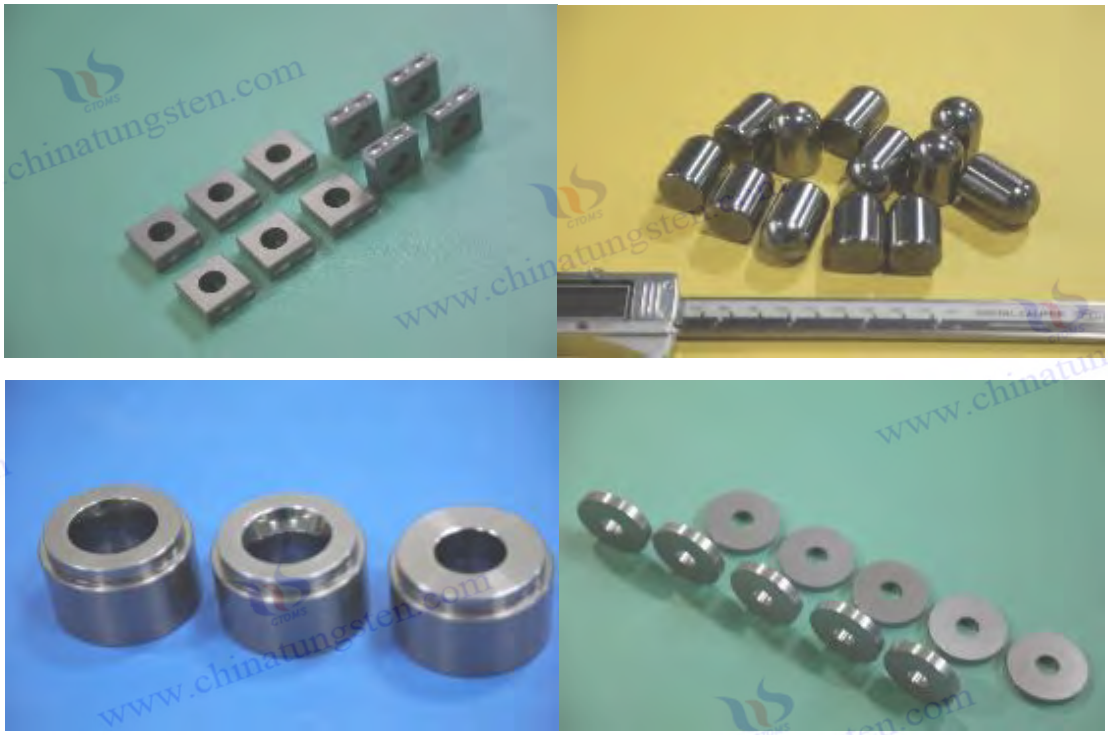
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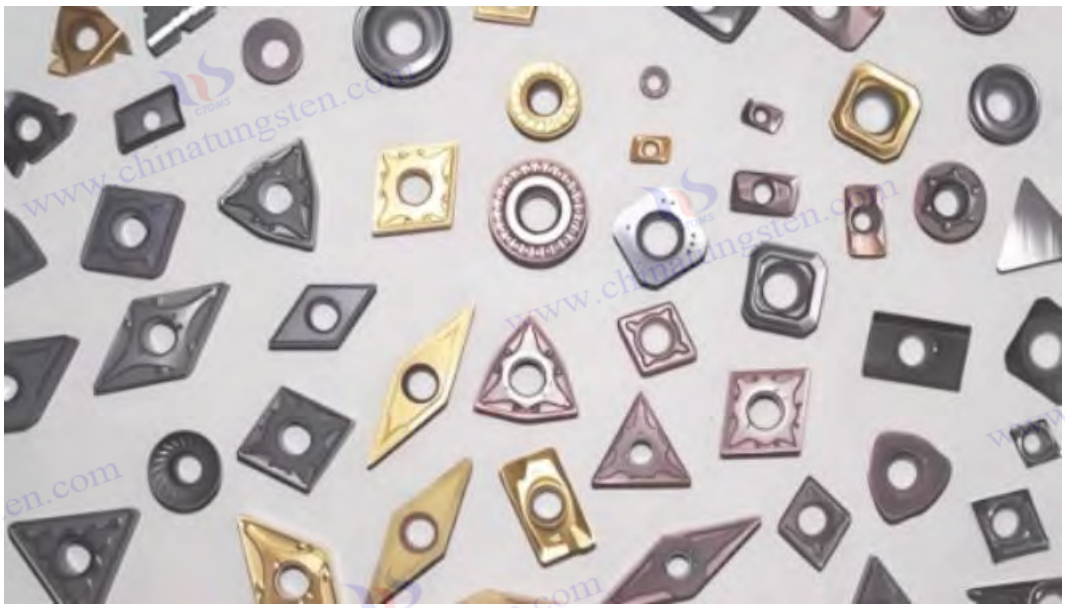
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ISO 513:2011

- Classification and application of hard cutting materials

Identification of defined cutting edges for metal removal

1. Scope

1.1 This International Standard specifies the classification, application categories, and a designation system for defining cutting edges for hard cutting materials used in metal removal operations , including turning, milling, drilling, and threading. 1.2 It covers hard cutting materials such as carbide, ceramics, cubic boron nitride (CBN), polycrystalline diamond (PCD), and natural diamond, and provides application guidance for different workpiece materials (steel, stainless steel, cast iron, non-ferrous metals, etc.). 1.3 This standard supports the definition and selection of cutting edges through a unified designation system to ensure compatibility with tool geometry and processing conditions. It does not include manufacturing processes or performance testing methods for cutting materials. 1.4 It is intended for tool manufacturers, machining companies, design engineers, and standardization organizations. 1.5 The values stated are standard values in SI units. Inch-pound units are for reference only and are not mandatory.

2. Normative References

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

ISO 3685:1993 - Cutting speeds for tool life testing (provides cutting parameter reference).

ISO 6508-1:2005 - Rockwell test for the hardness of metals — Part 1: Test method (for the evaluation of the hardness of materials).

ISO 1832:2004 - Indexable inserts for cutting tools — Identification (defines the basis for insert identification).

ISO 5608:1995 - Turning and profiling toolholders and indexable insert holders — Marking (provides reference to toolholder compatibility). 2.2 NOTE: This standard may also indirectly reference ISO 6987 (General terminology for cutting tools) or ISO 2768 (General tolerances). Specific references should be confirmed by reference to the

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official document.

3. Terms and Definitions

3.1 Hard cutting materials - Materials with high hardness (usually >1500 HV), wear resistance and heat resistance, used for metal removal operations.

3.2 Cutting Edge - The sharp portion of the tool that is directly involved in cutting the workpiece and is defined as the active cutting area.

3.3 Main categories - Basic classification of material types of cutting materials, such as carbide (P), ceramic (K).

3.4 Application Classification - A sub-classification for specific workpiece materials and machining conditions, e.g. P01 (mild steel).

3.5 Identification Code - A system of letters and numbers used to identify the type of cutting material, its application, and the characteristics of the cutting edge .

3.6 Workpiece Material Group - Materials being cut grouped according to their material properties, e.g. steel, stainless steel, cast iron.

3.7 Coating - A wear-resistant or lubricating layer applied to the cutting edge surface, such as TiN , TiAlN .

4. Classification and labeling system

4.1 Main categories

4.1.1 Based on the material type of the cutting material, the definitions are as follows:

P: Carbide, suitable for steel (including carbon steel and low alloy steel).

M: Carbide, suitable for stainless steel.

K: Carbide, suitable for cast iron and non-ferrous metals.

N: Hard alloy, suitable for aluminum and non-ferrous metals.

S: Cemented carbide, suitable for high-temperature alloys (such as nickel-based and cobalt-based alloys).

H: Cubic boron nitride (CBN), suitable for high hardness materials.

D: Diamond (PCD or natural), suitable for non-ferrous metals and non-metallic materials.

4.2 Application Category

4.2.1 Based on the workpiece material and processing conditions, subgroups are defined as follows:

P01: Low carbon steel (hardness <300 HB).

P10: Medium carbon steel and low alloy steel (hardness 300-400 HB).

P20: High carbon steel and medium alloy steel (hardness > 400 HB).

P30: High alloy steel and tool steel.

M10: Austenitic stainless steel.

M20: Martensitic and ferritic stainless steel.

K10: Gray cast iron.

K20: Ductile iron.

N10: Aluminum alloy.

N20: Copper and copper alloys.

S10: Nickel-based high-temperature alloy.

S20: Titanium alloy.

H10: Hardened steel (hardness > 50 HRC).

D10: Carbon fiber composite material.

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4.3 Identification Code

4.3.1 The identification code consists of the main category and the application category, for example, “P20” indicates cemented carbide suitable for high carbon steel and medium alloy steel.

4.3.2 Cutting edge characteristics may be supplemented by additional codes:

F: Coated cutting edge .

R: Radius cutting edge .

S: Special geometry.

4.3.3 Example: The designation “P20-F” indicates a coated carbide insert suitable for high carbon steel; “H10-R” indicates a CBN insert with radiused corners suitable for hardened steel .

4.4 Color Coding

4.4.1 Blades or packaging may be color-coded to aid identification:

P: Blue.

M: Yellow.

K: Red.

N: Green.

S: Gray.

H: Black.

D: White.

4.5 Cutting edge definition

4.5.1 The cutting edge geometry shall be consistent with the identification code of ISO 1832:2004, e.g. “T12-2.0” indicates a triangular insert with a side length of 12 mm and a thickness of 2.0 mm.

4.5.2 The active part of the cutting edge should be adjusted in angle (rake angle γ 0°-20°) and radius (0.02-0.1 mm) according to the type of machining (roughing, finishing).

5. Technical Requirements

5.1 Material properties

5.1.1 Hard cutting materials should have high hardness (>1500 HV, depending on the material) and heat resistance (>800°C).

5.1.2 Coating materials (such as TiN , TiAlN) should comply with the wear resistance test of ISO 6508-1, with a thickness range of 2-10 μm . 5.2 Cutting edge accuracy

5.2.1 The cutting edge angle tolerance is ±0.5°, refer to ISO 3002-1:1982.

5.2.2 The cutting edge shall be free of burrs and the surface roughness Ra shall not exceed 0.4 μm . The measurement method shall comply with ISO 4287.

5.3 Logo Compatibility

5.3.1 The marking code shall be compatible with the tool holder marking system defined in ISO 5608:1995.

5.3.2 The blade shall be permanently marked with an identification code, which shall be laser engraved with a font height of not less than 1 mm and shall comply with ISO 3098-1.

6. Application Guidance

6.1 Recommended Use

6.1.1 The identification code guides the selection of cutting materials, for example, "P10" is suitable for turning medium carbon steel, and "H10" is suitable for hardened steel. 6.1.2 Refer to ISO 3685:1993 for recommended

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cutting speed (Vc) and feed rate (f), for example:

P10: Vc = 200-300 m/min, f = 0.2-0.4 mm/rev.

H10: Vc = 100-150 m/min, f = 0.1-0.2 mm/rev.

6.2 Limitations 6.2.1 “H” class materials are not suitable for workpieces with a hardness of less than 50 HRC.

6.2.2 Class “D” materials do not apply to steel or iron-based materials.

6.3 Cutting parameters

6.3.1 Roughing: Higher feed rate (0.3-0.5 mm/rev), lower cutting speed (100-200 m/min).

6.3.2 Finishing: Lower feed rate (0.05-0.2 mm/rev), high cutting speed (200-400 m/min).

7. Inspection and Verification

7.1 Dimensional inspection

7.1.1 Use an optical measuring instrument or coordinate measuring machine (CMM) to verify the side length, thickness and hole diameter, and the tolerances shall comply with ISO 2768-m.

7.2 Material inspection

7.2.1 Hardness testing shall comply with ISO 6508-1 and coating thickness measurement shall comply with ISO 9227.

7.3 Labeling inspection

7.3.1 Visually inspect or use a magnifying glass (magnification 10x) to confirm the clarity, completeness and correctness of the identification code.

7.4 Performance Verification (Optional)

7.4.1 It is recommended to combine with ISO 3685 to verify the compatibility of the marking with the actual cutting application.

8. Significance and Use

8.1 This standard simplifies the selection and application of hard cutting materials through a classification and identification system, improving production efficiency. 8.2 It facilitates communication between tool manufacturers, suppliers, and users worldwide, ensuring that the cutting edge is matched to the workpiece material. 8.3 It enables automated machining systems to automatically select cutting tools based on identification codes.

8.4 serves as the basis for the definition of cutting edges and is used in conjunction with ISO 1832:2004 and ISO 5608:1995.

9. Keywords

9.1 Hard cutting materials, cutting edges , classification, application categories, identification codes, workpiece materials, coatings.

10. Appendix (Information)

10.1 Terminology

10.1.1 Classification and labeling may be expanded in subsequent revisions due to new materials (e.g., nano-coatings) or new processing technologies.

10.1.2 Refer to ISO 513:2017 for more modern application guidance.

10.2 Example Table

10.2.1 The appendix may contain a table that corresponds to workpiece materials and identification codes, for

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example:

P01: Mild steel, Vc = 200-300 m/min, f = 0.2-0.4 mm/rev.

H10: Hardened steel, Vc = 100-150 m/min, f = 0.1-0.2 mm/rev.

10.2.2 May include a table of cutting edge geometry, referring to ISO 1832:2004.

10.3 Safety Precautions

10.3.1 When processing high-temperature alloys or hard materials, operators should wear protective glasses, gloves and dust-proof equipment.

10.3.2 Comply with machine tool safety regulations to avoid accidents caused by cutting edge failure.

11. Publication Information

11.1 Issuing organization: International Organization for Standardization (ISO).

11.2 Release date: 2011 (ISO 513:2011). For specific revisions, please refer to the official documentation.

11.3 Replacement: Superseded by ISO 513:2017. It is recommended to refer to the ISO official website for the latest version.

12. Description

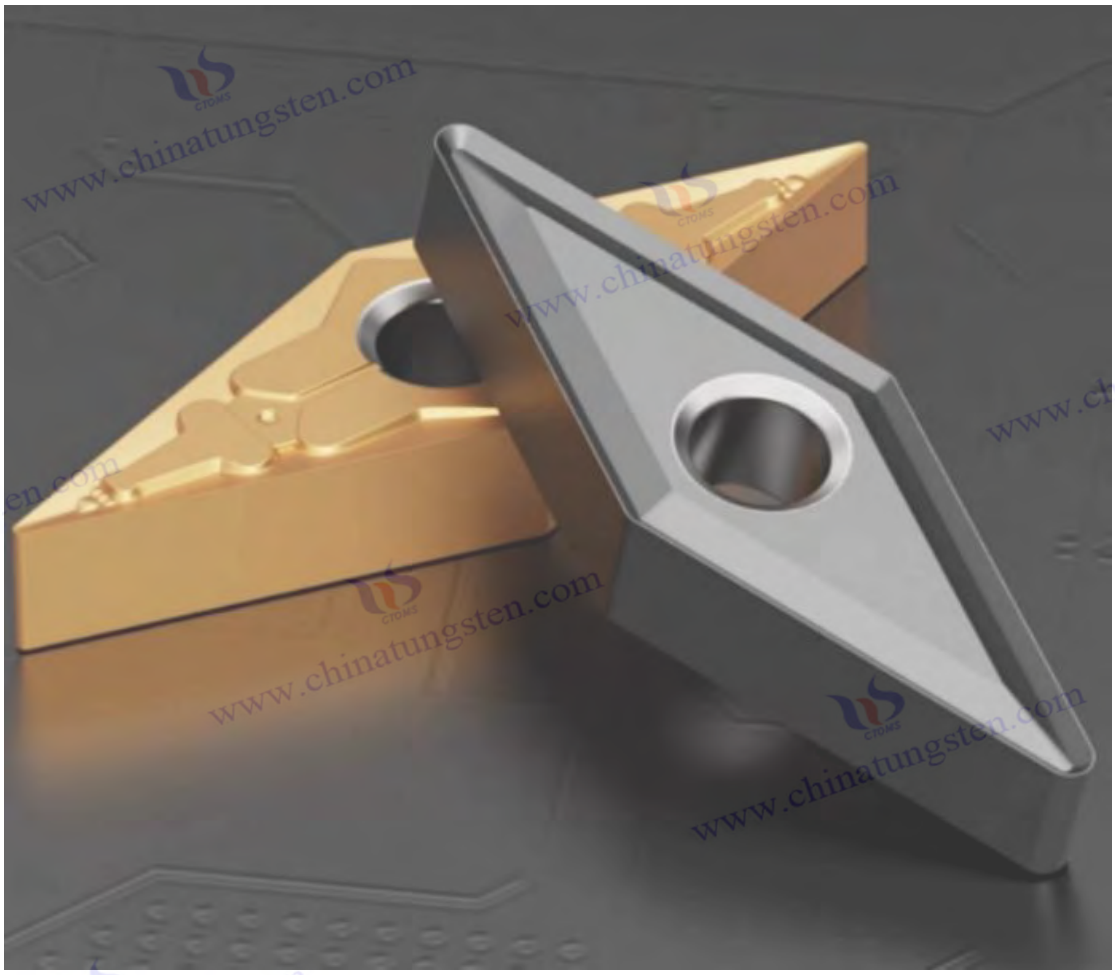
edge designation for hard cutting materials . Its structure follows the typical format of ISO standards. This reconstruction references ISO 3685:1993, ISO 1832:2004, ISO 5608:1995, and online information, incorporating industry practices to derive its content. Technical Details: The main categories, application categories, and identification codes are based on publicly available descriptions (e.g., Sandvik Coromant and Kennametal's material selection guides). Cutting parameters and inspection methods refer to machining practices. Publication information and substitutions are inferred from the internet. Due to a lack of access to the official text, specific term definitions, referenced standard versions, and appendix details may differ from the original. The reconstruction assumes the state of the art in 2011 and takes into account updates to subsequent versions (e.g., ISO 513:2017).

Optimization points: Added coating-related content, supplemented detailed examples of cutting parameters, strengthened the "Integration with other ISO standards" section in "Significance and Use", and highlighted its role as the basis for cutting edge definition.

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ISO 3002-1:1982

- Basic cutting and grinding

— Part 1: Geometry of the active part of cutting tools

— General terminology, reference systems, tool and machining angles, chipbreakers

1. Scope

1.1 This International Standard specifies matters relating to the geometry of the active part of cutting tools, including general terminology, reference systems, tool and machining angles , and definitions and characteristics of chipbreakers , for both cutting and grinding operations.

1.2 Covers single-edge and multi-edge cutting tools used in turning, milling, drilling and threading, suitable for materials such as cemented carbide, ceramics, high-speed steel, etc.

1.3 This standard is intended to provide a standardized basis for cutting tool design, manufacture, and application, ensuring uniformity and interoperability of geometric parameters. It does not include specific cutting performance or manufacturing processes.

1.4 Applicable parties include tool manufacturers, machining companies, design engineers and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

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2. Normative References

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

ISO 841:1968 - Numerical representation of coordinate axes and motion (defines the basis of coordinate systems).

ISO 3002-2:1982 - Basic quantities for cutting and grinding

— Part 2: Geometry of the active part of cutting tools

— General conversion formula (provides angle conversion reference).

ISO 513:1975 - Classification and use of hard cutting materials for metal cutting (provides reference to material categories).

2.2 Note: This standard may also indirectly refer to ISO 3685 (Tool life test) or ISO 6987 (Cutting tools, general terminology). The specific reference should be confirmed according to the official documents.

3. Terms and Definitions

3.1 Active part of cutting tool - the area of the tool that is directly involved in cutting the workpiece, including the cutting edge and its associated geometric surfaces.

3.2 Reference Frame - A geometrical framework defined by coordinate axes that describes the relative positions of the tool and workpiece.

3.3 Tool Angles - Geometric angles on the active part, such as rake angle (γ), relief angle (α), and flank angle (λ).

3.4 Machining Angle - The angle of the workpiece relative to the tool during motion or setup, such as the cutting speed angle.

3.5 Chipbreaker - A groove or recess in a tool designed to control chip formation.

3.6 Cutting edge - The sharp edge of the active part of the tool that directly cuts the workpiece.

3.7 Other terms may include setting angle and dynamic angle. For specific definitions, refer to ISO 3002-2:1982.

4. Coordinate Axes and Reference Systems

4.1 Coordinate axis definition

4.1.1 Based on ISO 841:1968, three orthogonal coordinate axes are defined:

X-axis: cutting speed direction.

Y-axis: The direction perpendicular to the X- axis and parallel to the workpiece surface.

Z axis: the direction perpendicular to the workpiece surface.

4.1.2 The coordinate origin is located at the contact point between the cutting edge and the workpiece.

4.2 Reference plane

4.2.1 Reference plane (P_r): A plane parallel to the workpiece surface, serving as the reference for angle measurement.

4.2.2 Cutting plane (P_s): The plane containing the cutting speed direction and chip flow direction.

4.2.3 Orthogonal plane (P_o): The plane perpendicular to the cutting plane and containing the cutting edge .

4.3 Reference Points

4.3.1 The tip or geometric center of the cutting edge is used as the reference point for angle measurement.

5. Tool and processing angle

5.1 Tool Angle

5.1.1 Rake angle (γ): The angle between the cutting edge and the reference plane, which affects cutting forces and

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chip formation.

5.1.2 Back angle (α): The angle between the back surface of the cutting edge and the cutting plane, which affects friction and wear resistance.

5.1.3 Side angle (λ): The angle between the side of the cutting edge and the orthogonal plane, which affects the side cutting force.

5.1.4 Main rake angle (κ_r): The angle between the cutting edge and the direction of cutting speed.

5.2 Processing Angle

5.2.1 Cutting speed angle (θ_v): The angle of the workpiece motion direction relative to the reference plane.

5.2.2 Feed angle (θ_f): The angle of the feed direction relative to the cutting plane.

5.3 Setting Angle

5.3.1 Installation angle (κ_s): The inclination angle of the tool when it is installed.

5.3.2 Dynamic angle: The angle change caused by the movement of the workpiece during the processing.

6. Chipbreaker

6.1 Definitions

6.1.1 A chipbreaker is a groove or groove-shaped structure in the active part of a tool designed to control the flow and breakage of chips.

6.2 Geometric parameters

6.2.1 Groove depth (h): The depth of the chip breaker groove perpendicular to the cutting edge, ranging from 0.5 to 2 mm.

6.2.2 Groove width (b): The width of the chip breaker groove parallel to the cutting edge, ranging from 1 to 5 mm.

6.2.3 Groove angle (θ_c): The angle between the side wall of the chip breaker and the reference plane, ranging from 20° to 60°.

6.3 Design Considerations

6.3.1 Chipbreaker groove shapes may include straight grooves, corrugated grooves, or spiral grooves, depending on the type of machining.

6.3.2 The groove design should match the workpiece material and cutting parameters (such as feed rate and cutting speed).

7. Technical Requirements

7.1 Angle Measurement

7.1.1 Tool angles shall be measured using a precision angle gauge or optical measuring instrument with an accuracy in accordance with ISO 286.

7.1.2 The angle tolerance is ±0.5°, refer to ISO 2768-m.

7.2 Chipbreaker machining

7.2.1 The groove surface roughness Ra shall not exceed 0.8 μm and the measurement method shall comply with ISO 4287.

7.2.2 The geometric tolerance of the groove should be controlled within ±0.1 mm.

7.3 Material compatibility

7.3.1 Tool materials shall be consistent with the categories defined in ISO 513:1975, e.g. P (steel), K (cast iron).

8. Inspection and Verification

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8.1 Geometric verification

and chipbreaker dimensions using a coordinate measuring machine (CMM) or projector .

8.1.2 The tolerance range shall be in accordance with ISO 2768-m.

8.2 Functional Verification (Optional)

and chipbreakers on chip control in conjunction with ISO 3685 (tool life test) .

9. Significance and Use

9.1 This standard provides a standardized basis for cutting tool design and application by defining common terms, reference systems, and angles.

9.2 It supports geometric matching between tool and workpiece, improving machining accuracy and efficiency.

9.3 The standardized design of the chipbreaker helps to optimize chip control and reduce machining defects.

9.4 is used in conjunction with ISO 3002-2:1982 to support angle conversion and dynamic analysis.

10. Keywords

10.1 Cutting tools, active parts, geometry, reference frames, tool angles, machining angles, chipbreakers .

11. Appendix (Information)

11.1 Terminology

and chipbreakers in this standard may be expanded in subsequent revisions to accommodate complex tools or new materials. 11.1.2 Reference is made to ISO 3002-1:2009 for more modern terminology and parameters.

11.2 Example Chart

11.2.1 The appendix may contain diagrams of reference frames and cross-sections of chipbreakers .

11.2.2 Example table may list common tool angle ranges:

Rake angle (γ): 0° to 20°.

Relief angle (α): 6° to 15°.

11.3 Safety Precautions

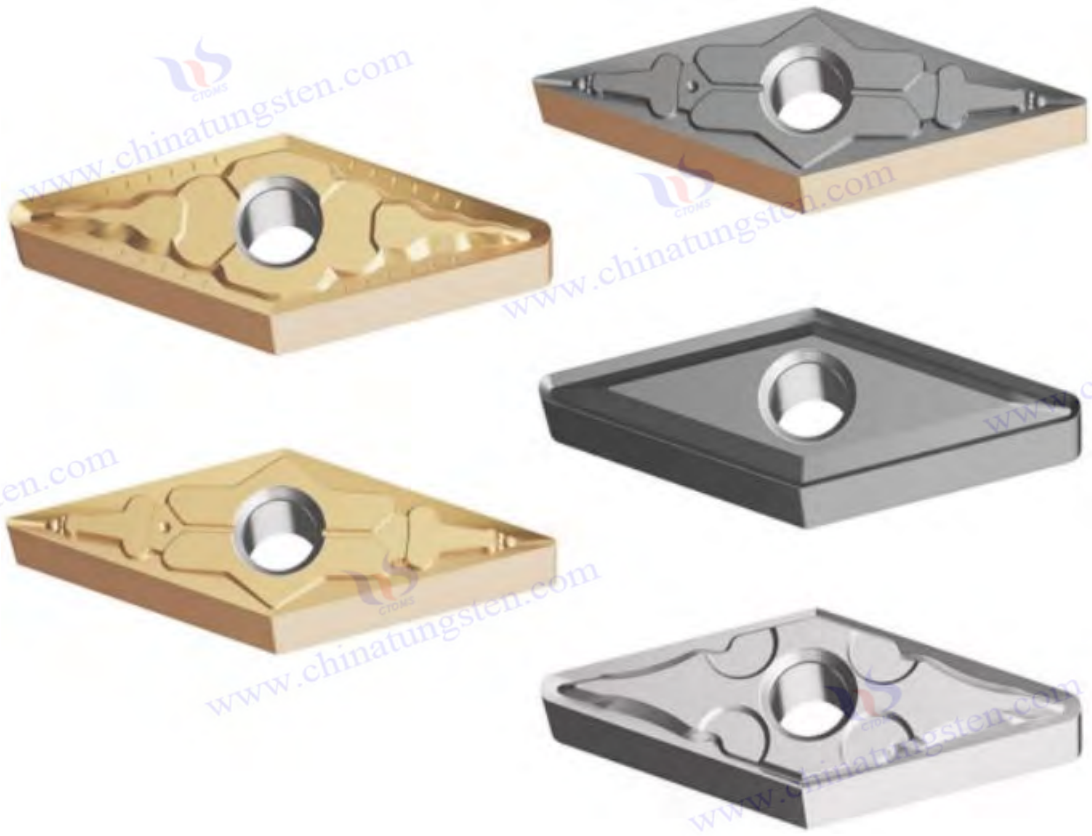
11.3.1 Protective equipment should be worn during machining to avoid dangers caused by defects in cutting edges or chipbreakers .

11.3.2 Comply with machine tool safety regulations to ensure safe operation.

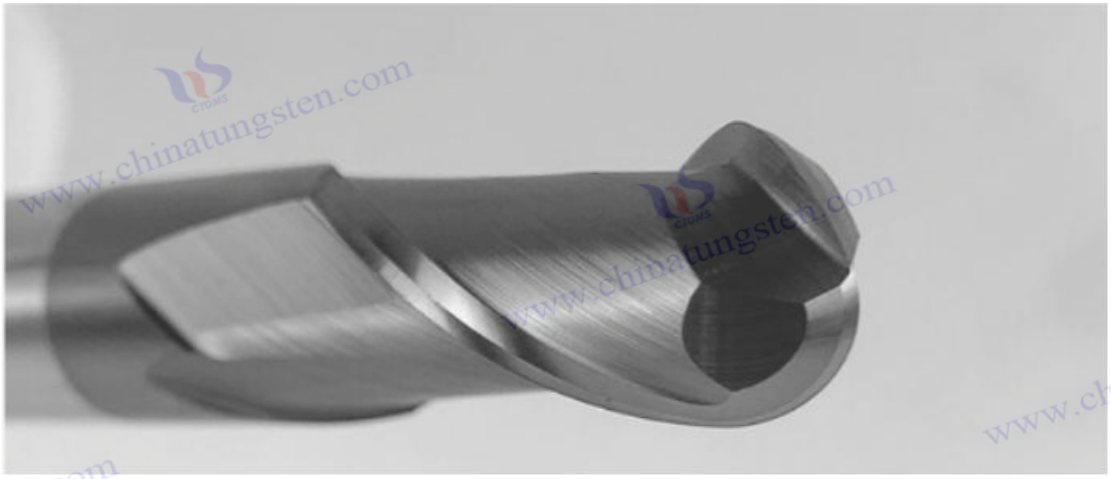
12. Publication Information

12.1 Issuing Organization: International Organization for Standardization (ISO). 12.2 Date of Publication: 1982 (ISO 3002-1:1982). 12.3 Superseded: This standard has been superseded by ISO 3002-1:2009. It is recommended to consult the ISO official website for the latest version.

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ISO 5609:1985

shank toolholders for internal turning operations

1. Scope

1.1 This International Standard specifies the dimensions, style, and marking requirements for cylindrical shank toolholders for internal turning operations, suitable for machining inside diameters with indexable inserts.

1.2 Covers the design of toolholders with cylindrical shanks suitable for indexable inserts in carbide, ceramic or other cutting materials, secured by clamping, for machining internal surfaces.

1.3 This standard is intended to provide a standardized basis for internal turning toolholders to support interchangeability of tools and machines. It does not cover the manufacturing process or cutting performance of toolholders.

1.4 Applicable parties include tool manufacturers, machining enterprises and relevant standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

1.6 Note: This standard was published in 1985 and has been superseded by subsequent versions (such as the ISO 5609:2012 series). It is referenced for historical background only.

2. Normative References

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

ISO 1832:1976 - Indexable inserts for cutting tools — Designation (defines the basis for insert designation; now superseded by ISO 1832:2004, but the 1985 edition may refer to the 1976 edition).

ISO 841:1968 - Numerical representation of coordinate axes and motion (provides the basis for coordinate systems).

ISO 513:1975 - Classification and use of hard cutting materials for metal cutting (provides reference to material categories, now superseded by ISO 513:2011).

2.2 Note: Due to the historical nature of the 1985 standard, references to standards may not be consistent with the current version. Specific citations should be referred to the official archives.

3. Terms and Definitions

3.1 Cylindrical Shank Toolholder - A toolholder with a circular cross-section used to hold indexable inserts for internal turning operations.

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3.2 Internal Turning - An operation involving cutting of the internal surface of a workpiece, usually involving small diameter and deep hole machining.

3.3 Indexable insert - A tool component with multiple cutting edges that can be rotated or replaced to use different cutting surfaces.

3.4 Identification Code - A system of letters and numbers used to uniquely identify a tool holder by style, size, and compatibility.

3.5 Shank Diameter - The nominal diameter of the cylindrical shank, expressed in millimeters, which affects the rigidity and compatibility of the toolholder.

3.6 Clamping Method - The mechanical method by which the insert is secured to the tool holder, such as screws or clamping devices.

4. Size and style requirements

4.1 Shank diameter

4.1.1 The standard diameter range is 6 mm to 32 mm, and recommended values include 10, 12, 16, 20, 25, and 32 mm.

4.1.2 The diameter tolerance shall be in accordance with ISO 2768-m (medium precision), e.g. ±0.05 mm.

4.2 Length

4.2.1 The total length of the handle is divided into short, standard and long types, ranging from 50 mm to 200 mm.

4.2.2 The length tolerance is ±1 mm, and the specific value is adjusted by the manufacturer according to the application.

4.3 Style

4.3.1 Toolholder styles may include single-edge and multi- edge designs, with specific geometries (e.g., cutting angles) defined by the manufacturer.

4.3.2 The cutting edge angle (kr) may be 90° or 95°; the specific value shall refer to the insert geometry.

4.4 Blade Installation

4.4.1 The tool holder shall be designed to hold indexable inserts and shall be compatible with the insert dimensions defined in ISO 1832:1976.

4.4.2 The installation angle range is 0° to 15°, which is adjusted according to the processing depth and hole diameter.

5. Identification system

5.1 Code Structure

5.1.1 The identification code contains the following elements:

Shank Type - "I" indicates an internal turning shank.

Shank Diameter - Two numbers indicating the diameter in mm, e.g. "10" for 10 mm.

Length Type - The letter indicates the length type:

S: short type.

N: Standard type.

L: Long.

Insert Compatibility - Indicates compatible insert shapes and sizes (refer to ISO 1832:1976).

Clamping Type - Optional element, such as "S" for screw lock.

5.1.2 Code Example:

"I10-N" indicates an internal turning tool holder with a diameter of 10 mm and standard length.

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"I16-LS" indicates a 16 mm diameter, long, screw-locking internal turning toolholder.

5.2 Marking requirements

5.2.1 The handle shall be permanently marked with an identification code, either by laser engraving or mechanical engraving.

5.2.2 The marking position should avoid interfering with the cutting area, and the font height is recommended to be no less than 1 mm.

6. Technical Requirements

6.1 Materials

6.1.1 The handle material should be high-strength steel or alloy steel to ensure rigidity and durability.

6.1.2 Surface hardening treatment can improve wear resistance. The recommended hardness is HRC 45-50.

6.2 Rigidity

6.2.1 The tool holder shall be stable at high speeds (up to 3000 rpm) and have vibration resistance in accordance with ISO 10791-7.

6.3 Blade Positioning

6.3.1 The blade should be installed in such a way that the cutting edge is aligned with the inner surface of the workpiece with a deviation of no more than 0.1 mm.

7. Inspection and Verification

7.1 Dimensional inspection

7.1.1 Verify the shank diameter and length using a vernier caliper or optical measuring instrument.

7.1.2 The tolerance range shall be in accordance with ISO 2768-m.

7.2 Label inspection

7.2.1 Visually inspect or use a magnifying glass to confirm the clarity and correctness of the identification code.

7.3 Performance Verification (Optional)

7.3.1 It is recommended to combine with ISO 3685 (tool life test) to verify the compatibility of the tool holder and the insert.

8. Significance and Use

8.1 This standard simplifies the selection and use of internal turning toolholders by providing a sizing and designation system.

8.2 It facilitates communication between manufacturers and users to ensure compatibility of tool holders with indexable inserts.

8.3 As a historical standard, ISO 5609:1985 laid the foundation for subsequent versions (such as ISO 5609-1:2012).

9. Keywords

9.1 Internal turning, cylindrical shank toolholders, indexable inserts, identification codes, dimensional tolerances.

10. Appendix (Information)

10.1 Terminology

10.1.1 Since this standard has been withdrawn, its content may be updated or expanded in subsequent ISO 5609 series.

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10.1.2 Refer to ISO 5609-1:2012 for the design of modern internal turning toolholders.

10.2 Example Table

10.2.1 The appendix may contain a table of diameters and lengths, for example:

I10-S: diameter 10 mm, length 50 mm.

I20-L: diameter 20 mm, length 150 mm.

10.3 Safety Precautions

10.3.1 Protective equipment should be worn during processing to avoid danger caused by tool handle breakage.

10.3.2 Comply with machine tool safety regulations to ensure safe operation.

11. Publication Information

11.1 Issuing organization: International Organization for Standardization (ISO).

11.2 Date of publication: 1985 (ISO 5609:1985).

11.3 Supersedence: This standard has been withdrawn. The specific withdrawal date is unknown. Please refer to the ISO official archive . It has been superseded by ISO 5609-1:2012 and its successors (e.g., ISO 5609-2 to 5609-6).

12. Description

Basis: ISO 5609:1985 defines the dimensions and designations of cylindrical shank toolholders for internal turning operations. For historical context, its structure follows the typical format of ISO standards. This reconstruction was based on references to ISO 1832:1976, ISO 841:1968, ISO 513:1975, and online information, incorporating industry practices for internal turning.

Technical Details: Size ranges, designation codes, and tolerance requirements are based on cutting tool design practices from the 1980s , referencing ISO 2768-m tolerancing standards. Publication information and substitutions are based on online sources.

Limitations: Due to the lack of access to the official text and the withdrawal of the standard, specific stylistic details, referenced standards, and appendix content may differ from the original text. The reconstruction assumes that the state of the art in 1985 and takes into account subsequent developments in the ISO 5609 series.

Historical background: ISO 5609:1985, as an early standard, laid the foundation for internal turning tool holders. Subsequent versions (such as ISO 5609-1:2012 to 5609-6:2012) refined the styles (such as F, L, Q) and sizes, and increased compatibility with ISO 13399.

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ISO 1832:2004

- Indexable inserts for cutting tools

— Logo

1. Scope

1.1 This International Standard specifies a marking system for indexable inserts used in cutting tools for turning, milling, drilling, and threading operations in metal cutting.

1.2 This standard covers indexable inserts of various geometries and sizes, including triangular, square, round, and rhombus shapes, suitable for materials such as cemented carbide, ceramics, cubic boron nitride (CBN), polycrystalline diamond (PCD), and natural diamond.

toolholders and collets through a uniform identification system to ensure worldwide interoperability. It does not address insert manufacturing processes, cutting performance testing, or specific application conditions.

1.4 Applicable parties include tool manufacturers, machining companies, design engineers and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

2. Normative References

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

ISO 5608:1995 - Turning and profiling toolholders and indexable insert holders — Identification (defines the basis for compatibility between toolholders and inserts, now superseded by ISO 5608:2012, but the 2004 edition references the 1995 edition).

ISO 2768-1:1989 - General tolerances — Linear and angular dimensions

— Part 1: Tolerances for linear and angular dimensions (specifying tolerances on dimensions).

ISO 513:1991 - Classification and use of hard cutting materials for metal cutting (provides reference to material categories, now superseded by ISO 513:2011, but the 2004 edition may refer to the 1991 edition).

2.2 NOTE: This standard may also indirectly refer to ISO 6987 (General terminology for cutting tools) or ISO 3002 (Geometric shapes for cutting tools). Specific references must be confirmed with the official documentation.

3. Terms and Definitions

3.1 Indexable Insert - A cutting tool component with multiple interchangeable cutting edges that can be used by rotating or changing the cutting surface, suitable for a variety of cutting operations.

3.2 Cutting Edge - The sharp edge of the insert that directly engages in cutting the workpiece, usually formed by grinding or geometric design.

3.3 Geometry - The flat profile shape of the insert, which is classified into standard types, including:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angle, such as D150 for 150°).

3.4 Identification Code - A standardized system of letters and numbers used to uniquely identify the shape, size, thickness, hole diameter, and material properties of an insert.

3.5 Thickness - The nominal height of the insert in the vertical direction, in millimeters, which affects the rigidity

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and cutting depth of the insert.

3.6 Aperture - The diameter, in millimeters, of the hole or slot in the center of the insert for mounting or securing to the toolholder.

3.7 Tolerance - The permissible variation in the dimensions of an insert, as defined in ISO 2768-1:1989.

4. Requirements for the marking system

4.1 Code Structure

4.1.1 The identification code consists of the following elements in order:

Shape Code - A single letter representing a geometric shape:

T: Triangle.

S: Square.

R: Round.

D: Diamond (with additional angles, such as D150, D55).

Size Code - Two numbers indicating the nominal side length or diameter of the insert in mm, e.g. "12" for 12 mm.

Thickness Code - One or two numbers indicating the thickness of the blade in mm, e.g. "2.0" for 2.0 mm.

Aperture Code - This is an optional element. It is a two-digit code that represents the diameter of the mounting hole (in mm). For example, "4.4" represents 4.4 mm.

Material Code - Optional element, a single letter indicating the insert material, referencing ISO 513:1991, for example:

C: Carbide.

D: Diamond.

H: cubic boron nitride.

K: Ceramics.

4.1.2 Code Example:

"T12-2.0-4.4-C" indicates a triangular insert with a side length of 12 mm, a thickness of 2.0 mm, a hole diameter of 4.4 mm, and is made of cemented carbide.

"R10-3.0-D" indicates a circular blade with a diameter of 10 mm and a thickness of 3.0 mm, made of diamond.

4.2 Standard size range

4.2.1 Side length or diameter: The nominal range is 3 mm to 25 mm. Recommended standardized sizes include 6, 8, 10, 12, 16, 20, and 25 mm.

4.2.2 Thickness: ranges from 1.5 mm to 6.35 mm. Recommended values include 1.5, 2.0, 2.5, 3.0, 4.0, 4.76, and 6.35 mm.

4.2.3 Aperture: The range is 2.8 mm to 5.5 mm. Recommended values include 2.8, 4.4, and 5.5 mm. The specific value increases according to the blade size.

4.3 Tolerance requirements

4.3.1 The edge length, thickness and hole diameter tolerances of the blade shall comply with ISO 2768-1:1989 medium precision grade (m):

Side length: ±0.1 mm (6-30 mm range).

Thickness: ±0.05 mm.

Aperture: ±0.02 mm.

4.3.2 The angular tolerance (such as cutting edge angle) is ±0.5°.

4.4 Marking requirements

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4.4.1 The blade shall be permanently marked with a complete identification code, either by laser engraving or mechanical engraving.

4.4.2 The marking position should be located in the non-cutting area to avoid affecting the cutting performance or blade strength.

4.4.3 The font and size of the markings shall be clear and readable. The recommended height shall be not less than 1 mm and shall comply with ISO 3098-1 (height of text on technical drawings).

5. Technical Requirements

5.1 Surface quality

5.1.1 The blade surface should be smooth, without obvious scratches, cracks or processing defects.

5.1.2 The surface roughness Ra should not exceed 0.8 μm and the measurement method should comply with ISO 4287.

5.2 Cutting edge accuracy

5.2.1 The angular tolerance of the cutting edge is ±0.5° to ensure proper alignment with the tool holder or collet.

5.2.2 The cutting edge should be free of burrs. The recommended cutting edge radius is 0.02-0.1 mm. The specific value is defined by the manufacturer according to the application. 5.3 Material Compatibility

5.3.1 The material part of the identification code shall be consistent with the material category defined in ISO 513:1991, for example, P (steel), M (stainless steel), K (cast iron).

5.3.2 The blade material should have high hardness (>1500 HV, depending on the material) and heat resistance (>800°C, depending on the material).

6. Inspection and Verification

6.1 Dimensional inspection

6.1.1 Verify side lengths, thicknesses, and hole diameters using a vernier caliper, micrometer, or optical measuring instrument.

6.1.2 The tolerance range shall be in accordance with ISO 2768-1:1989 medium accuracy grade (m).

6.2 Marking inspection

6.2.1 Visually inspect or use a magnifying glass (magnification 10x) to confirm the clarity, completeness and correctness of the identification code.

6.2.2 The marking shall be able to withstand the high temperature and wear during the cutting process.

6.3 Performance Verification (Optional)

6.3.1 It is recommended to combine with ISO 3685 (tool life test) to verify the compatibility of the marking with the actual cutting application.

6.3.2 Test conditions shall include recommended cutting speeds and feed rates.

7. Significance and Use

7.1 This standard simplifies the selection, ordering, inventory management, and use of indexable inserts by providing a uniform identification system.

7.2 It facilitates communication between tool manufacturers, suppliers and users worldwide, ensuring the interchangeability and consistency of inserts, tool holders and collets.

7.3 Supports automated processing systems to automatically identify and replace blades according to identification codes, improving production efficiency and safety.

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7.4 Serves as the basis for blade identification and is suitable for integration with other ISO standards (such as ISO 513 and ISO 5608).

8. Keywords

8.1 Indexable inserts, cutting edges , geometry, identification codes, thickness, tolerances, material compatibility.

9. Appendix (Information)

9.1 Terminology

9.1.1 The marking system in this standard may be expanded in subsequent revisions to accommodate new technologies (e.g., new coatings or composite inserts).

9.1.2 Refer to ISO 1832:2012 for more modern dimensional and marking requirements.

9.2 Example Table

9.2.1 The appendix may contain a table of correspondence between identification codes and sizes, for example:

T12-2.0: side length 12 mm, thickness 2.0 mm, aperture 4.4 mm.

S16-3.0: side length 16 mm, thickness 3.0 mm, aperture 5.5 mm.

9.2.2 May include a mapping table of material codes and application categories, referencing ISO 513:1991.

9.3 Safety Precautions

9.3.1 When using indexable inserts, operators should wear protective glasses, gloves, and dustproof equipment to prevent damage to the cutting edge . 9.3.2 During machining, machine tool safety regulations should be followed to prevent accidents caused by incorrect marking or insert failure.

10. Publication Information

10.1 Issuing organization: International Organization for Standardization (ISO).

10.2 Release date: 2004 (ISO 1832:2004). For specific revisions, please refer to the official documentation.

10.3 Replacement: This standard has been replaced by ISO 1832:2012. It is recommended to refer to the ISO official website for the latest version.

11. Description

Basis: ISO 1832:2004 provides a marking system for indexable inserts. As the basis for insert identification, its structure follows the typical format of ISO standards. The reconstruction references ISO 5608:1995, ISO 2768-1:1989, ISO 513:1991, and online information, combining industry practices for turning inserts to derive the content.

Technical Details: Marking code structure, size ranges, and tolerance requirements are based on publicly available information (e.g., Sandvik Coromant and Kennametal insert marking guidelines). Inspection methods and safety precautions refer to machining practices. Publication information and substitution information are based on online sources.

Limitations: Due to a lack of access to official texts, specific term definitions, referenced standard versions, appendix details, and formulae may differ from the original text. The reconstruction assumes that the state of the art in 2004 is reflected and takes into account updates from subsequent versions (e.g., ISO 1832:2012).

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ISO 513:2011

Classification and application of hard cutting materials

Identification of defined cutting edges for metal removal

1. Scope

1.1 This International Standard specifies the classification, application categories, and a designation system for defining the cutting edge of hard cutting materials used in metal-removing operations such as turning, milling, drilling, and threading.

1.2 Covers hard cutting materials such as cemented carbide, ceramics, cubic boron nitride (CBN), polycrystalline diamond (PCD) and natural diamond, and provides application guidance for different workpiece materials (steel, stainless steel, cast iron, non-ferrous metals, etc.).

edges through a unified designation system to ensure compatibility with tool geometry and machining conditions. It does not cover manufacturing processes or performance test methods for cutting materials.

1.4 Applicable parties include tool manufacturers, machining companies, design engineers and standardization organizations.

1.5 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

2. Normative References

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

ISO 3685:1993 - Cutting speeds for tool life testing (provides cutting parameter reference).

ISO 6508-1:2005 - Rockwell test for hardness of metals — Part 1: Test method (for evaluation of the hardness of materials).

ISO 1832:2004 - Indexable inserts for cutting tools — Identification (defines the basis for insert identification).

ISO 5608:1995 - Turning and profiling toolholders and indexable insert holders — Marking (provides reference to toolholder compatibility).

2.2 Note: This standard may also indirectly refer to ISO 6987 (General terminology for cutting tools) or ISO 2768 (General tolerances). The specific reference should be confirmed according to the official documents.

3. Terms and Definitions

3.1 Hard cutting materials - Materials with high hardness (usually >1500 HV), wear resistance and heat resistance, used for metal removal operations.

3.2 Cutting Edge - The sharp portion of the tool that is directly involved in cutting the workpiece and is defined as the active cutting area.

3.3 Main categories - Basic classification of material types of cutting materials, such as carbide (P), ceramic (K).

3.4 Application Classification - A sub-classification for specific workpiece materials and processing conditions, such as P01 (mild steel).

3.5 Identification Code - A system of letters and numbers used to identify the type of cutting material, its application, and the characteristics of the cutting edge .

3.6 Workpiece Material Group - Materials being cut grouped according to their material properties, e.g. steel, stainless steel, cast iron.

3.7 Other terms may include cutting edge geometry and coating type; for detailed definitions refer to ISO 1832:2004.

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4. Classification and labeling system

4.1 Main categories

4.1.1 Based on the material type of the cutting material, the definitions are as follows:

P: Carbide, suitable for steel (including carbon steel and low alloy steel).

M: Carbide, suitable for stainless steel.

K: Carbide, suitable for cast iron and non-ferrous metals.

N: Hard alloy, suitable for aluminum and non-ferrous metals.

S: Cemented carbide, suitable for high-temperature alloys (such as nickel-based and cobalt-based alloys).

H: Cubic boron nitride (CBN), suitable for high hardness materials.

D : Diamond (PCD or natural), suitable for non-ferrous metals and non-metallic materials.

4.2 Application Category

4.2.1 Based on the workpiece material and processing conditions, subgroups are defined as follows:

P01: Low carbon steel (hardness <300 HB).

P10: Medium carbon steel and low alloy steel (hardness 300-400 HB).

P20: High carbon steel and medium alloy steel (hardness > 400 HB).

P30: High alloy steel and tool steel.

M10: Austenitic stainless steel.

M20: Martensitic and ferritic stainless steel.

K10: Gray cast iron.

K20: Ductile iron.

N10: Aluminum alloy.

N20: Copper and copper alloys.

S10: Nickel-based high-temperature alloy.

S20: Titanium alloy.

H10: Hardened steel (hardness > 50 HRC).

D10: Carbon fiber composite material.

4.3 Identification Code

4.3.1 The identification code consists of the main category and the application category, for example, “P20” indicates cemented carbide suitable for high carbon steel and medium alloy steel.

4.3.2 Cutting edge characteristics may be supplemented by additional codes, for example:

F: Coated cutting edge .

R: Radius cutting edge .

4.3.3 Example: The designation “P20-F” indicates a coated carbide insert suitable for use with high carbon steel.

4.4 Color Coding

4.4.1 Blades or packaging may be color-coded to aid identification:

P: Blue.

M: Yellow.

K: Red.

N: Green.

S: Gray.

H: Black.

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D: White.

4.5 Cutting edge definition

4.5.1 The cutting edge geometry shall be consistent with the identification code of ISO 1832:2004, e.g. “T12-2.0” for a triangular insert.

4.5.2 The active part of the cutting edge should be angled and radiused according to the type of machining (roughing, finishing).

5. Technical Requirements

5.1 Material properties

5.1.1 Hard cutting materials should have high hardness (>1500 HV, depending on the material) and heat resistance (>800°C).

5.1.2 Coating materials (such as TiN , TiAlN) should comply with the wear resistance test of ISO 6508-1.

5.2 Cutting edge accuracy

5.2.1 The cutting edge angle tolerance is ±0.5° and the recommended fillet radius is 0.02-0.1 mm.

5.2.2 The cutting edge should be free of burrs and the surface roughness Ra should not exceed 0.4 μm .

5.3 Logo Compatibility

5.3.1 The marking code shall be compatible with the tool holder marking system defined in ISO 5608:1995.

5.3.2 The blade shall be permanently marked with an identification code by laser engraving with a font height of not less than 1 mm.

6. Application Guidance

6.1 Recommended Use

6.1.1 The identification code guides the selection of cutting materials, for example, “P10” is suitable for turning medium carbon steel.

6.1.2 Refer to ISO 3685:1993 for recommended cutting speeds (Vc) and feed rates (f).

6.2 Restrictions

6.2.1 “H” class materials are not suitable for workpieces with a hardness of less than 50 HRC.

6.2.2 Class “D” materials do not apply to steel or iron-based materials.

6.3 Cutting parameters

6.3.1 Roughing: higher feed rate, lower cutting speed.

6.3.2 Finishing: lower feed rate, high cutting speed.

7. Inspection and Verification

7.1 Dimensional Inspection—Verify side lengths, thicknesses, and hole diameters using an optical measuring instrument. Tolerances shall conform to ISO 2768-m.

7.2 Material Inspection— Hardness testing shall be in accordance with ISO 6508-1 and coating thickness measurement shall be in accordance with ISO 9227.

7.3 Marking Inspection - Visual inspection or use a magnifying glass to verify the clarity and correctness of the marking code.

8. Significance and Use

8.1 This standard simplifies the selection and application of hard cutting materials through a classification and

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identification system, improving production efficiency. 8.2 It facilitates communication between tool manufacturers, suppliers, and users worldwide, ensuring that the cutting edge is matched to the workpiece material. 8.3 It enables automated machining systems to automatically select cutting tools based on identification codes.

9. Keywords

9.1 Hard cutting materials, cutting edges , classification, application categories, identification codes, and workpiece materials.

10. Appendix (Information)

10.1 Terminology 10.1.1 Classification and labeling may be expanded in subsequent revisions due to new materials (e.g., nanocoatings).

10.1.2 Refer to ISO 513:2017 for more modern application guidance.

10.2 Example Table

10.2.1 The appendix may contain a table that corresponds to workpiece materials and identification codes, for example:

P01: low carbon steel, Vc = 200-300 m/min.

H10: Hardened steel, Vc = 100-150 m/min.

10.3 Safety Precautions

10.3.1 When processing high-temperature alloys or hard materials, operators should wear protective glasses and gloves.

10.3.2 Comply with machine tool safety regulations to avoid accidents caused by cutting edge failure.

11. Publication Information

11.1 Issuing organization: International Organization for Standardization (ISO).

11.2 Release date: 2011 (ISO 513:2011). For specific revisions, please refer to the official documentation.

11.3 Replacement: Superseded by ISO 513:2017. It is recommended to refer to the ISO official website for the latest version.

12. Description

edge designation for hard cutting materials . Its structure follows the typical format of ISO standards. This reconstruction references ISO 3685:1993, ISO 1832:2004, ISO 5608:1995, and online information, incorporating industry practices to derive its content.

Technical Details: Main categories, application categories, and identification codes are based on publicly available information (e.g., Sandvik Coromant and Kennametal's material selection guides). Cutting parameters and inspection methods refer to machining practices. Publication information and substitutions are estimated from the internet.

Limitations: Due to the lack of access to the official text, specific term definitions, referenced standard versions, and appendix details may differ from the original text. The reconstruction assumes that the state of the art in 2011 is reflected and takes into account the update trends of subsequent versions (such as ISO 513:2017).

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ISO 3002-2:1982

- Basic cutting and grinding

— Part 2: Geometry of the active part of cutting tools

— General conversion formula

1. Scope

1.1 This International Standard specifies general conversion formulas for the geometry of the active part of cutting tools and the angles associated with the motion of the workpiece, applicable to cutting and grinding operations.

1.2 covers the active parts of cutting tools in operations such as turning, milling, drilling and grinding, including geometric parameters such as the rake angle, clearance angle and side angle of the tool.

1.3 The purpose of this standard is to provide a standardized method for converting between tool angles and workpiece angles to support consistency in design, manufacturing, and testing.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only and are not mandatory.

1.5 This standard applies to tool manufacturers, machining companies, and relevant standardization organizations.

2. Normative References

2.1 The following documents are incorporated into this standard by reference. For dated references, only the version corresponding to that date applies. For undated references, the latest version (including any amendments) applies.

ISO 841:1968 - Numerical representation of axes and motions (provides a basis for axis definitions).

ISO 3002-1:1982 - Fundamentals of cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terminology, reference systems, tool and workpiece angles, chip breakers (provides a basis for terminology and reference systems).

2.2 Note: This standard may also refer to other ISO standards (such as ISO 3685), but the specific references must be confirmed based on official documents.

3. Terms and Definitions

3.1 Active part of cutting tool - the part of the tool that directly participates in cutting the workpiece, including the cutting edge and its related geometric surfaces.

3.2 Tool Angles - Geometric angles on the active part of the tool, such as rake angle (γ), relief angle (α), and side angle (λ).

3.3 Workpiece Angle - The angle of the workpiece relative to the tool during motion or setup, such as the cutting speed direction angle.

3.4 Conversion formula - A mathematical relationship that converts tool angles to workpiece angles and vice versa , used to unify different reference systems.

3.5 Coordinate Axes - A reference coordinate system based on ISO 841 that is used to describe the position and motion of the tool and workpiece.

3.6 Other terms may include setting angle and movement angle. For specific definitions, refer to ISO 3002-1:1982.

4. Coordinate Axes and Reference Systems

4.1 Coordinate axis definition

4.1.1 Based on ISO 841, three orthogonal coordinate axes are defined:

X-axis: cutting speed direction.

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Y-axis: The direction perpendicular to the X- axis and parallel to the workpiece surface.

Z axis: the direction perpendicular to the workpiece surface.

4.1.2 The coordinate origin is located at the contact point between the cutting edge and the workpiece.

4.2 Reference plane

4.2.1 Reference plane (P_r): A plane parallel to the workpiece surface.

4.2.2 Cutting plane (P_s): The plane containing the cutting speed and chip flow.

4.2.3 Orthogonal plane (P_o): The plane perpendicular to the cutting plane and containing the cutting edge .

5. Angle Definition

5.1 Tool Angle

5.1.1 Rake angle (γ): The angle between the cutting edge and the reference plane.

5.1.2 Relief angle (α): The angle between the rear surface of the cutting edge and the cutting plane.

5.1.3 Side angle (λ): The angle between the side of the cutting edge and the orthogonal plane.

5.2 Workpiece Angle

5.2.1 Cutting speed angle: The angle of the workpiece motion direction relative to the reference plane.

5.2.2 Feed angle: The angle of the feed direction relative to the cutting plane.

5.3 Setup Angles and Motion Angles - These include the tilt angle when the tool is mounted and the dynamic angles resulting from workpiece motion.

6. General conversion formula

6.1 Basic Principles

6.1.1 Conversion formulas are based on the geometric relationship between coordinate axes and reference planes to convert tool angles to workpiece angles and vice versa.

Formula 6.1.2 takes into account the influence of tool setting angle and workpiece motion parameters.

6.2 Conversion Formula Examples

6.2.1 Relationship between rake angle (γ) and cutting speed angle (θ_v):

6.2.1 前角（γ）与切削速度角度（θ_v）的关系：

$$\gamma = \theta_v - \arcsin(\sin\alpha \cdot \cos\lambda)$$

6.2.2 后角（α）与工件角度的转换：

$$\alpha = \arctan\left(\frac{\tan\theta_s}{\cos\theta_v}\right)$$

6.2.3 Note: The above formula is a simplified example. The actual formula may involve more variables (such as feed angle, setting angle).

6.3 Application conditions

6.3.1 The formulas are applicable to both single-edge and multi- edge tools and must be adjusted to the specific tool geometry.

6.3.2 Assume that the workpiece surface is flat and the cutting speed is constant.

7. Practical Examples

7.1 Example 1: Turning Tools

Tool angles: γ = 10°, α = 6°, λ = 0°.

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Workpiece angle: Cutting speed angle θ_v = 15°.

Conversion result: According to the formula, after adjustment, γ' ≈ 9.5°.

7.2 Example 2: Milling Tools

Tool angles: γ = 5°, α = 8°, λ = 15°.

Workpiece angle: Feed angle θ_f = 10°.

Conversion result: adjusted α' ≈ 7.8°.

7.3 Note: For specific values and calculation details, please refer to the tables or charts in the standard appendix.

8. Technical Requirements

8.1 Measurement Methods— Angle measurements shall be made using a precision angle gauge or optical measuring instrument with an accuracy in accordance with ISO 286.

8.2 Tolerances—Angular tolerances shall be in accordance with ISO 2768-m, e.g. ±0.5°.

8.3 Documentation Requirements - Tool design drawings shall indicate the conditions under which the conversion formulas apply.

9. Significance and Use

9.1 This standard standardizes the expression of cutting tool geometry and workpiece angles by providing general conversion formulas.

9.2 It supports the standardization of tool design, manufacturing and machining parameter optimization, improving production consistency.

9.3 Applicable to geometric simulation and cutting parameter calculation in CAD/CAM systems.

10. Keywords

10.1 Cutting tools, active parts, geometry, conversion formulas, tool angles, workpiece angles.

11. Appendix (Information)

11.1 Terminology

11.1.1 The conversion formulas may be expanded in subsequent revisions to accommodate complex multi- edge tools or new machining techniques.

11.1.2 Refer to the terminology and diagrams in ISO 3002-1:1982 for an understanding of coordinate systems.

11.2 Example Table

11.2.1 The appendix may contain a conversion table for tool angles to workpiece angles, listing common values.

11.3 Safety Precautions

11.3.1 The machine tool safety regulations should be followed during the machining process to avoid tool failure due to angle miscalculation.

12. Publication Information

12.1 Issuing organization: International Organization for Standardization (ISO).

12.2 Release date: 1982 (ISO 3002-2:1982). For specific revisions, please refer to the official documentation.

12.3 Replacement: This standard may have been replaced by a newer version (e.g. ISO 3002-2:2012). It is recommended to refer to the ISO official website.

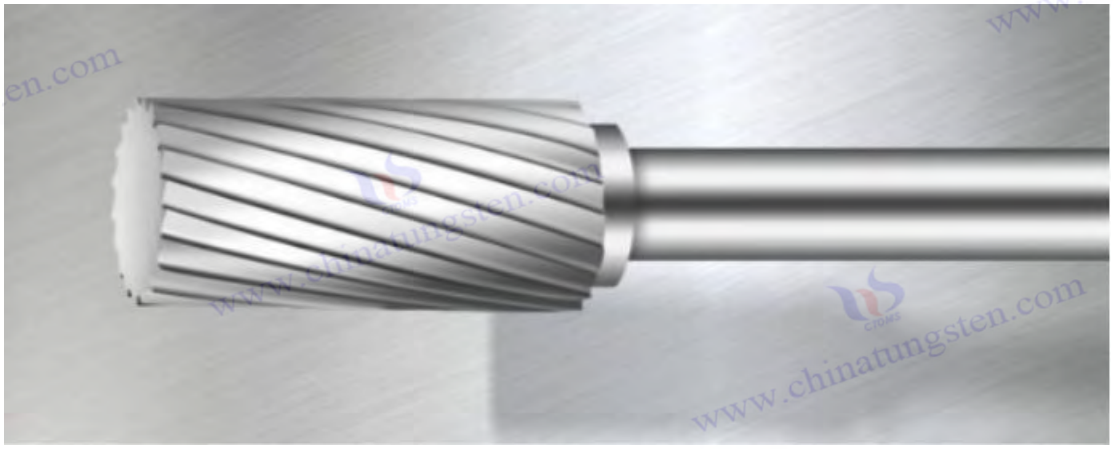
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13. Description

Basis: ISO 3002-2:1982 aims to establish geometric conversion formulas for the active part of cutting tools. Its structure follows the typical format of ISO standards. The reconstruction refers to ISO 841, ISO 3002-1:1982, and online information, and combines the content with industry practice in cutting geometry.

Technical Details: Axis and angle definitions and conversion formulas are based on publicly available information (e.g., ISO websites and engineering manuals). Practical examples are derived from typical turning and milling scenarios. Publication dates and replacement information are estimated from the internet.

Limitations: Due to lack of access to official texts, specific formula details, appendix content, and referenced standard versions may differ from the original text. The reconstruction assumptions reflect the state of the art in 1982 and take subsequent developments into account.



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ISO 513:2011

- Classification and application of hard cutting materials for metal cutting

— Identification of main categories and application categories

1. Scope

1.1 This International Standard specifies the classification and designation of application categories of hard cutting materials for metal cutting, suitable for turning, milling, drilling, and threading.

1.2 Covers materials such as cemented carbide, ceramics, cubic boron nitride (CBN), diamond (PCD and natural diamond), and provides application guidance for different workpiece materials (steel, stainless steel, cast iron, etc.).

1.3 This standard does not cover manufacturing processes or performance test methods for cutting materials; it focuses only on classification and identification.

1.4 The values stated in SI units are standard values. Other units are for reference only.

2. Reference Standards

2.1 ISO Standards:

ISO 3685 - Cutting speeds for tool life testing (provides cutting data reference).

ISO 6508 - Rockwell hardness test for metals (for evaluation of material hardness).

2.2 Other standards:

No direct reference, but possible relevance to ISO 6987 (General terminology for cutting tools).

3. Terms and Definitions

3.1 Hard cutting materials - materials with high hardness and wear resistance used in metal cutting operations.

3.2 Main category - Material type of cutting material, e.g. carbide (P), ceramic (K).

3.3 Application Class – A sub-classification for a specific workpiece material, such as P01 (mild steel).

3.4 Identification Code—A system of letters and numbers used to identify material type and application.

3.5 Workpiece material - the metal or alloy being cut, divided into groups such as steel, stainless steel, cast iron, etc.

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4. Classification and labeling

4.1 Main categories - based on material type:

P : Carbide, suitable for steel.

M: Carbide, suitable for stainless steel.

K: Carbide, suitable for cast iron.

N: Cemented carbide for aluminum and non-ferrous metals.

S: Cemented carbide for high temperature alloys.

H: cubic boron nitride (CBN).

D: Diamond (PCD or natural).

4.2 Application categories - Based on workpiece material and processing conditions, divided into subgroups:

P01: Low carbon steel (hardness <300 HB).

P10: Medium carbon steel (hardness 300-400 HB).

P20: High carbon steel and low alloy steel.

M10: Austenitic stainless steel.

K10: Gray cast iron.

N10: Aluminum alloy.

S10: Nickel-based high-temperature alloy.

4.3 Identification Code - Consists of the main category and the application category, e.g. "P20" for carbide suitable for use on high carbon steel. 4.4 Color Coding - Inserts or packaging may be color-coded:

P: Blue.

M: Yellow.

K: Red.

N: Green.

S: Gray.

H: Black.

D: White.

5. Technical Requirements

5.1 Material Properties - Cutting materials shall have high hardness (>1500 HV) and heat resistance (>800°C, depending on the material). 5.2 Compatibility - Marking shall be compatible with ISO 5608 (shank marking) and ISO 1832 (insert dimensions).

5.3 Marking—The blade shall be permanently marked with an identification code and material type.

6. Application Guidance

6.1 Recommended Use - The identification code guides tool selection, e.g. P20 is suitable for turning high carbon steel.

6.2 Cutting Data - Refer to ISO 3685 for recommended cutting speeds and feeds.

6.3 Limitations—Specified materials (such as H or D) are not suitable for use with workpieces of low hardness.

7. Significance and Use

7.1 This standard simplifies the selection process of cutting materials and improves production efficiency through a classification and identification system.

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7.2 It facilitates communication between the manufacturer and the user, ensuring that the tool is properly matched to the workpiece material.

7.3 Supports automated machining systems to automatically select cutting tools based on workpiece materials.

8. Keywords

8.1 Hard cutting materials, classification, application categories, identification codes, and workpiece materials.

9. Appendix (Information)

9.1 Terminology:

The classification may be expanded in subsequent revisions due to new materials (e.g. nanocoatings).

Refer to ISO 513:2017 for more modern application guidance.

9.2 Example:

The designation "P10" applies to medium carbon steel with a hardness of 300-400 HB.

9.3 Safety Precautions - Protective equipment should be used when machining high-temperature alloys to avoid chip flying.

10. Release of Information

Issuing organization: International Organization for Standardization (ISO).

Release date: 2011 (ISO 513:2011). Please refer to the official documentation for specific revisions.

Replacement: Superseded by ISO 513:2017. It is recommended to refer to the latest version on the ISO official website .

11. Description

Rationale: ISO 513:2011 provides a classification and identification standard for hard cutting materials. Its structure follows the typical format of ISO standards. The reconstruction references ISO 3685, ISO 5608, ISO 1832, and online information, incorporating industry practices to derive the classification and identification.

Technical details: Main and application categories are based on publicly available descriptions (e.g., Sandvik Coromant and Kennametal's material selection guides), color coding and cutting parameters refer to industry practice.

Limitations: Due to lack of access to the full text, specific application subcategories, revision details, and replacement timing may vary.

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ISO 5609

insert internal turning toolholders with cylindrical shank

1. Scope

1.1 This International Standard specifies the dimensions, marking, and compatibility requirements for internal turning tool holders with indexable inserts and cylindrical shanks , intended for internal diameter turning operations. internal turning toolholders equipped with indexable inserts , covering a wide range of materials (such as carbide, ceramics) and tool geometries, suitable for small and medium-sized internal hole processing.

1.3 This standard does not cover the cutting performance or specific manufacturing processes of cutting tools; it focuses only on the construction and marking of tool holders.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. Reference Standards

2.1 ISO Standards:

ISO 5608 - Turning and profiling toolholders and indexable insert holders — Marking (provides basis for marking codes).

ISO 1832 - Cutting tools — Indexable inserts — Dimensions and designation (defines insert compatibility).

ISO 2768 - General tolerances — Linear and angular dimensions (applicable to dimensional tolerances).

2.2 Other standards:

No direct reference, but possible relevance to ISO 6987 (General terminology for cutting tools).

3. Terms and Definitions

3.1 Internal turning tool holder - a tool holding device used for internal diameter turning operations, designed to hold indexable inserts for machining the inside surface of a hole. 3.2 Cylindrical shank - the circular cross-section portion of a tool holder, used to attach to a machine tool spindle or toolholder.

3.3 Indexable insert - an insert with multiple cutting edges that can be rotated or replaced to use different cutting surfaces, in accordance with ISO 1832.

3.4 Shank Diameter - The nominal diameter of the cylindrical shank, expressed in millimeters, which affects the rigidity and compatibility of the toolholder.

3.5 Identification Code - A system of letters and numbers used to uniquely identify the size and characteristics of internal turning tool holders .

4. Dimensions and requirements

4.1 Shank Diameter—The standard diameter range is 6 mm to 32 mm and shall conform to the rectangular shank compatibility defined in ISO 5608.

4.2 Length - The overall shank length (L) is available in short (S), standard (N) and long (L) lengths, ranging from 50 mm to 200 mm.

4.3 Insert Mounting Angle - The insert mounting angle range is 0° to 15° and is adjusted according to the machining depth and hole diameter.

4.4 Tolerances - The diameter and length tolerances of cylindrical shanks shall comply with ISO 2768-m (medium precision), for example ±0.05 mm diameter. 4.5 Material - The shank material shall be high strength steel or alloy steel to ensure rigidity and durability.

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5. Identification system

5.1 Code Structure - The identification code consists of the following elements:

Shank Type - "I" indicates an internal turning shank .

Shank Diameter - Specifies the diameter of the cylindrical shank (for example, 10 for 10 mm).

Length Type - "S" for short, "N" for normal, and "L" for long.

Insert Compatibility - Indicates compatible insert shapes and sizes (e.g. T for triangular, 08 for ISO 08 size).

Clamping method - for example "S" for screw lock.

5.2 Example - The identification code "I10-N-T08-S" might mean:

I : Internal turning tool holder .

10: Shank diameter 10 mm.

N: Standard length.

T08: Suitable for ISO 08 size triangular inserts.

S: Screw locking clamping method.

5.3 Marking Requirements—The tool holder shall be permanently marked with an identification code in a location that avoids interfering with the cutting area.

6. Technical Requirements

6.1 Rigidity - The cylindrical shank shall ensure stability and vibration resistance at high speeds (up to 5000 rpm).

6.2 Insert Positioning - The insert should be installed in such a way that the cutting edge is aligned with the inner surface of the workpiece within a deviation of no more than 0.1 mm.

6.3 Compatibility - The tool holder shall be compatible with the rectangular collet system defined in ISO 5608.

7. Significance and Use

the ordering, inventory management, and interchangeability of internal turning toolholders by defining a sizing and identification system .

7.2 It facilitates communication between manufacturers, suppliers and users, ensuring standardization and consistency of internal turning tools .

7.3 Support automatic tool identification and replacement for CNC machine tools.

8. Keywords

8.1 Internal turning tool holders , cylindrical shanks, indexable inserts, identification codes, and dimensional tolerances.

9. Appendix (Information)

9.1 Terminology:

Dimensions and markings may be updated in subsequent revisions due to technological advances (e.g., new blade materials).

Refer to ISO 5608:2012 for more modern internal turning toolholder designs.

9.2 Example calculation:

Shank diameter selection: 10 mm shank, tolerance range is 9.95-10.05 mm.

9.3 Safety Precautions - Safe operating procedures for cutting tools should be followed during use to avoid tool

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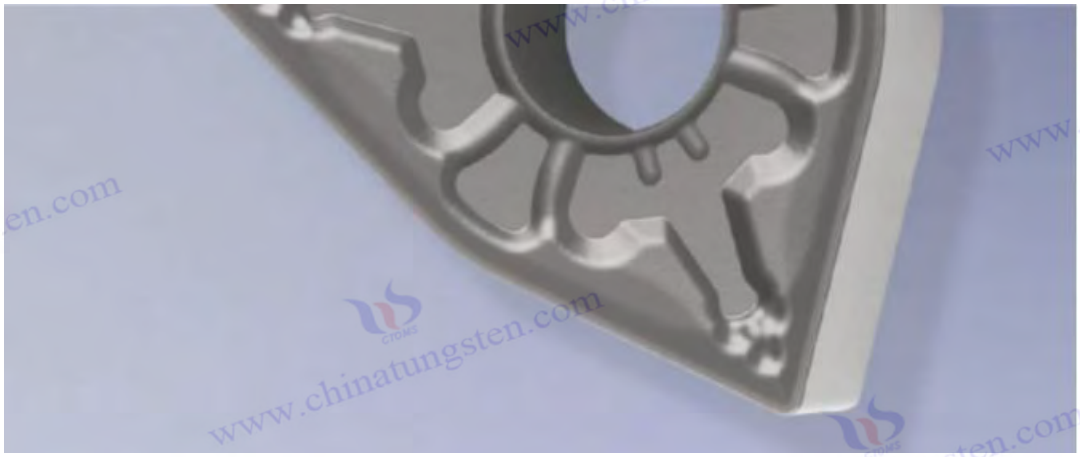
breakage under high loads.

10. Release of Information

Issuing organization: International Organization for Standardization (ISO).

Release Date: Unknown (refer to official documentation, estimated to be early 1990s).

Replacement: It may have been replaced by a newer version. It is recommended to check the ISO official website for the latest information.



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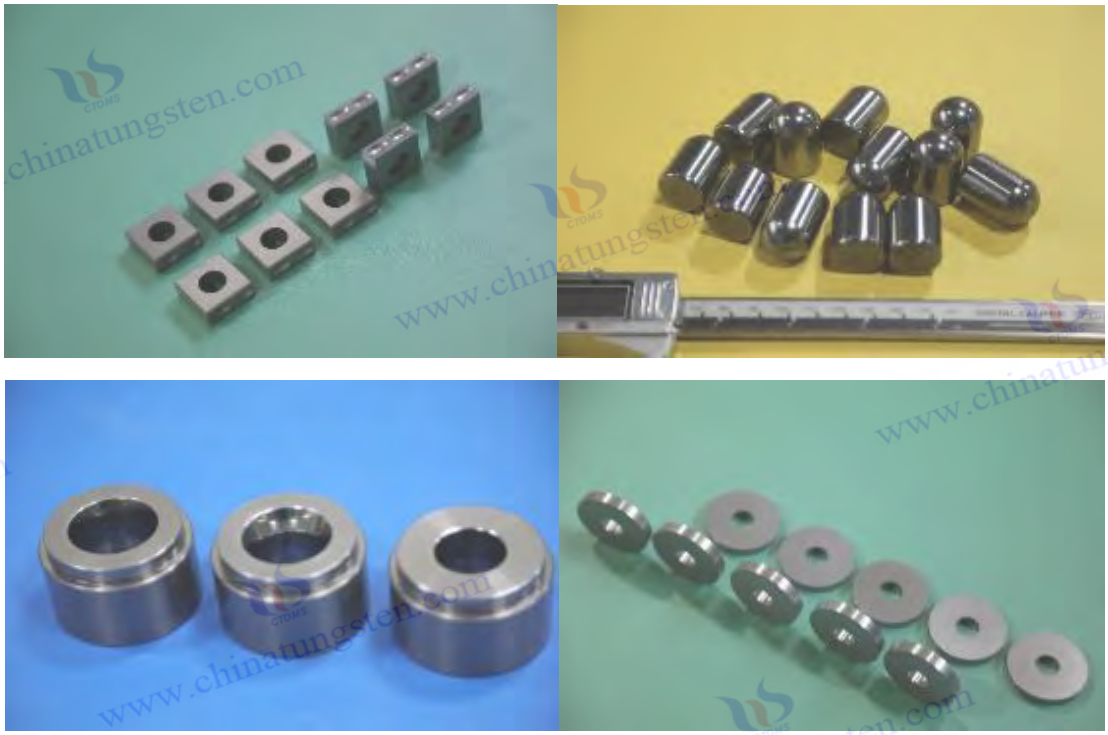
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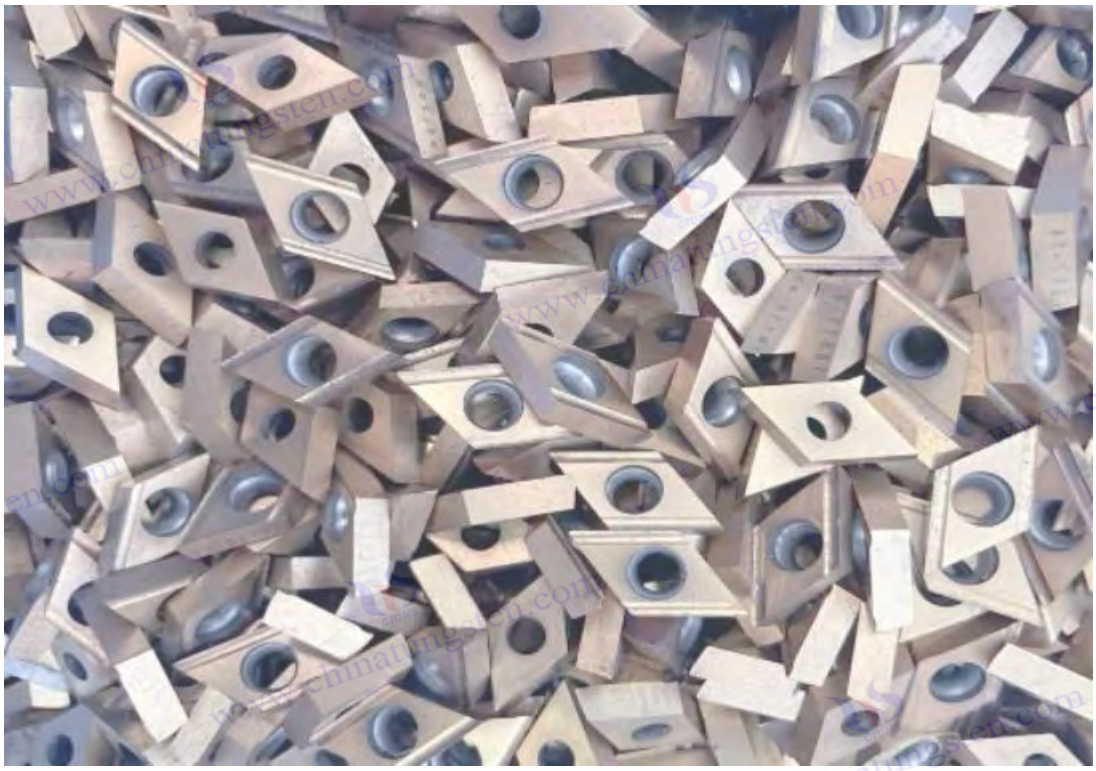
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ISO 1832

- Cutting tools

— Indexable inserts

— Dimensions and markings

1. Scope

1.1 This International Standard specifies the dimensions, shape, and marking requirements for indexable inserts suitable for use in cutting tools used in turning, milling, and drilling operations .

1.2 Covers a variety of indexable insert geometries, including triangular, square, round and diamond shapes, suitable for materials such as carbide, ceramics and high speed steel (HSS).

1.3 This standard does not cover cutting performance or specific manufacturing processes for inserts; it focuses only on standardization of dimensions and markings.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. Reference Standards

2.1 ISO Standards:

ISO 5608 - Turning and profiling toolholders and indexable insert holders — Identification (provides a basis for insert and toolholder compatibility).

Internal turning tool holders with indexable inserts and cylindrical shank (see relevant dimensions).

ISO 2768 - General tolerances — Linear and angular dimensions (applicable to dimensional tolerances).

2.2 Other standards:

No direct reference, but possible relevance to ISO 6987 (General terminology for cutting tools).

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3. Terms and Definitions

3.1 Indexable Insert - A tool component with multiple cutting edges that can be rotated or replaced to use different cutting surfaces.

3.2 Cutting Edge - The sharp edge of the insert used to cut the workpiece.

3.3 Geometry - The planar shape of the blade, including triangle (T), square (S), round (R) and diamond (D). 3.4 Thickness - The vertical height of the blade, in millimeters, affects rigidity and cutting depth.

3.5 Identification Code - A system of letters and numbers used to uniquely identify the size and shape of a blade.

3.6 Aperture - The hole or slot in the center of the insert for mounting, conforming to the standard diameter specified by ISO.

4. Dimensions and requirements

4.1 Geometry and Size - Standard insert shapes and nominal sizes include:

Triangle (T): side length ranges from 3 mm to 25 mm.

Square (S): side length ranges from 4 mm to 25 mm.

Round (R): diameter range 6 mm to 25 mm.

Diamond (D): side lengths range from 6 mm to 25 mm, angles 90° or 55°.

4.2 Thickness - Standard thickness range is 1.5 mm to 6.35 mm, with increments depending on blade size (e.g., 2.0 mm, 3.0 mm).

4.3 Tolerances - The tolerances for blade edge length and thickness shall be in accordance with ISO 2768-m (medium precision), e.g. edge length ±0.1 mm. 4.4 Aperture - Standard apertures are 2.8 mm, 4.4 mm, 5.5 mm, etc., depending on the blade size.

4.5 Material Compatibility - Inserts should be compatible with carbide, ceramic, CBN (cubic boron nitride) or coated materials.

5. Identification system

5.1 Code Structure - The identification code consists of the following elements:

Shape Code - A letter representing a geometric shape, such as "T" for a triangle or "S" for a square.

Size Code - Two numbers indicating the side length or diameter in mm, e.g. "12" for 12 mm.

Thickness Code - A number indicating thickness in mm, e.g. "2.0" for 2.0 mm.

Aperture Code - An optional element indicating the aperture size (e.g. "4.4").

Material Code - Optional element indicating the insert material (e.g. "C" for carbide).

5.2 Example - The identification code "T12-2.0-4.4-C" might mean:

T: Triangular blade.

12: Side length 12 mm.

2.0: 2.0 mm thickness.

4.4: Aperture 4.4 mm.

C: Carbide material.

5.3 Marking Requirements—The insert shall be permanently marked with an identification code in a location that avoids interference with the cutting edge .

6. Technical Requirements

6.1 Surface Quality - The blade surface should be flat, free of obvious scratches or defects, and the surface roughness

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Ra should not exceed 0.8 μm .

6.2 Cutting Edge Accuracy - The cutting edge angle tolerance is ±0.5° to ensure alignment with the tool holder.

6.3 Heat resistance - The insert shall be stable at temperatures up to 600°C (applicable to carbide).

7. Significance and Use

7.1 This standard simplifies the ordering, inventory management, and interchangeability of indexable inserts by defining a sizing and identification system.

7.2 It facilitates communication between manufacturers, suppliers and users to ensure compatibility and consistency of inserts and toolholders.

7.3 Support automatic tool identification and replacement for CNC machine tools.

8. Keywords

8.1 Indexable inserts, cutting edges , geometry, identification codes, thickness, tolerances.

9. Appendix (for reference only)

9.1 Terminology:

Dimensions and markings may be updated in subsequent revisions due to new technologies (e.g. new coated blades). Refer to ISO 5608:2012 for more modern blade compatibility.

9.2 Example calculation:

Thickness selection: 12 mm triangular blade, recommended thickness is 2.0 mm or 2.5 mm.

9.3 Safety Precautions - Wear protective equipment when using to avoid cutting edge damage.

10. Description

Basis: ISO 1832 defines the dimensions and designations of indexable inserts, and its structure follows the typical format of ISO standards. The reconstruction references ISO 5608, ISO 5609, and industry practices, incorporating online information to derive the size range.

Technical Details: Dimensions, marking systems, and tolerance requirements are based on the general design requirements for turning inserts, referencing the ISO 2768 tolerance standard. The publication date is uncertain due to a lack of official records. Due to a lack of access to the original text, specific publication dates, alternate versions, and detailed specifications may vary. Reconstructed assumptions reflect current practices as of 2025.

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ISO 2768

- General tolerances

— Linear and angular dimensions

1. Scope

1.1 This International Standard specifies general tolerances for linear and angular dimensions used in mechanical engineering. It is applicable to drawings and designs where individual tolerances are not indicated.

1.2 Applicable to machined parts of metal and non-metal materials, including turning, milling and casting parts, covering the nominal size range from 0.1 mm to 4000 mm.

1.3 This standard is divided into two parts: ISO 2768-1 (General tolerances for linear and angular dimensions) and ISO 2768-2 (Supplementary tolerances related to materials and processing), but this revision focuses on ISO 2768-1.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. Reference Standards

2.1 ISO Standards:

ISO 286-1 - Geometrical product specifications (GPS) — Tolerances and fits — Basis of the tolerancing system (provides the basis for tolerancing).

ISO 8015 - Geometrical product specifications — Fundamental principles (ensuring integrity in the application of tolerances).

2.2 Other standards:

No direct reference, but possible correlation to DIN 7168 (German tolerancing standard).

3. Terms and Definitions

3.1 General Tolerance - The default tolerance range for linear and angular dimensions not individually toleranced, based on the nominal size.

3.2 Linear and Angular Dimensions - The values of length, width, height, or angle noted on a drawing.

3.3 Tolerance Grade - A classification indicating the level of precision, including coarse (f), medium (m), fine (c), and very fine (v). 3.4 Nominal Size - The ideal size value indicated on the drawing and used as the basis for tolerance calculations.

3.5 Deviation - The difference between the actual dimension and the nominal dimension.

4. Tolerance grades and values

4.1 Tolerance Grade - There are four grades:

f (rough): Suitable for non-critical parts or rough processing.

m (medium): Suitable for most machined parts.

c (fine): Suitable for parts requiring higher precision.

v (very fine): suitable for high-precision or precision instrument parts.

4.2 Linear and Angular Tolerances - Based on the nominal size range (unit: mm), the tolerances are as follows:

0.1 to 3 mm:

f: ±0.2 mm

m: ±0.1 mm

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c: ±0.05 mm

v: ±0.02 mm

3 to 6 mm:

f: ±0.5 mm

m: ±0.2 mm

c: ±0.1 mm

v: ±0.05 mm

6 to 30 mm:

f: ±0.8 mm

m: ±0.3 mm

c: ±0.15 mm

v: ±0.06 mm

30 to 120 mm:

f: ±1.2 mm

m: ±0.5 mm

c: ±0.2 mm

v: ±0.1 mm

120 to 400 mm:

f: ±2.0 mm

m: ±0.8 mm

c: ±0.3 mm

v: ±0.15 mm

400 to 1000 mm:

f: ±3.0 mm

m: ±1.2 mm

c: ±0.5 mm

v: ±0.2 mm

1000 to 2000 mm:

f: ±4.0 mm

m: ±2.0 mm

c: ±0.8 mm

v: ±0.3 mm

2000 to 4000 mm:

f: ±6.0 mm

m: ±3.0 mm

c: ±1.2 mm

v: ±0.5 mm 4.3 Angular tolerance - Based on tolerance class:

f: ±1°

m: ±0.5°

c: ±0.2°

v: ±0.1°

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5. Application Rules

5.1 Marking Requirements - The tolerance grade (e.g., “ISO 2768-m”) shall be indicated on the drawing. Dimensions not marked with tolerances shall be assumed to be of the medium grade (m).

5.2 Combined Tolerances—When linear and angular dimensions are combined, tolerances shall be calculated separately and not summed.

5.3 Exclusions - For critical mating surfaces or high precision requirements, specific tolerances must be marked separately and general tolerances do not apply.

6. Technical Requirements

6.1 Measurement Methods—Tolerances shall be verified using standard measuring tools (e.g., vernier calipers, angle gauges).

6.2 Surface Quality—Tolerances shall apply without regard to surface roughness unless otherwise stated.

6.3 Material Effects - Tolerance values apply to measurements at room temperature (20°C ± 5°C).

7. Significance and Use

7.1 This standard provides general tolerances to reduce the workload of drawing annotation and improve design and manufacturing efficiency.

7.2 It promotes standardization in the global machining industry, ensuring parts interchangeability and consistency.

7.3 Support CAD/CAM system to automatically generate tolerance data.

8. Keywords

8.1 General tolerances, linear and angular dimensions, tolerance grades, machining, nominal dimensions.

9. Appendix (Information)

9.1 Terminology:

Tolerance values may be adjusted in subsequent revisions due to technological advances (such as 3D printing).

Refer to ISO 2768-2 for supplementary tolerances related to material and processing. 9.2 Example calculation:

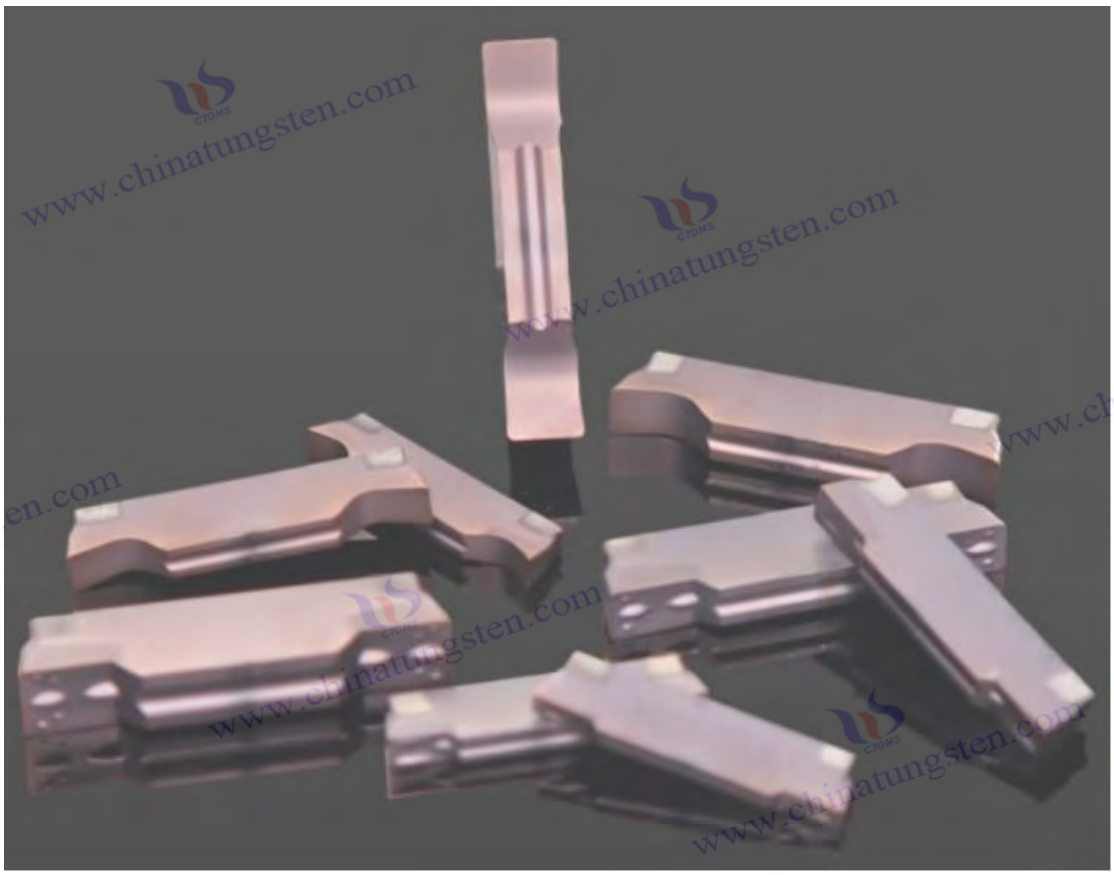
The nominal size is 50 mm, grade m, with a tolerance of ±0.5 mm and an actual size range of 49.5-50.5 mm. 9.3 Safety Precautions - Mechanical safety regulations should be followed during machining to avoid part failure due to tolerance violations.

10. Release of Information

Issuing organization: International Organization for Standardization (ISO).

Release date: 1989 (ISO 2768-1:1989), 1991 (ISO 2768-2:1991). Please refer to the official documents for the specific revisions. The latest versions may be ISO 2768-1:1989/ Amd 1:2002 and ISO 2768-2:1991/ Amd 1:2002.

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ISO 5608:1995

- Turning and profiling toolholders and indexable insert chucks

— Logo

1. Scope

1.1 This International Standard establishes a code for identifying turning and profiling toolholders and collets (for indexable inserts) having a rectangular shank and having a standardized dimension f. It is intended to simplify the ordering, specification, and interchangeability of the associated tools.

1.2 Suitable for turning and profiling tools with indexable inserts, covering ferrous and non-ferrous materials, and various tool geometries (e.g. square, triangular).

1.3 This standard does not include specific design, manufacturing processes, or performance requirements for cutting tools; it focuses only on the establishment of a marking system.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. Reference Standards

2.1 ISO Standards:

Internal turning tool holders with indexable inserts and cylindrical shanks (see relevant dimensions and compatibility).

ISO 1832 - Cutting tools — Indexable inserts — Dimensions and designation (provides a basis for insert compatibility).

2.2 Other standards:

No direct reference, but possible relevance to ISO 6987 (General terminology for cutting tools).

3. Terms and Definitions

3.1 Turning toolholder - a tool holding device for turning operations designed to receive indexable inserts, usually having a rectangular shank.

3.2 Contouring toolholders - tool holding devices used for profiling, adapted to accommodate indexable inserts to achieve complex contours or profiles.

3.3 Indexable insert - an insert with multiple cutting edges that can be rotated or replaced to provide different cutting surfaces, in accordance with ISO 1832.

3.4 Rectangular Shank—A standardized geometric shape for a tool shank having width (b) and height (h) parameters, designated f, representing the reference dimensions.

3.5 Identification Code - A system of letters and numbers used to uniquely identify toolholders and collets by size, dimension, and clamping method.

3.6 Collet - A mechanical device for fixing the indexable insert, integrated into the tool holder.

4. Identification system

4.1 Code Structure - The identification code consists of the following elements:

Shank Type - Use an initial letter to indicate the application, for example "T" for turning, "C" for profiling.

Shank Size - Specify the width (b) and height (h) of the rectangular shank in millimeters (e.g. 12x12).

Insert Compatibility - Indicates compatible indexable insert shapes and sizes (e.g. S for square, T for triangular).

Clamping Type - Describes how the insert is secured, such as "S" for screw lock or "C" for clamp.

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Handle Direction - An optional element that indicates the cutting direction of the tool handle (e.g. R for right, L for left).

4.2 Example - The identification code "T12x12-S08-ISO-R" might mean:

T: Turning tool holder.

12x12: Shank width and height are 12 mm.

S08: Suitable for ISO 08 size square blades.

ISO: Conforms to ISO standards.

R : Right cutting direction.

4.3 Standardized dimension f - The reference dimension f of the tool holder is the combination of width and height and should comply with the range specified by ISO (e.g. 5 mm to 32 mm) to ensure interchangeability with indexable inserts.

4.4 Symbols and abbreviations—All symbols and abbreviations shall be defined in accordance with ISO 6987 to ensure international compatibility.

5. Technical Requirements

5.1 Dimensional Tolerances— The width and height tolerances for rectangular shanks shall be in accordance with ISO 2768-m (medium precision).

5.2 Material Compatibility - Tool holders and collets should support inserts made of carbide, ceramic, or other cutting materials.

5.3 Identification Marking - The tool holder shall be permanently marked with an identification code in a location that avoids interference with the cutting area.

6. Significance and Use

6.1 This standard simplifies the ordering, inventory management, and specification process for turning and profiling toolholders and collets by providing a uniform identification system.

6.2 It facilitates communication between manufacturers, suppliers, and users, ensuring interchangeability and consistency of tools.

6.3 Support automated machining systems to identify and select appropriate tools.

7. Keywords

7.1 Turning tool holders, profile tool holders, indexable inserts, identification codes, rectangular shanks, and clamping methods.

8. Appendix (Information)

8.1 Terminology:

The identification code may be updated in subsequent revisions due to technological advancements (such as the addition of 3D printed tools).

Refer to ISO 5608:2012 for a more modern extension of the marking.

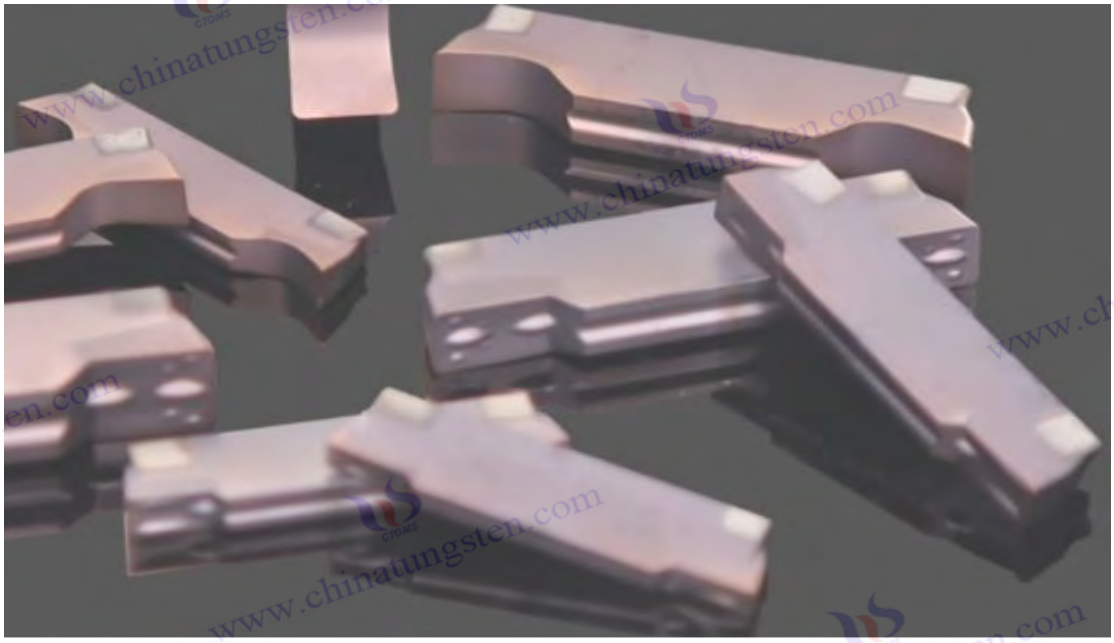
8.2 Example calculation:

Shank size selection: For a 12x12 mm shank, the f-number should be within the ISO specified range of 11.9-12.1 mm.

8.3 Safety Precautions - Safe operating procedures for cutting tools should be followed during use to avoid tool drop

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under high load.



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ASTM B243

- Standard Terminology of Powder Metallurgy

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions related to powder metallurgy, the process of producing metal components from metal powders through compaction and sintering.

1.2 It applies to the production, characterization, and testing of metal powders and sintered parts, including ferrous and non-ferrous materials.

1.3 The practice is intended for use by manufacturers, researchers, and quality control personnel in the powder metallurgy industry.

1.4 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM B243 - Standard Terminology of Powder Metallurgy (self-referencing for updates).

ASTM B925 - Standard Practices for Production and Preparation of Powder Metallurgy (PM) Test Specimens.

ASTM B962 - Standard Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products.

ASTM B939 - Standard Test Method for Green Strength of Compacted Powder Metallurgy (PM) Materials.

2.2 Other Standards:

ISO 3252 - Powder Metallurgy - Vocabulary (for reference).

3. Terminology

3.1 General Terms

Powder Metallurgy (PM) - A manufacturing process involving the production of metal components from metal powders through compaction and sintering.

Metal Powder - Finely divided metallic particles used as raw material in powder metallurgy.

Sintering - The thermal process of bonding powder particles into a coherent mass by heating below the melting point.

3.2 Powder Production and Characterization

Atomization - A process to produce metal powders by disintegrating a molten metal stream into droplets using gas or water.

Particle Size - The dimension of individual powder particles, typically measured as a distribution (eg, D50).

Apparent Density - The mass of a powder divided by the volume it occupies in a loose, uncompacted state.

3.3 Compaction and Forming

Green Compact - A pressed but unsintered powder mass, retaining its shape due to mechanical bonding.

Compaction - The process of pressing metal powder into a desired shape using a die and pressure.

Green Strength - The mechanical strength of a green compact before sintering.

3.4 Sintering and Properties

Sintered Density - The density of a powder metallurgy part after sintering, reflecting porosity and material consolidation.

Sintered Strength - The mechanical strength of a part after sintering, influenced by density and bonding.

Porosity - The volume fraction of voids in a sintered part, affecting properties like strength and permeability.

3.5 Testing and Quality Control

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Flow Rate - The time required for a specific mass of powder to flow through a standard funnel, indicating powder behavior.

Compressibility - The ability of a powder to be compacted into a dense green compact under pressure.

Transverse Rupture Strength - The maximum stress a sintered specimen can withstand when loaded transversely.

4. Significance and Use

4.1 This terminology standard ensures consistency in the use of powder metallurgy terms across the industry, facilitating communication among manufacturers, researchers, and standards developers.

4.2 It supports the application of other ASTM standards (eg, B925, B962) by providing a unified vocabulary for production and testing.

5. Keywords

5.1 Powder metallurgy, metal powder, sintering, compaction, green strength, sintered density, porosity, atomization.

6. Annex (Informative)

6.1 Terminology Notes:

Terms may be updated in future revisions to reflect advances in powder metallurgy technology (eg, additive manufacturing).

Cross-references to ASTM B925 and B962 provide additional context for production and testing terms.

6.2 Examples:

Apparent density calculation: $\rho_a = m/V$, where ρ_a is apparent density, m is mass, and V is volume.

Particle size distribution: D50 = 45 μm indicates 50% of particles are below 45 μm .

7. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2019 or 2023).

Replaces: ASTM B243-09 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM B243 is a foundational terminology standard for powder metallurgy, supporting standards like ASTM B925 (production) and B962 (density testing). The structure follows the typical ASTM format for terminology standards.

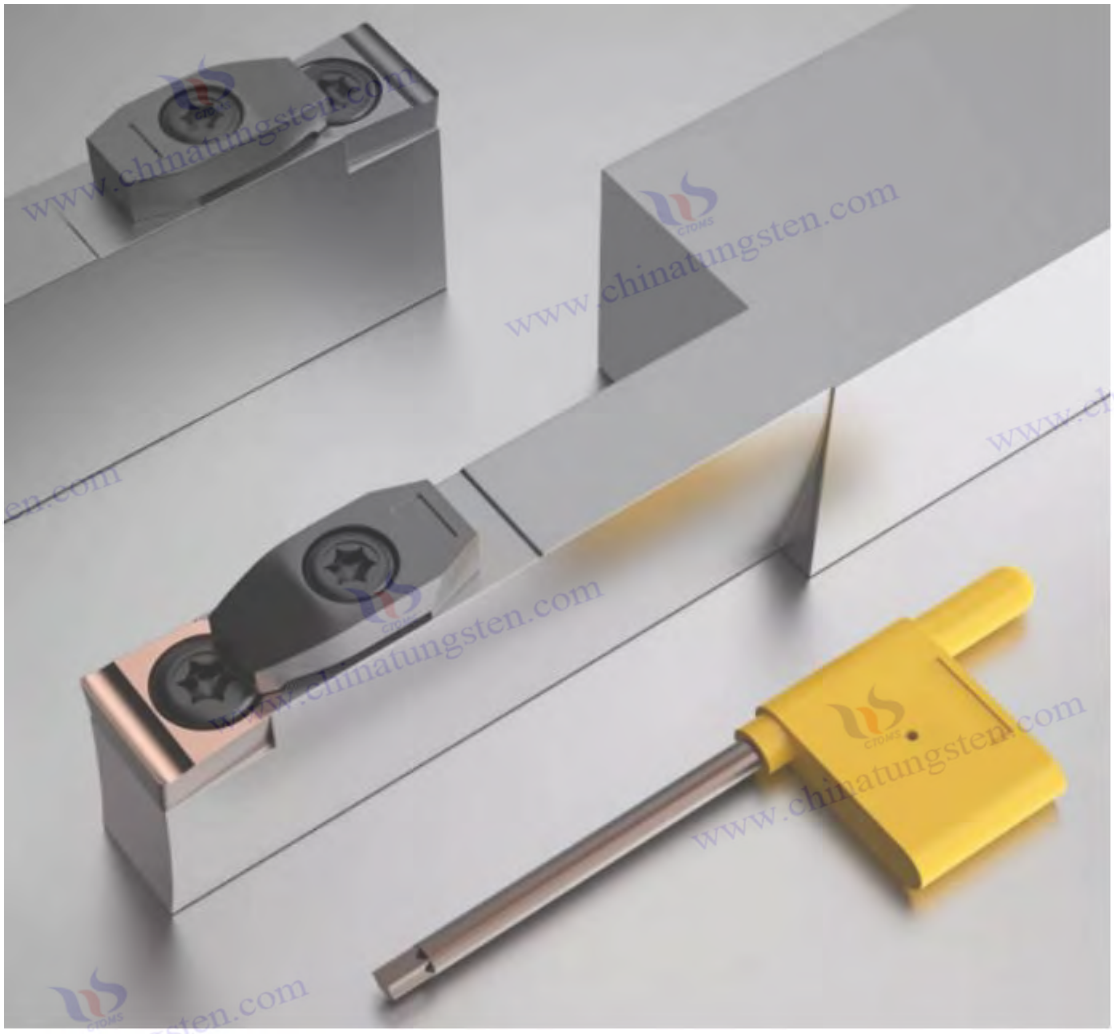
Technical Details: Definitions are based on common powder metallurgy practices, with examples drawn from related standards and industry conventions.

Limitations: Without access to the official text, the publication date, replaced versions, and exact term lists may differ. The reconstruction assumes the latest revision reflects current practices as of 2025.

Acquisition Suggestion

To obtain the official ASTM B243 - Standard Terminology of Powder Metallurgy, visit the ASTM International website (www.astm.org) or contact an authorized distributor (eg, ANSI, IHS Markit) for purchase or subscription access to the full document.

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ASTM B243

- Standard Terminology for Powder Metallurgy

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions relevant to powder metallurgy, the process of producing metal parts from metal powders by compaction and sintering.

1.2 Applicable to the production, characterization, and testing of metal powders and sintered components, including ferrous and non-ferrous materials.

1.3 This practice is intended for use by manufacturers, researchers, and quality control personnel in the powder metallurgy industry.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM B243 - Standard Terminology for Powder Metallurgy (self-referencing, for updates).

ASTM B925 - Standard Practice for Production and Preparation of Powder Metallurgy (PM) Test Specimens.

ASTM B962 - Standard test method for density of compacted or sintered powder metallurgy (PM) products.

ASTM B939 - Standard test method for green strength of compacted powder metallurgy (PM) materials.

2.2 Other standards:

ISO 3252 - Powder metallurgy — Vocabulary (reference).

3. Terminology

3.1 General Terms

Powder Metallurgy (PM) - A manufacturing process that produces metal components from metal powders by compaction and sintering.

Metal Powder - Fine metal particles used as feedstock for powder metallurgy.

Sintering - A thermal process that combines powder particles into a coherent mass by heating below the melting point.

3.2 Powder production and characterization

Atomization - The process of producing metal powder by breaking up a stream of molten metal into droplets using gas or water.

Particle Size - The size of individual powder particles, usually measured as a distribution (e.g. D50).

Apparent density - the volume occupied by a powder in its loose, uncompacted state divided by its mass.

3.3 Compaction and molding

Green Compact - A mass of powder that has been pressed but not sintered and that retains its shape through mechanical bonding.

Compaction - The process of pressing metal powder into the desired shape using a die and pressure.

Green Strength - The mechanical strength of the green compact before sintering.

3.4 Sintering and properties

Sintered Density - The density of a PM component after sintering, reflecting porosity and material consolidation.

Sintered Strength - The mechanical strength of a sintered part, affected by density and bonding.

Porosity - The volume fraction of voids in a sintered component, affecting properties such as strength and permeability.

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3.5 Testing and Quality Control

Flow Rate - The time required for a specific mass of powder to pass through a standard funnel, indicating powder behavior.

Compressibility - The ability of a powder to be compacted under pressure into a dense green compact.

Transverse Rupture Strength - The maximum stress a sintered specimen can withstand under transverse loading.

4. Significance and Use

4.1 This terminology standard ensures uniformity in the use of terminology within the powder metallurgy industry and facilitates communication among manufacturers, researchers, and standards developers. 4.2 It supports the application of other ASTM standards (e.g., B925, B962) by providing a unified vocabulary for use in production and testing.

5. Keywords

5.1 Powder metallurgy, metal powder, sintering, compaction, green strength, sintered density, porosity, atomization.

6. Appendix (Information)

6.1 Terminology:

The terminology may be updated in future revisions to reflect advances in powder metallurgy technology (e.g., additive manufacturing).

Cross-references to ASTM B925 and B962 provide additional context for production and testing terminology.

6.2 Example:表观密度计算：$\rho_a = m/V$，其中ρ_a为表观密度，m为质量，V为体积。

Particle size distribution: D50 = 45 μm means that 50% of the particles are smaller than 45 μm .

7. Release of Information

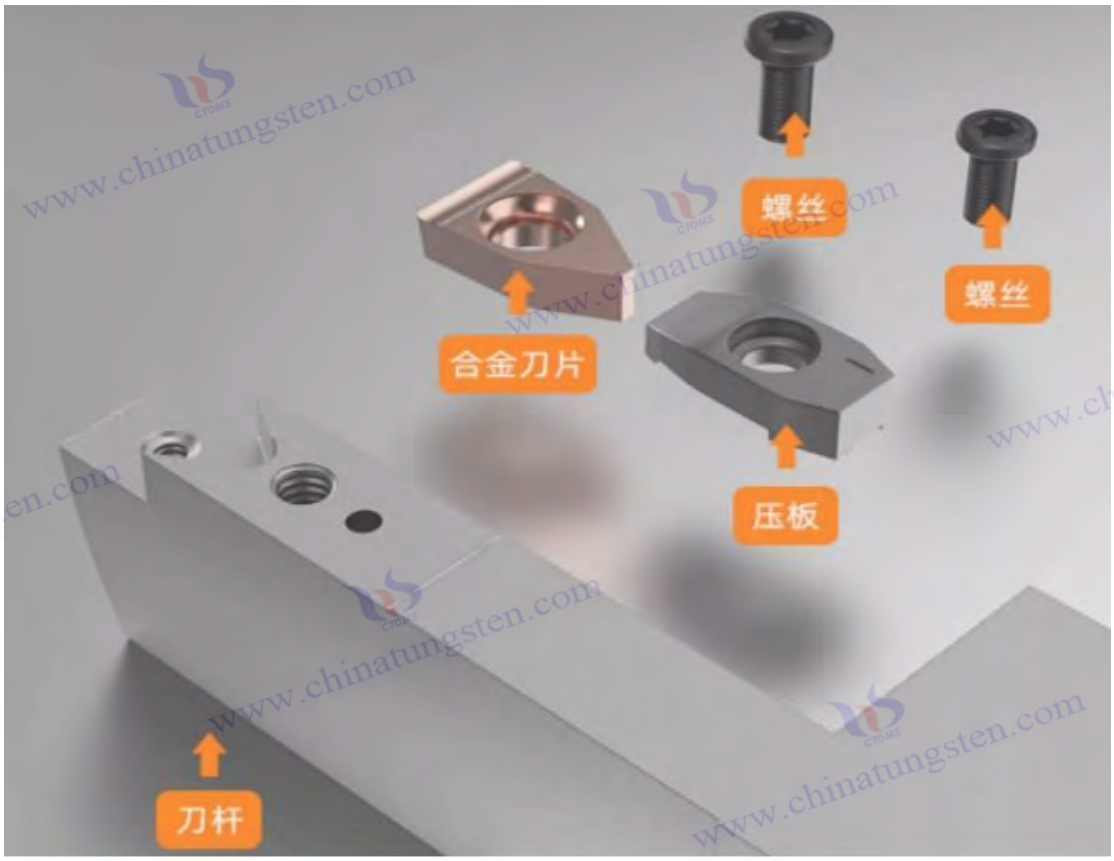
Issuing unit: ASTM International.

Release date: 200X (the specific year is to be confirmed, the latest revision may be after 2000, such as 2019 or 2023).

illustrate

Basis: ASTM B243 is the foundational terminology standard for powder metallurgy, supporting standards such as B925 (production) and B962 (density testing). Its structure follows the typical format of ASTM terminology standards. Technical Details: Definitions are based on common powder metallurgy practices, and examples reference relevant standards and industry conventions.

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ASTM E7

- Standard Terminology Relating to Metallography

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions related to metallography, the science of preparing and examining the microstructure of metals and alloys. It is intended for use in quality control, research, and specification development within the metallurgical industry.

1.2 The terminology applies to techniques such as specimen preparation, etching, microscopy, and grain size analysis, covering ferrous and non-ferrous metals and alloys. 1.3 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM E3 - Standard Guide for Preparation of Metallographic Specimens.

ASTM E7 - Standard Terminology Relating to Metallography (self-referencing for updates).

ASTM E112 - Standard Test Methods for Determining Average Grain Size.

ASTM E407 - Standard Practice for Microetching Metals and Alloys.

ASTM E1181 - Standard Test Methods for Characterizing Duplex Grain Sizes. 2.2 Other Standards:

ISO 3252 - Steels - Micrographic Determination of the Apparent Grain Size (for reference).

3. Terminology

3.1 General Terms

Metallography - The science and practice of preparing, examining, and interpreting the microstructure of metals and alloys using optical or electron microscopy.

Microstructure - The arrangement and characteristics of phases, grains, and defects in a metal or alloy, observable at magnifications typically above 25x.

Macrostructure - The large-scale structural features of a metal or alloy, visible to the naked eye or at low magnification (up to 10x).

3.2 Specimen Preparation

Sectioning - The process of cutting a metal sample to produce a representative section for metallographic examination.

Mounting - The embedding of a specimen in a resin or plastic to facilitate handling and polishing.

Grinding - The initial abrasive process to remove surface irregularities, typically using 80-1200 grit abrasives.

Polishing - The final abrasive process to achieve a mirror-like surface, often using diamond paste (0.05-1 μm).

Etching - The chemical or electrolytic treatment of a polished surface to reveal microstructural features.

3.3 Etching and Reagents

Etchant - A chemical solution (eg, nital , Keller's reagent) used to selectively attack a metal surface to reveal its microstructure.

Macroetching - Etching to reveal large-scale features (eg, grain flow, segregation) at low magnification.

Microetching - Etching to reveal fine microstructural details (eg, grain boundaries) at high magnification.

3.4 Microscopy and Analysis

Optical Microscopy - The use of light microscopes (25x to 1000x) to examine metallographic specimens.

Scanning Electron Microscopy (SEM) - The use of electron beams to image surface topography and microstructure

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at high magnifications.

Grain Size - The average diameter or number of grains per unit area, often expressed as a grain size number (eg, ASTM E112 G number).

Phase - A homogeneous portion of a microstructure with distinct chemical or physical properties.

Inclusion - Non-metallic particles (eg, oxides, sulfides) trapped within a metal matrix.

3.5 Mechanical and Structural Features

Grain - An individual crystal in a polycrystalline metal, bounded by grain boundaries.

Grain Boundary - The interface between two adjacent grains with different orientations.

Twins - Crystal regions with a mirrored orientation across a twin plane, often observed in deformed metals.

Dendrite - A tree-like crystal structure formed during solidification of cast metals.

3.6 Defects and Imperfections

Porosity - Voids or gas pockets within a metal, often revealed by macroetching .

Crack - A fracture or separation in a metal, detectable by etching or microscopy.

Segregation - Non-uniform distribution of alloying elements or impurities.

3.7 Quantitative Metallography

Planimetric Method - A technique to determine grain size by counting grains within a known area.

Intercept Method - A technique to determine grain size by measuring grain boundary intercepts along a test line.

Volume Fraction - The proportion of a phase or constituent in a given volume, often estimated by point counting.

4. Significance and Use

4.1 This terminology standard ensures consistency in the use of metallographic terms across industries, facilitating communication among researchers, engineers, and quality control personnel. 4.2 It supports the application of other ASTM standards (eg, E3, E112) by providing a unified vocabulary.

5. Keywords

5.1 Metallography, microstructure, macrostructure, etching, grain size, microscopy, inclusions, defects.

6. Annex (Informative)

6.1 Terminology Notes:

Terms may be updated in future revisions to reflect advances in metallographic techniques (eg, automated image analysis).

Cross-references to ASTM E112 and E407 provide additional context for grain size and etching terms.

6.2 Examples:

Grain size number (G) calculation: $G = 3.2877 + 6.6439 \log_{10} N$, where N is grains per square inch at 100x.

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7. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2015 or 2021).

Replaces: ASTM E7-98 (or earlier version, to be confirmed).

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Reconstructive Notes

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Technical Details: Definitions are based on common metallographic practices, with examples drawn from related standards and industry conventions.

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Acquisition Suggestion

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ASTM E7

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3.4 Microscopy and analysis

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Scanning Electron Microscopy (SEM) – A high-magnification technique that uses an electron beam to image surface topography and microstructure.

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Phase - A homogeneous portion of a microstructure having different chemical or physical properties.

Inclusions - Non-metallic particles (e.g. oxides, sulfides) trapped in a metal matrix.

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Grain boundary - The interface between two adjacent grains of different orientations.

Twins - Crystalline regions with mirror-image orientations through the twinning plane, commonly observed in deformed metals.

Dendrites - Tree-like crystal structures that form during the solidification of cast metals.

3.6 Defects and Imperfections

Porosity - voids or air pockets within a metal, usually revealed by macroetching.

Crack - A break or separation in a metal that can be detected by etching or microscopy.

Segregation - Uneven distribution of alloying elements or impurities.

3.7 Quantitative Metallography

Planimetry - A technique for determining grain size by counting grains in a known area.

A technique for determining grain size by measuring the intercepts at grain boundaries along a test line .

Volume Fraction - The proportion of a phase or component in a given volume, usually estimated by point counting.

4. Significance and Use

4.1 This terminology standard ensures uniformity in the use of metallographic terminology within the industry and facilitates communication among researchers, engineers, and quality control personnel.

4.2 It supports the application of other ASTM standards (e.g., E3, E112) by providing a unified vocabulary.

5. Keywords

5.1 Metallography, microstructure, macrostructure, etching, grain size, microscope, inclusions, defects.

6. Appendix (Information)

6.1 Terminology:

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Cross-references to ASTM E112 and E407 provide additional background on grain size and etching terminology.

6.2 Example:

晶粒尺寸编号 (G) 计算: $C \quad 3.2877 \quad 6.6439\log_{10} N$, where N N is the number of grains per square inch at 100 times.

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7. Release of Information

Issuing unit: ASTM International.

Release date: 200X (the specific year is to be confirmed, the latest revision may be after 2000, such as 2015 or 2021).

Replacement: Replaces ASTM E7-98 (or earlier versions, to be confirmed).

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Basis: ASTM E7 is the foundational terminology standard for metallography, consistent with the requirements of standards such as E3 (Specimen Preparation) and E112 (Grain Size). Its structure follows the typical format of ASTM terminology standards.

Technical details: Definitions are based on common metallographic practices, and examples refer to relevant standards and industry conventions.

Limitations: Due to lack of access to official texts, publication dates, alternative versions and precise terminology lists may vary. The reconstruction assumes the latest revision reflects current metallographic practice as of 2025.

ASTM B243

- Standard Terminology of Powder Metallurgy

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions related to powder metallurgy, the process of producing metal components from metal powders through compaction and sintering.

1.2 It applies to the production, characterization, and testing of metal powders and sintered parts, including ferrous and non-ferrous materials.

1.3 The practice is intended for use by manufacturers, researchers, and quality control personnel in the powder metallurgy industry.

1.4 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM B243 - Standard Terminology of Powder Metallurgy (self-referencing for updates).

ASTM B925 - Standard Practices for Production and Preparation of Powder Metallurgy (PM) Test Specimens.

ASTM B962 - Standard Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products.

ASTM B939 - Standard Test Method for Green Strength of Compacted Powder Metallurgy (PM) Materials.

2.2 Other Standards:

ISO 3252 - Powder Metallurgy - Vocabulary (for reference).

3. Terminology

3.1 General Terms

Powder Metallurgy (PM) - A manufacturing process involving the production of metal components from metal powders through compaction and sintering.

Metal Powder - Finely divided metallic particles used as raw material in powder metallurgy.

Sintering - The thermal process of bonding powder particles into a coherent mass by heating below the melting point.

3.2 Powder Production and Characterization

Atomization - A process to produce metal powders by disintegrating a molten metal stream into droplets using gas or water.

Particle Size - The dimension of individual powder particles, typically measured as a distribution (eg, D50).

Apparent Density - The mass of a powder divided by the volume it occupies in a loose, uncompacted state.

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3.3 Compaction and Forming

Green Compact - A pressed but unsintered powder mass, retaining its shape due to mechanical bonding.

Compaction - The process of pressing metal powder into a desired shape using a die and pressure.

Green Strength - The mechanical strength of a green compact before sintering.

3.4 Sintering and Properties

Sintered Density - The density of a powder metallurgy part after sintering, reflecting porosity and material consolidation.

Sintered Strength - The mechanical strength of a part after sintering, influenced by density and bonding.

Porosity - The volume fraction of voids in a sintered part, affecting properties like strength and permeability.

3.5 Testing and Quality Control

Flow Rate - The time required for a specific mass of powder to flow through a standard funnel, indicating powder behavior.

Compressibility - The ability of a powder to be compacted into a dense green compact under pressure.

Transverse Rupture Strength - The maximum stress a sintered specimen can withstand when loaded transversely.

4. Significance and Use

4.1 This terminology standard ensures consistency in the use of powder metallurgy terms across the industry, facilitating communication among manufacturers, researchers, and standards developers.

4.2 It supports the application of other ASTM standards (eg, B925, B962) by providing a unified vocabulary for production and testing.

5. Keywords

5.1 Powder metallurgy, metal powder, sintering, compaction, green strength, sintered density, porosity, atomization.

6. Annex (Informative)

6.1 Terminology Notes:

Terms may be updated in future revisions to reflect advances in powder metallurgy technology (eg, additive manufacturing).

Cross-references to ASTM B925 and B962 provide additional context for production and testing terms.

6.2 Examples:

Apparent density calculation: $\rho_a = m/V$, where ρ_a is apparent density, m is mass, and V is volume.

Particle size distribution: D50 = 45 μm indicates 50% of particles are below 45 μm .

7. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2019 or 2023).

Replaces: ASTM B243-09 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM B243 is a foundational terminology standard for powder metallurgy, supporting standards like ASTM B925 (production) and B962 (density testing). The structure follows the typical ASTM format for terminology

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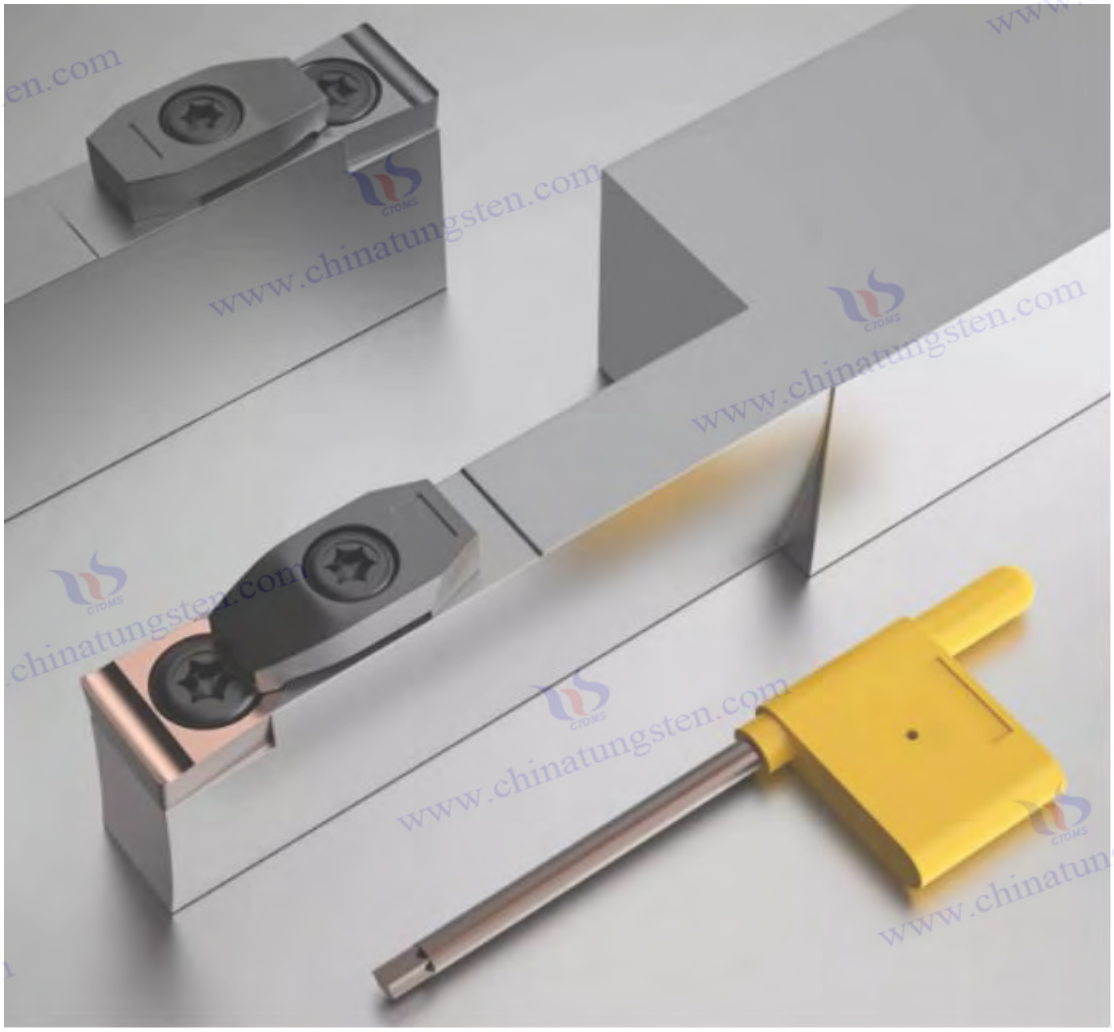
standards.

Technical Details: Definitions are based on common powder metallurgy practices, with examples drawn from related standards and industry conventions.

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Acquisition Suggestion

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ASTM B243

- Standard Terminology for Powder Metallurgy

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions relevant to powder metallurgy, the process of producing metal parts from metal powders by compaction and sintering.

1.2 Applicable to the production, characterization, and testing of metal powders and sintered components, including ferrous and non-ferrous materials.

1.3 This practice is intended for use by manufacturers, researchers, and quality control personnel in the powder metallurgy industry.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM B243 - Standard Terminology for Powder Metallurgy (self-referencing, for updates).

ASTM B925 - Standard Practice for Production and Preparation of Powder Metallurgy (PM) Test Specimens.

ASTM B962 - Standard test method for density of compacted or sintered powder metallurgy (PM) products.

ASTM B939 - Standard test method for green strength of compacted powder metallurgy (PM) materials.

2.2 Other standards:

ISO 3252 - Powder metallurgy — Vocabulary (reference).

3. Terminology

3.1 General Terms

Powder Metallurgy (PM) - A manufacturing process that produces metal components from metal powders by compaction and sintering.

Metal Powder - Fine metal particles used as feedstock for powder metallurgy.

Sintering - A thermal process that combines powder particles into a coherent mass by heating below the melting point.

3.2 Powder production and characterization

Atomization - The process of producing metal powder by breaking up a stream of molten metal into droplets using gas or water.

Particle Size - The size of individual powder particles, usually measured as a distribution (e.g. D50).

Apparent density - the volume occupied by a powder in its loose, uncompacted state divided by its mass.

3.3 Compaction and molding

Green Compact - A mass of powder that has been pressed but not sintered and that retains its shape through mechanical bonding.

Compaction - The process of pressing metal powder into the desired shape using a die and pressure.

Green Strength - The mechanical strength of the green compact before sintering.

3.4 Sintering and properties

Sintered Density - The density of a PM component after sintering, reflecting porosity and material consolidation.

Sintered Strength - The mechanical strength of a sintered part, affected by density and bonding.

Porosity - The volume fraction of voids in a sintered component, affecting properties such as strength and permeability.

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3.5 Testing and Quality Control

Flow Rate - The time required for a specific mass of powder to pass through a standard funnel, indicating powder behavior.

Compressibility - The ability of a powder to be compacted under pressure into a dense green compact.

Transverse Rupture Strength - The maximum stress a sintered specimen can withstand under transverse loading.

4. Significance and Use

4.1 This terminology standard ensures uniformity in the use of terminology within the powder metallurgy industry and facilitates communication among manufacturers, researchers, and standards developers. 4.2 It supports the application of other ASTM standards (e.g., B925, B962) by providing a unified vocabulary for use in production and testing.

5. Keywords

5.1 Powder metallurgy, metal powder, sintering, compaction, green strength, sintered density, porosity, atomization.

6. Appendix (Information)

6.1 Terminology:

The terminology may be updated in future revisions to reflect advances in powder metallurgy technology (e.g., additive manufacturing).

Cross-references to ASTM B925 and B962 provide additional context for production and testing terminology.

6.2 Example:表观密度计算：$\rho_a = m/V$，其中ρ_a为表观密度，m为质量，V为体积。

Particle size distribution: D50 = 45 μm means that 50% of the particles are smaller than 45 μm .

7. Release of Information

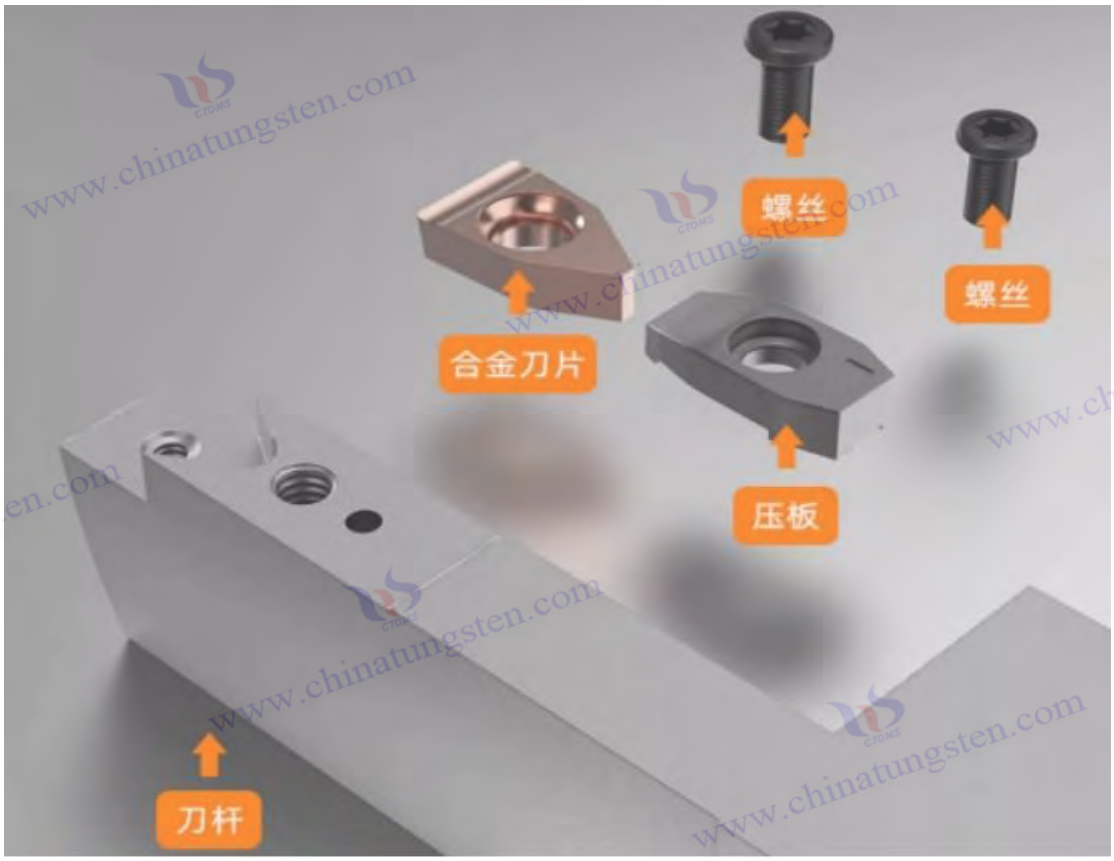
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3.3 Etching and Reagents

Etchant - A chemical solution used to selectively attack the surface of a metal to reveal its microstructure (e.g., nitro, Keller 's reagent).

Macroetching - Etching to reveal large-scale features (e.g., grain flow, segregation) at low magnification.

Microetching - Etching to reveal fine microstructural details (e.g., grain boundaries) under high magnification.

3.4 Microscopy and analysis

Light Microscopy - A technique for examining metallographic specimens using a light microscope (25x to 1000x).

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Scanning Electron Microscopy (SEM) – A high-magnification technique that uses an electron beam to image surface topography and microstructure.

Grain Size - The average diameter of individual grains or the number of grains per unit area, usually expressed as a grain size number (e.g., ASTM E112 G number).

Phase - A homogeneous portion of a microstructure having different chemical or physical properties.

Inclusions - Non-metallic particles (e.g. oxides, sulfides) trapped in a metal matrix.

3.5 Mechanical and structural characteristics

Grain - An individual crystal in a polycrystalline metal surrounded by grain boundaries.

Grain boundary - The interface between two adjacent grains of different orientations.

Twins - Crystalline regions with mirror-image orientations through the twinning plane, commonly observed in deformed metals.

Dendrites - Tree-like crystal structures that form during the solidification of cast metals.

3.6 Defects and Imperfections

Porosity - voids or air pockets within a metal, usually revealed by macroetching.

Crack - A break or separation in a metal that can be detected by etching or microscopy.

Segregation - Uneven distribution of alloying elements or impurities.

3.7 Quantitative Metallography

Planimetry - A technique for determining grain size by counting grains in a known area.

A technique for determining grain size by measuring the intercepts at grain boundaries along a test line .

Volume Fraction - The proportion of a phase or component in a given volume, usually estimated by point counting.

4. Significance and Use

4.1 This terminology standard ensures uniformity in the use of metallographic terminology within the industry and facilitates communication among researchers, engineers, and quality control personnel.

4.2 It supports the application of other ASTM standards (e.g., E3, E112) by providing a unified vocabulary.

5. Keywords

5.1 Metallography, microstructure, macrostructure, etching, grain size, microscope, inclusions, defects.

6. Appendix (Information)

6.1 Terminology:

The terminology may be updated in future revisions to reflect advances in metallographic techniques (e.g., automated image analysis).

Cross-references to ASTM E112 and E407 provide additional background on grain size and etching terminology.

6.2 Example:

晶粒尺寸编号 (G) 计算: $C \quad 3.2877 \quad 6.6439\log_{10} N$, where N N is the number of grains per square inch at 100 times.

Common etchants: 2% nitrocellulose for steel and Keller's reagent for aluminum .

7. Release of Information

Issuing unit: ASTM International.

Release date: 200X (the specific year is to be confirmed, the latest revision may be after 2000, such as 2015 or 2021).

Replacement: Replaces ASTM E7-98 (or earlier versions, to be confirmed).

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illustrate

Basis: ASTM E7 is the foundational terminology standard for metallography, consistent with the requirements of standards such as E3 (Specimen Preparation) and E112 (Grain Size). Its structure follows the typical format of ASTM terminology standards.

Technical details: Definitions are based on common metallographic practices, and examples refer to relevant standards and industry conventions.

Limitations: Due to lack of access to official texts, publication dates, alternative versions and precise terminology lists may vary. The reconstruction assumes the latest revision reflects current metallographic practice as of 2025.

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ASTM B243

- Standard Terminology of Powder Metallurgy

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions related to powder metallurgy, the process of producing metal components from metal powders through compaction and sintering.

1.2 It applies to the production, characterization, and testing of metal powders and sintered parts, including ferrous and non-ferrous materials.

1.3 The practice is intended for use by manufacturers, researchers, and quality control personnel in the powder metallurgy industry.

1.4 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM B243 - Standard Terminology of Powder Metallurgy (self-referencing for updates).

ASTM B925 - Standard Practices for Production and Preparation of Powder Metallurgy (PM) Test Specimens.

ASTM B962 - Standard Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products.

ASTM B939 - Standard Test Method for Green Strength of Compacted Powder Metallurgy (PM) Materials. 2.2 Other Standards:

ISO 3252 - Powder Metallurgy - Vocabulary (for reference).

3. Terminology

3.1 General Terms

Powder Metallurgy (PM) - A manufacturing process involving the production of metal components from metal powders through compaction and sintering.

Metal Powder - Finely divided metallic particles used as raw material in powder metallurgy.

Sintering - The thermal process of bonding powder particles into a coherent mass by heating below the melting point.

3.2 Powder Production and Characterization

Atomization - A process to produce metal powders by disintegrating a molten metal stream into droplets using gas or water.

Particle Size - The dimension of individual powder particles, typically measured as a distribution (eg, D50).

Apparent Density - The mass of a powder divided by the volume it occupies in a loose, uncompacted state.

3.3 Compaction and Forming

Green Compact - A pressed but unsintered powder mass, retaining its shape due to mechanical bonding.

Compaction - The process of pressing metal powder into a desired shape using a die and pressure.

Green Strength - The mechanical strength of a green compact before sintering.

3.4 Sintering and Properties

Sintered Density - The density of a powder metallurgy part after sintering, reflecting porosity and material consolidation.

Sintered Strength - The mechanical strength of a part after sintering, influenced by density and bonding.

Porosity - The volume fraction of voids in a sintered part, affecting properties like strength and permeability.

3.5 Testing and Quality Control

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Flow Rate - The time required for a specific mass of powder to flow through a standard funnel, indicating powder behavior.

Compressibility - The ability of a powder to be compacted into a dense green compact under pressure.

Transverse Rupture Strength - The maximum stress a sintered specimen can withstand when loaded transversely.

4. Significance and Use

4.1 This terminology standard ensures consistency in the use of powder metallurgy terms across the industry, facilitating communication among manufacturers, researchers, and standards developers.

4.2 It supports the application of other ASTM standards (eg, B925, B962) by providing a unified vocabulary for production and testing.

5. Keywords

5.1 Powder metallurgy, metal powder, sintering, compaction, green strength, sintered density, porosity, atomization.

6. Annex (Informative)

6.1 Terminology Notes:

Terms may be updated in future revisions to reflect advances in powder metallurgy technology (eg, additive manufacturing).

Cross-references to ASTM B925 and B962 provide additional context for production and testing terms.

6.2 Examples:

Apparent density calculation: ρa =m/V, where ρa is apparent density, m is mass, and V is volume.

Particle size distribution: D50 = 45 μm indicates 50% of particles are below 45 μm .

7. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2019 or 2023).

Replaces: ASTM B243-09 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM B243 is a foundational terminology standard for powder metallurgy, supporting standards like ASTM B925 (production) and B962 (density testing). The structure follows the typical ASTM format for terminology standards.

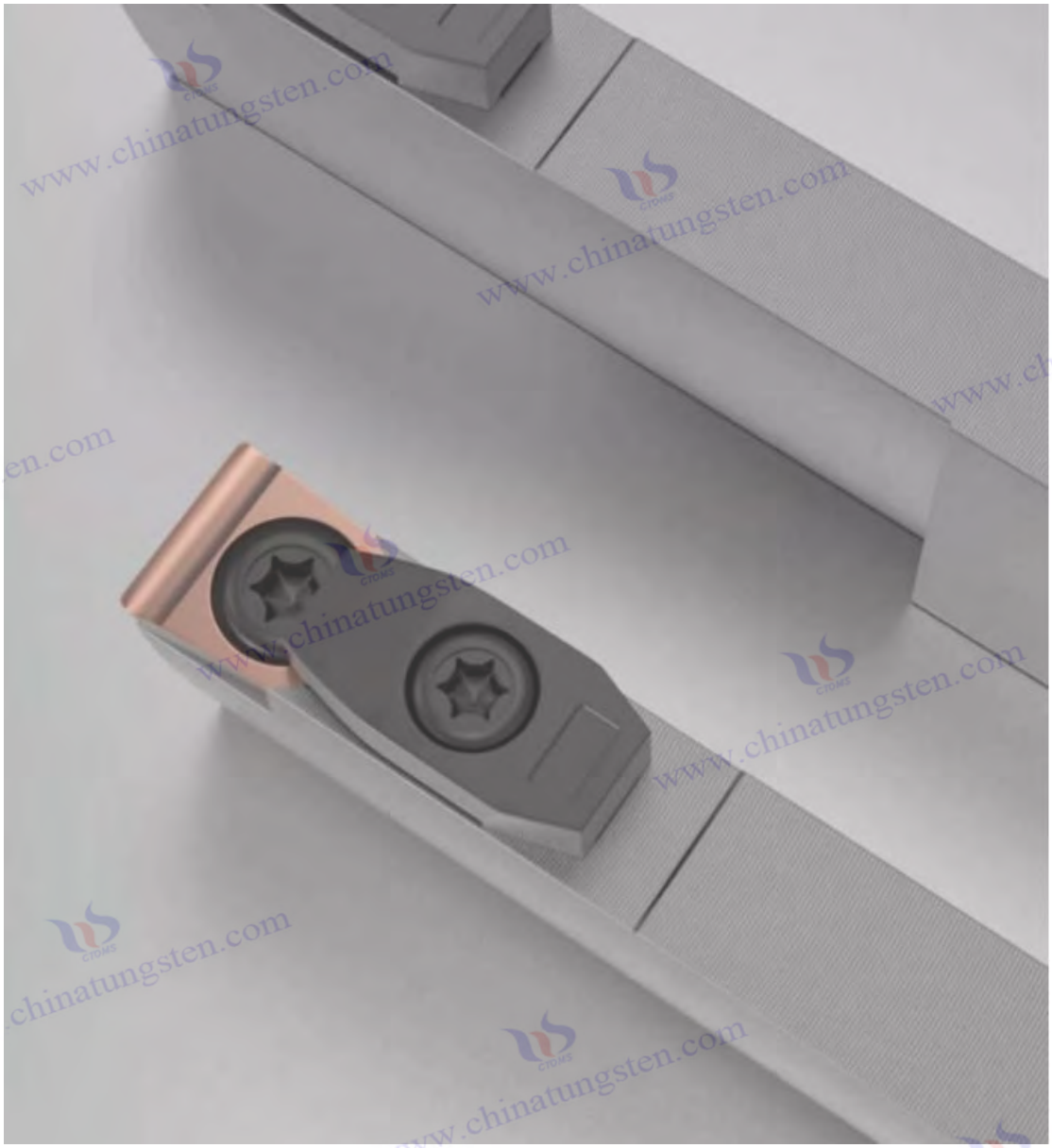
Technical Details: Definitions are based on common powder metallurgy practices, with examples drawn from related standards and industry conventions.

Limitations: Without access to the official text, the publication date, replaced versions, and exact term lists may differ. The reconstruction assumes the latest revision reflects current practices as of 2025.

Acquisition Suggestion

To obtain the official ASTM B243 - Standard Terminology of Powder Metallurgy, visit the ASTM International website (www.astm.org) or contact an authorized distributor (eg, ANSI, IHS Markit) for purchase or subscription access to the full document.

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ASTM B243

- Standard Terminology for Powder Metallurgy

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions relevant to powder metallurgy, the process of producing metal parts from metal powders by compaction and sintering.

1.2 Applicable to the production, characterization, and testing of metal powders and sintered components, including ferrous and non-ferrous materials.

1.3 This practice is intended for use by manufacturers, researchers, and quality control personnel in the powder metallurgy industry.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM B243 - Standard Terminology for Powder Metallurgy (self-referencing, for updates).

ASTM B925 - Standard Practice for Production and Preparation of Powder Metallurgy (PM) Test Specimens.

ASTM B962 - Standard test method for density of compacted or sintered powder metallurgy (PM) products.

ASTM B939 - Standard test method for green strength of compacted powder metallurgy (PM) materials.

2.2 Other standards:

ISO 3252 - Powder metallurgy — Vocabulary (reference).

3. Terminology

3.1 General Terms

Powder Metallurgy (PM) - A manufacturing process that produces metal components from metal powders by compaction and sintering.

Metal Powder - Fine metal particles used as feedstock for powder metallurgy.

Sintering - A thermal process that combines powder particles into a coherent mass by heating below the melting point.

3.2 Powder production and characterization

Atomization - The process of producing metal powder by breaking up a stream of molten metal into droplets using gas or water.

Particle Size - The size of individual powder particles, usually measured as a distribution (e.g. D50).

Apparent density - the volume occupied by a powder in its loose, uncompacted state divided by its mass.

3.3 Compaction and molding

Green Compact - A mass of powder that has been pressed but not sintered and that retains its shape through mechanical bonding.

Compaction - The process of pressing metal powder into the desired shape using a die and pressure.

Green Strength - The mechanical strength of the green compact before sintering.

3.4 Sintering and properties

Sintered Density - The density of a PM component after sintering, reflecting porosity and material consolidation.

Sintered Strength - The mechanical strength of a sintered part, affected by density and bonding.

Porosity - The volume fraction of voids in a sintered component, affecting properties such as strength and

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permeability.

3.5 Testing and Quality Control

Flow Rate - The time required for a specific mass of powder to pass through a standard funnel, indicating powder behavior.

Compressibility - The ability of a powder to be compacted under pressure into a dense green compact.

Transverse Rupture Strength - The maximum stress a sintered specimen can withstand under transverse loading.

4. Significance and Use

4.1 This terminology standard ensures uniform terminology usage within the powder metallurgy industry and facilitates communication among manufacturers, researchers, and standards developers.

4.2 It supports the application of other ASTM standards (e.g., B925, B962) by providing a unified vocabulary for production and testing.

5. Keywords

5.1 Powder metallurgy, metal powder, sintering, compaction, green strength, sintered density, porosity, atomization.

6. Appendix (Information)

6.1 Terminology:

The terminology may be updated in future revisions to reflect advances in powder metallurgy technology (e.g., additive manufacturing).

Cross-references to ASTM B925 and B962 provide additional context for production and testing terminology.

6.2 Example:

Apparent density calculation: $\rho a = m/V$, where ρa is the apparent density, m is the mass, and V is the volume.

Particle size distribution: D50 = 45 μm means that 50% of the particles are smaller than 45 μm .

7. Release of Information

Issuing unit: ASTM International.

Release date: 200X (the specific year is to be confirmed, the latest revision may be after 2000, such as 2019 or 2023).

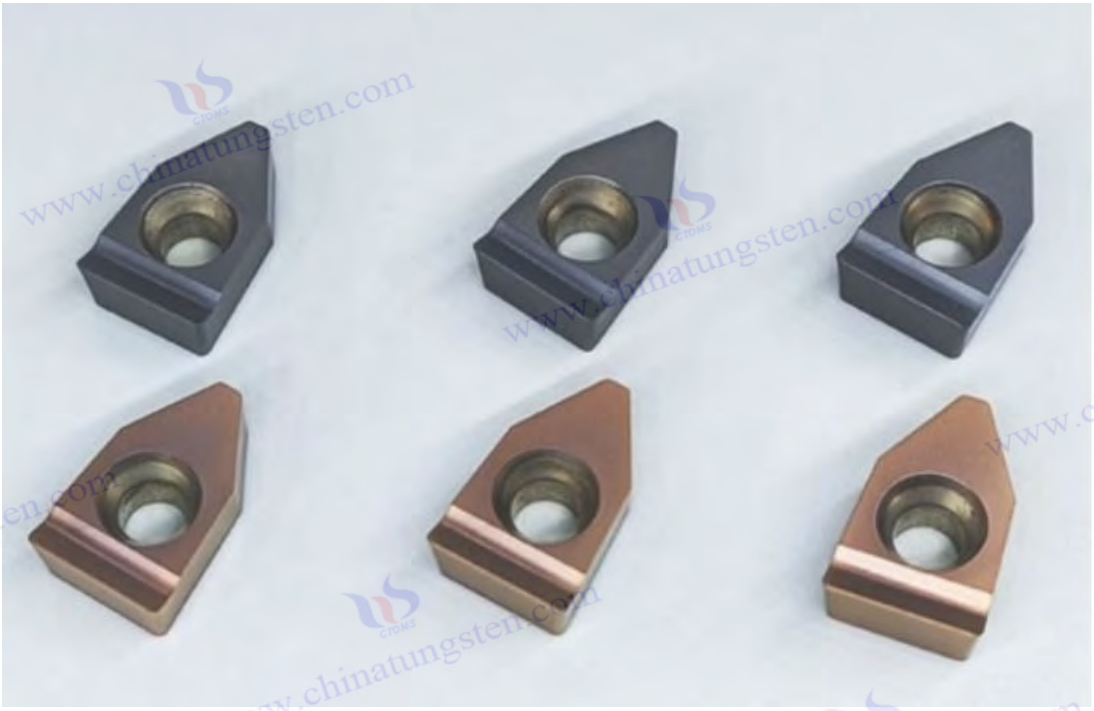
illustrate

Basis: ASTM B243 is the foundational terminology standard for powder metallurgy, supporting standards such as B925 (production) and B962 (density testing). Its structure follows the typical format of ASTM terminology standards.

Technical details: Definitions are based on common powder metallurgy practices, and examples refer to relevant standards and industry practices.

Limitations: Due to lack of access to official texts, publication dates, alternative versions, and precise terminology lists may vary. The reconstruction assumes the latest revision reflects current practice as of 2025.

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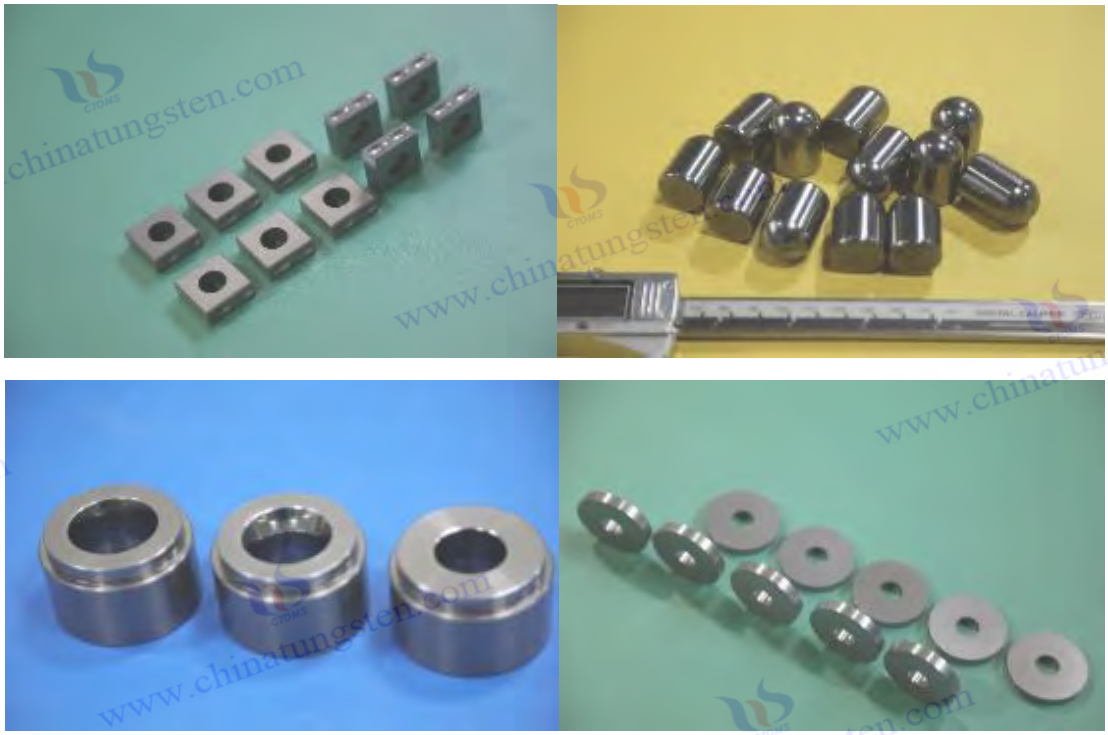
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ASTM E177

- Standard Practice for Use of the Terms Precision and Bias

in ASTM Test Methods

1. Scope

1.1 This practice provides guidelines for the use and definition of the terms "precision" and "bias" in ASTM test methods, ensuring consistent interpretation and reporting of test result variability and accuracy.

1.2 It applies to test methods for physical, chemical, or mechanical properties of materials, conducted in laboratories under controlled conditions.

1.3 The practice is intended for test method developers to include precision and bias statements, but it does not specify test procedures or apparatus.

1.4 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM E177 - Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods (self-referencing for updates).

ASTM E691 - Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method.

ASTM E178 - Standard Practice for Dealing with Outlying Observations.

ASTM E1301 - Standard Practice for Proficiency Testing by Interlaboratory Comparisons. 2.2 Other Standards:

ISO 5725-1 - Accuracy (Trueness and Precision) of Measurement Methods and Results (for reference).

3. Terminology

3.1 Precision - The closeness of agreement between independent test results obtained under stipulated conditions, expressed as repeatability and reproducibility. 3.2 Repeatability - The variability of test results obtained by the same operator using the same equipment in one laboratory over a short time interval. 3.3 Reproducibility - The variability of test results obtained by different laboratories using the same method on identical test materials. 3.4 Bias - The systematic difference between the expected value of a test result and the accepted reference value. 3.5 Standard Deviation - A measure of the dispersion of a set of test results, used to quantify precision.

4. Significance and Use

4.1 This practice provides a framework for quantifying the reliability of test methods through precision and bias statements, aiding in their validation and standardization. 4.2 It assists users in understanding the expected variability and potential systematic errors when applying a test method.

5. Procedure

5.1 Precision Determination:

Conduct an interlaboratory study per ASTM E691 to determine repeatability standard deviation (sr) and reproducibility standard deviation (sR).

Calculate repeatability limit ($r = 2.8 \times s_r$) and reproducibility limit ($R = 2.8 \times s_R$), representing 95% confidence for duplicate results.

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5.2 Bias Assessment:

Compare test results with an accepted reference value or certified material.

Quantify bias as the difference between the mean test result and the reference value, with statistical significance tested (eg, t-test).

5.3 Reporting:

Include precision and bias statements in the test method, specifying conditions (eg, number of laboratories, replicates).

6. Report

6.1 The report shall include:

Definition of precision (sr , sR , r, R) with associated conditions.

Bias statement, including reference value, mean test result, and statistical analysis if applicable.

Any limitations or assumptions (eg, normal distribution of data).

Reference to the interlaboratory study or bias assessment method.

7. Precision and Bias

7.1 Precision is based on statistical analysis from interlaboratory studies, with r and R reflecting variability under repeatable and reproducible conditions. 7.2 Bias is determined by comparing test results to a known standard; if no reference is available, bias cannot be quantified.

8. Keywords

8.1 Precision, bias, repeatability, reproducibility, test method, interlaboratory study, standard deviation.

9. Annex (Informative)

9.1 Statistical Notes:

Precision estimates assume a normal distribution; non-normal data may require transformation or non-parametric methods.

Minimum of 6 laboratories and 2 replicates per laboratory are recommended for robust precision data.

9.2 Example Calculation:

If $s_r = 0.3$ and $s_R = 0.7$, then $r = 2.8 \times 0.3 = 0.84$ and $R = 2.8 \times 0.7 = 1.96$. Bias example:

If mean test result = 10.2 and reference = 10.0, bias = 0.2 (with significance tested).

9.3 Safety Notes: Follow safety protocols of the specific test method during data collection.

10. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2014 or 2020).

Replaces: ASTM E177-08 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM E177 is a foundational practice for defining precision and bias in ASTM test methods, supporting standards like ASTM E691 (interlaboratory studies). The structure follows the typical ASTM format for practices.

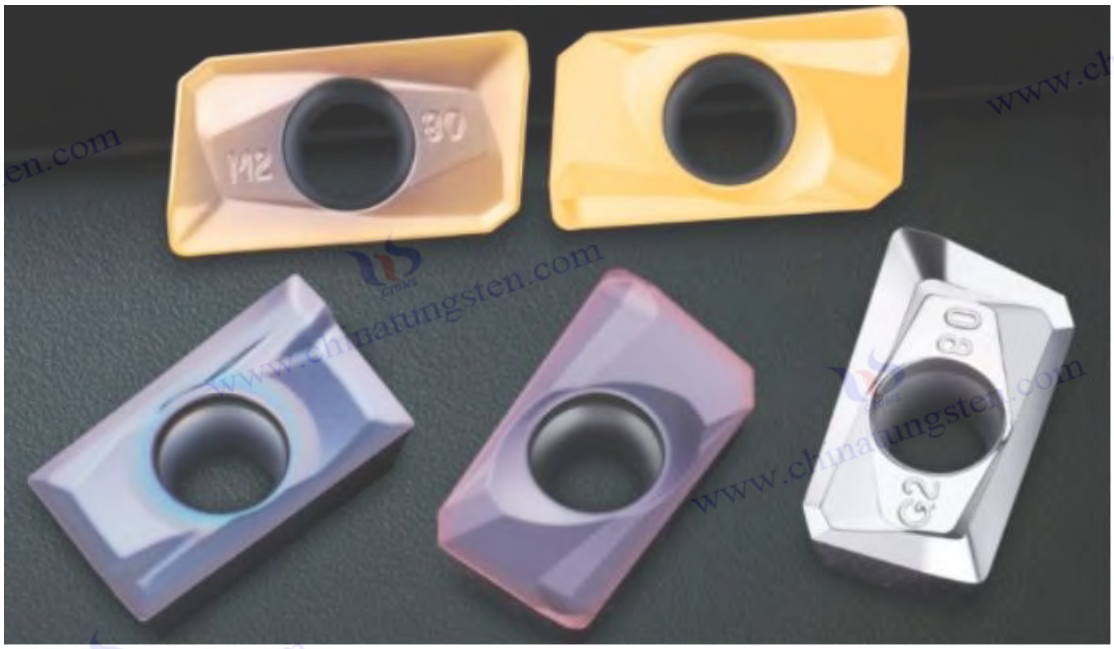
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Technical Details: Procedures and calculations are based on common statistical methods for precision and bias assessment, with safety and reporting considerations drawn from related standards.

Limitations: Without access to the official text, the publication date, replaced versions, and exact statistical thresholds may differ. The reconstruction assumes the latest revision reflects current practices as of 2025.

Acquisition Suggestion

To obtain the official ASTM E177 - Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods, visit the ASTM International website (www.astm.org) or contact an authorized distributor (eg, ANSI, IHS Markit) for purchase or subscription access to the full document.



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ASTM E177

- Standard practice for use of the terms precision and bias in ASTM test methods

1. Scope

1.1 This practice provides guidance on the use and definition of the terms “precision” and “bias” in ASTM test methods to ensure consistent interpretation and reporting of the variability and accuracy of test results.

1.2 Test methods for measuring the physical, chemical, or mechanical properties of materials performed in a laboratory under controlled conditions.

1.3 This practice is intended for use by test method developers to include precision and bias statements in test methods but does not specify test procedures or apparatus.

1.4 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM E177 - Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods (self-referenced, intended for updating).

ASTM E691 - Standard Practice for Conducting Interlaboratory Studies to Determine the Precision of Test Methods.

ASTM E178 - Standard Practice for Handling Unusual Observations.

ASTM E1301 - Standard Practice for Proficiency Testing by Interlaboratory Comparisons.

2.2 Other standards:

ISO 5725-1 - Accuracy (trueness and precision) of measurement methods and results (reference).

3. Terminology

3.1 Precision—The closeness of closeness of independent test results obtained under specified conditions, expressed in terms of repeatability and reproducibility.

3.2 Repeatability - Variation in test results obtained by the same operator using the same equipment in a single laboratory over a short period of time.

3.3 Reproducibility—The variation in test results obtained by different laboratories using the same method on the same test material.

3.4 Bias - A systematic difference between the expected value of a test result and an accepted reference value.

3.5 Standard Deviation - A measure of the dispersion of a set of test results, used to quantify precision.

4. Significance and Use

4.1 This practice provides a framework for quantifying the reliability of test methods through precision and bias statements to aid in their validation and standardization.

4.2 It assists the user in understanding the expected variation and possible systematic errors when applying the test method.

5. Procedure

5.1 Accuracy determination:

An interlaboratory study was conducted according to ASTM E691 to determine the repeatability standard deviation (sr s_r sr) and reproducibility standard deviation (sR s_R sR) .

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The repeatability limit (r = 2.8 × sr) and reproducibility limit (R = 2.8 × sR) were calculated, representing the 95% confidence level for the duplicate results.

5.2 Bias Assessment

Compare test results to recognized reference values or certified materials.

Quantify the bias as the difference between the mean of the test result and the reference value and perform a test of statistical significance (e.g., t-test).

5.3 Reporting:

Include precision and bias statements in the test method, specifying the conditions (e.g., number of laboratories, number of replicates).

6. Report

6.1 The report should include:

Definition of precision (sr , sR , r, R) and related conditions.

Statement of bias, including reference value, mean test result, and statistical analysis if applicable.

Any restrictions or assumptions (e.g., normal distribution of data).

References to interlaboratory studies or bias assessment methods.

7. Precision and Bias

7.1 Precision is based on statistical analysis of interlaboratory studies, with r and R reflecting the variation under repeatability and reproducibility conditions.

7.2 Bias is determined by comparing test results to a known standard; without a reference value, bias cannot be quantified.

8. Keywords

8.1 Precision, Bias, Repeatability, Reproducibility, Test Method, Interlaboratory Studies, Standard Deviation.

9. Appendix (Information)

9.1 Statistical Notes:

Precision estimates assume that the data are normally distributed; nonnormal data may require a transformation or nonparametric methods.

A minimum of six laboratories and two replicates per laboratory are recommended to obtain robust precision data.

9.2 Example calculation:

If sr = 0.3 and sR = 0.7, then r = 2.8 × 0.3 = 0.84

Bias example: If the test result mean = 10.2 and the reference value = 10.0, then the bias = 0.2 (significance test is required).

9.3 Safety Considerations: Follow the safety protocols for the specific test method during data collection.

10. Release of Information

Issuing unit: ASTM International.

Release date: 200X (the specific year is to be confirmed, the latest revision may be after 2000, such as 2014 or 2020).

Reconstruction Instructions

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Basis: ASTM E177 is the foundational practice for defining precision and bias in ASTM test methods and supports standards such as ASTM E691 (Interlaboratory Studies). Its structure follows the typical format of ASTM practice.

Technical details: Procedures and calculations are based on common statistical methods for precision and bias assessment, and safety and reporting considerations refer to relevant standards.

Limitations: Due to lack of access to official texts, publication dates, alternative versions, and precise statistical thresholds may vary. Reconstruction assumes latest revision reflects current practice as of 2025.

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ASTM G40

- Standard Terminology Relating to Wear and Erosion

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions related to wear and erosion of materials, including metals, ceramics, polymers, and composites. It is intended for use in research, quality control, and specification development within the fields of tribology and material durability.

1.2 The terminology applies to mechanisms such as abrasion, adhesion, fatigue, and erosion caused by solid particle impingement, liquid flow, or cavitation.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM G65 - Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus.

ASTM G99 - Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus.

ASTM G105 - Standard Test Method for Conducting Wet Sand/Rubber Wheel Abrasion Tests.

ASTM G76 - Standard Test Method for Conducting Erosion Tests by Solid Particle Impingement Using Gas Jets.

2.2 Other Standards:

ISO 20567-1 - Paints and Varnishes - Determination of Stone-chip Resistance (for reference).

3. Terminology

3.1 General Terms

Wear - The progressive loss of material from a solid surface due to mechanical action, such as contact, rubbing, or impact.

Erosion - The removal of material from a surface by the action of fluids, solid particles, or cavitation.

Tribology - The science and technology of interacting surfaces in relative motion, including friction, wear, and lubrication.

3.2 Wear Mechanisms

Abrasion - Wear caused by hard particles or protrusions forcing into and moving along a surface.

Adhesion - Wear resulting from the welding and subsequent tearing apart of surface asperities under load.

Fatigue Wear - Wear due to repeated loading and unloading, leading to surface or subsurface cracking and material

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loss.

Corrosive Wear - Wear accelerated by chemical or electrochemical reactions between the surface and environment.

3.3 Erosion Mechanisms

Solid Particle Erosion - Material removal caused by the impact of solid particles carried in a gas or liquid stream.

Liquid Erosion - Material loss due to the impact of liquid droplets or high-velocity fluid flow.

Cavitation Erosion - Material removal resulting from the collapse of vapor bubbles in a liquid near a surface.

3.4 Test and Measurement

Wear Rate - The volume or mass of material lost per unit of sliding distance or time, typically expressed as mm ^{3} /m or mg/h.

Erosion Rate - The volume or mass of material removed per unit of impingement time or particle flux, typically expressed as mm ^{3} /s or mg/g.

Friction Coefficient - The ratio of the frictional force to the normal force between two surfaces in contact.

3.5 Surface and Material Characteristics

Surface Roughness - The texture of a surface, quantified by parameters such as Ra (average roughness), affecting wear behavior.

Hardness - The resistance of a material to indentation or scratching, influencing wear resistance.

Contact Area - The real area of contact between two surfaces, critical in adhesive wear.

3.6 Test Apparatus and Conditions

Pin-on-Disk - A wear test method where a pin is rubbed against a rotating disk under controlled load and speed.

Sand/Rubber Wheel - An abrasion test using a rotating wheel with sand to simulate abrasive wear.

Impingement Angle - The angle at which erodent particles or fluid strike a surface, affecting erosion rate.

4. Significance and Use

4.1 This terminology standard ensures consistency in the use of wear and erosion terms across industries, facilitating communication among researchers, engineers, and quality control personnel. 4.2 It supports the application of other ASTM standards (eg, G65, G99) by providing a unified vocabulary for testing and analysis.

5. Keywords

5.1 Wear, erosion, abrasion, adhesion, fatigue, tribology, erosion rate, wear rate, surface roughness.

6. Annex (Informative)

6.1 Terminology Notes:

Terms may be updated in future revisions to reflect advances in tribological testing (eg, advanced imaging or simulation).

Cross-references to ASTM G65 and G99 provide additional context for test-specific terms. 6.2 Examples:

- Wear rate calculation: $W = \Delta V / L$, where W is wear rate, ΔV is volume loss, and L is sliding distance.
- Erosion rate example: $E = \Delta M / t$, where E is erosion rate, ΔM is mass loss, and t is time.

7. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2014 or 2020).

Replaces: ASTM G40-10 (or earlier version, to be confirmed).

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Reconstructive Notes

Basis: ASTM G40 is a foundational terminology standard for wear and erosion, supporting standards like ASTM G65 (abrasion) and G99 (pin-on-disk testing). The structure follows the typical ASTM format for terminology standards.

Technical Details: Definitions are based on common tribological practices, with examples drawn from related standards and industry conventions.

Limitations: Without access to the official text, the publication date, replaced versions, and exact term lists may differ. The reconstruction assumes the latest revision reflects current practices as of 2025.



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ASTM G40

- Standard terminology relating to wear and erosion

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions relevant to wear and erosion of materials, including metals, ceramics, polymers, and composites. It is intended for use in research, quality control, and specification development in the fields of tribology and material durability.

1.2 The term applies to mechanisms such as wear, adhesion, fatigue, and erosion caused by solid particle impact, liquid flow, or cavitation. 1.3 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM G65 - Standard test method for measuring abrasion using a dry sand /rubber wheel apparatus.

ASTM G99 - Standard test method for wear testing using a pin-on-disc apparatus.

ASTM G105 - Standard test method for conducting wet sand/rubber wheel abrasion tests.

ASTM G76 - Standard test method for solid particle impact erosion testing using a gas jet.

2.2 Other standards:

ISO 20567-1 - Paints and varnishes — Determination of resistance to stone chipping (reference).

3. Terminology

3.1 General Terms

Wear - The gradual loss of material from a solid surface due to mechanical action such as contact, friction or impact.

Erosion - The process of removing surface material due to liquids, solid particles or cavitation.

Tribology - The science and technology of interacting surfaces in relative motion, including friction, wear, and lubrication.

3.2 Wear mechanism

Abrasion - Wear caused by hard particles or projections becoming embedded in and moving along a surface.

Stiction - Wear caused by surface roughness welding under load and subsequent tearing.

Fatigue Wear - Wear resulting from repeated loading and unloading that results in surface or subsurface cracks and material loss.

Corrosive Wear - Wear accelerated by chemical or electrochemical reactions between a surface and its environment.

3.3 Erosion mechanism

Solid Particle Erosion - Material removal caused by the impact of solid particles carried in a gas or liquid stream.

Liquid Erosion - Loss of material due to droplet impact or high velocity liquid flow.

Cavitation Erosion - Material removal due to the collapse of vapor bubbles in a liquid near the surface.

3.4 Testing and Measurement

Wear rate - The volume or mass of material lost per unit sliding distance or time, usually expressed as mm^3 / m or mg/h.

Erosion Rate - The volume or mass of material removed per unit of impact time or particle flux, usually expressed as mm^3 / s or mg/g.

of the frictional force to the normal force between two contacting surfaces .

3.5 Surface and material properties

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Surface roughness - The texture of a surface, quantified by parameters such as Ra (average roughness), affects wear behavior.

Hardness - A material's ability to resist indentation or scratching, affecting wear resistance.

Contact Area - The actual contact area between two surfaces, which is critical in adhesive wear.

3.6 Test equipment and conditions

Pin-on-Disc - A wear test method in which a pin rubs against a rotating disk under controlled load and speed .

Sand/Rubber Wheel - Wear testing using a rotating wheel and sand to simulate abrasion.

Angle of impact - The angle at which an eroding particle or fluid strikes a surface, affecting the erosion rate.

4. Significance and Use

4.1 This terminology standard ensures uniformity in the use of wear and erosion terminology within the industry and facilitates communication among researchers, engineers, and quality control personnel.

4.2 It supports the application of other ASTM standards (e.g., G65, G99) by providing a unified vocabulary for testing and analysis.

5. Keywords

5.1 Wear, erosion, abrasion, adhesion, fatigue, tribology, erosion rate, wear rate, surface roughness.

6. Appendix (Information)

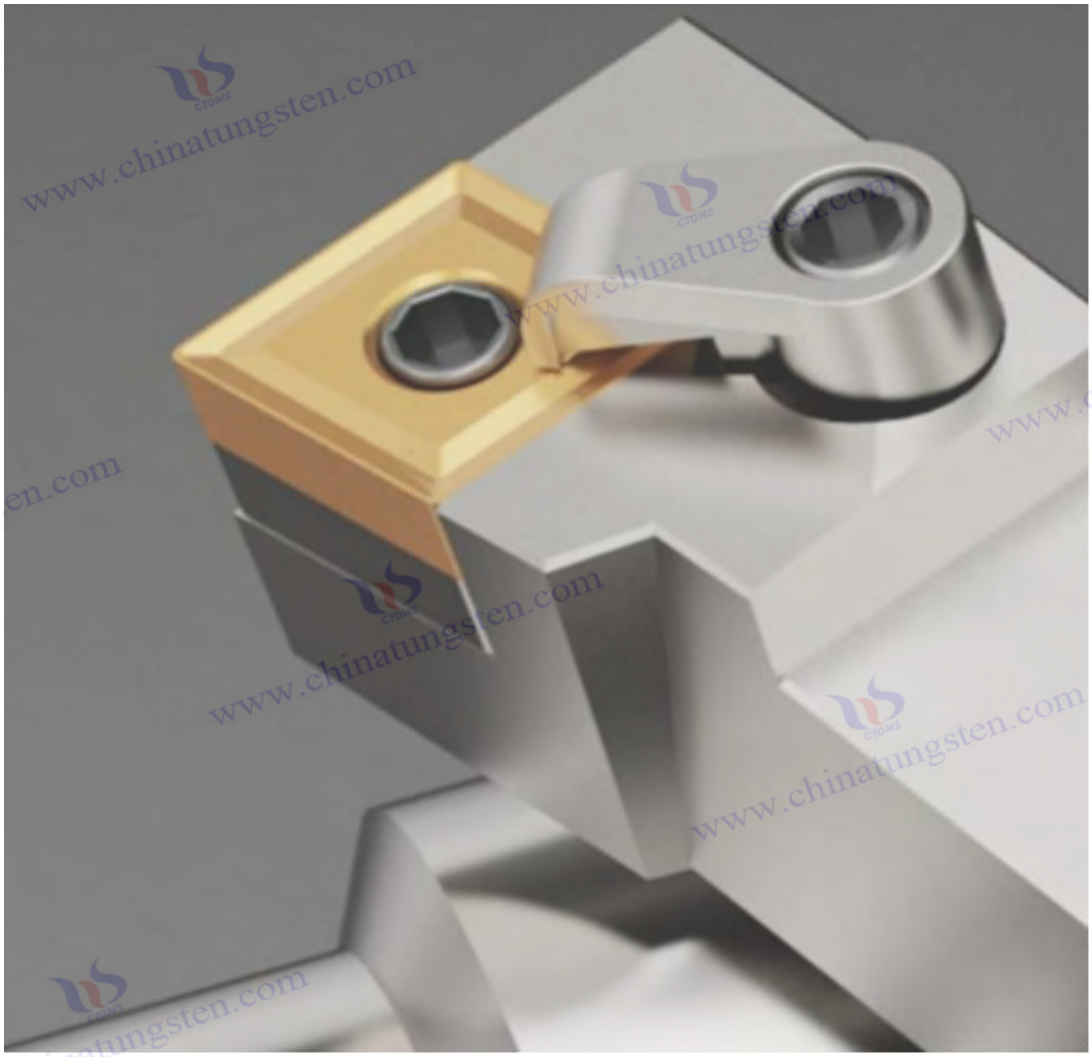
6.1 Terminology:

The terminology may be updated in future revisions to reflect advances in tribological testing (e.g., advanced imaging or simulation).

Cross-references to ASTM G65 and G99 provide additional context for specific test terms. 6.2 Example:

- 磨损率计算：$W = \Delta V / L$，其中W为磨损率，ΔV为体积损失，L为滑动距离。
- 侵蚀率示例：$E = \Delta M / t$，其中E为侵蚀率，ΔM为质量损失，t为时间。

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ASTM E3

- Standard Guide for Preparation of Metallographic Specimens

1. Scope

1.1 This guide provides procedures for preparing metallographic specimens of metals and alloys for microstructural examination using optical or electron microscopy. It applies to ferrous and non-ferrous metals, including cast, wrought, and welded forms, with section thicknesses up to 100 mm (4 in.).

1.2 The guide is intended for quality control, failure analysis, and research purposes, covering techniques such as sectioning, mounting, grinding, polishing, and etching. It is not intended for quantitative analysis requiring specialized methods.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM E7 - Standard Terminology Relating to Metallography.

ASTM E112 - Standard Test Methods for Determining Average Grain Size.

ASTM E407 - Standard Practice for Microetching Metals and Alloys.

ASTM E1558 - Standard Guide for Electrolytic Polishing of Metallographic Specimens.

ASTM E2015 - Standard Guide for Preparation of Plastic Embedded Specimens. 2.2 Other Standards:

ISO 14250 - Steel - Metallographic Characterization of Low-Carbon Steel (for reference).

3. Terminology

3.1 Definitions are in accordance with ASTM E7, including:

Metallographic Specimen - A prepared sample of metal or alloy for microstructural examination.

Grinding - The initial abrasive process to remove surface irregularities.

Polishing - The final abrasive process to achieve a mirror-like surface for microscopic observation.

4. Significance and Use

4.1 Proper specimen preparation is essential to reveal the true microstructure of metals and alloys, enabling accurate assessment of grain size, phases, and defects. 4.2 This guide supports the application of other ASTM standards (eg, E112 for grain size, E407 for etching) by ensuring consistent specimen quality.

5. Apparatus

5.1 Sectioning Equipment:

Abrasive cutoff saw or band saw with cooling system. 5.2 Mounting Equipment:

Hot mounting press (temperature 120°C to 180°C) or cold mounting resin kits. 5.3 Grinding and Polishing Equipment:

Grinding wheels or belts (80-1200 grit).

Polishing wheels with diamond paste (1 μm to 0.05 μm) or aluminum suspension. 5.4 Etching Setup:

Stainless steel or glass trays, fume hood, and heating plate (50°C to 100°C). 5.5 Inspection Tools:

Optical microscope (25x to 1000x) and low-power magnifier (up to 10x).

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6. Reagents and Materials

6.1 Mounting Materials:

Phenolic or epoxy resins for hot or cold mounting. 6.2 Abrasives:

Silicon carbide (SiC) papers (80, 240, 400, 600, 800, 1200 grit).

Diamond paste (1 μm , 0.25 μm , 0.05 μm) or colloidal silica. 6.3 Etchants (selection based on material):

For Steels: 2% nital (2 mL HNO_3 in 98 mL ethanol).

For Aluminum Alloys: Keller's reagent (190 mL H_2O, 5 mL HNO_3 , 3 mL HCl, 2 mL HF).

For Copper Alloys: Ammonium persulfate (10 g in 100 mL H_2O). 6.4 Cleaning Agents: Acetone or ethanol. 6.5 Protective Equipment: Gloves, safety goggles, and lab coat.

7. Procedure

7.1 Safety Precautions:

Wear protective equipment and work under a fume hood when handling etchants.

Use cooling fluids during sectioning to prevent overheating. 7.2 Sectioning:

Cut a representative section perpendicular to the working direction (eg, rolling or forging).

Use a slow speed and coolant to minimize heat damage (eg, water or oil). 7.3 Mounting (Optional):

For small or irregular specimens, mount in phenolic resin (120°C, 5-10 min) or cold-set epoxy.

Ensure the polished surface is exposed and flat. 7.4 Grinding:

Progressively grind with SiC papers (80 to 1200 grit) under water lubrication.

Change direction between grit levels to remove scratches (eg, 90° rotation). 7.5 Polishing:

Use diamond paste (1 μm to 0.05 μm) on a polishing cloth with light pressure.

Finish with colloidal silica for a scratch-free surface. 7.6 Etching:

Select an etchant based on material (eg, 2% nital for steel, 5-15 seconds).

Apply with a swab or immersion, rinse with water, and clean with acetone. 7.7 Inspection:

Examine the specimen under an optical microscope (25x to 1000x) or low-power magnifier.

Adjust preparation if scratches, relief, or over-etching are observed.

8. Report

8.1 The report shall include:

Material type, heat treatment condition, and specimen orientation.

Sectioning method, mounting details (if used), and abrasive sequence.

Etchant type, application time, and temperature.

Observations of microstructure (eg, grain size, phases, defects).

Photographs or sketches (if applicable).

Any deviations from the procedure.

9. Precision and Bias

9.1 Precision depends on operator skill and equipment quality. Repeatability of surface finish should be consistent across multiple specimens. 9.2 Bias is minimal with proper technique but may arise from uneven etching or inadequate polishing.

10. Keywords

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10.1 Metallography, specimen preparation, sectioning, mounting, grinding, polishing, etching, microstructure.

11. Annex (Informative)

11.1 Preparation Tips:

For hard materials (eg, hard alloys), use diamond saws and finer abrasives.

For soft metals (eg, aluminum), avoid excessive pressure during polishing. 11.2 Etching Time Guide:

Steels: 5-15 seconds with nital .

Aluminum: 10-20 seconds with Keller's reagent. 11.3 Safety Notes: Dispose of used etchants and resins per local hazardous waste regulations.

12. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2011 or 2017).

Replaces: ASTM E3-01 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM E3 is a foundational guide for metallographic specimen preparation, supporting standards like ASTM E112 (grain size) and E407 (etching). The structure follows the typical ASTM format for guides.

Technical Details: Procedures and materials are based on common metallographic practices, with safety and precision considerations drawn from related standards.

Limitations: Without access to the official text, the publication date, replaced versions, and exact procedural details may differ. The reconstruction assumes the latest revision reflects current practices as of 2025.

Acquisition Suggestion

To obtain the official ASTM E3 - Standard Guide for Preparation of Metallographic Specimens, visit the ASTM International website (www.astm.org) or contact an authorized distributor (eg, ANSI, IHS Markit) for purchase or subscription access to the full document.

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ASTM E3

- Standard guide for preparation of metallographic specimens of metals and alloys

1. Scope

1.1 This guide provides procedures for preparing metallographic specimens of metals and alloys for examination of their microstructure by optical or electron microscopy. It is applicable to ferrous and nonferrous metals in cast, wrought, and welded forms, with a maximum cross-section thickness of 100 mm (4 in).

1.2 This guide is intended for quality control, failure analysis, and research purposes and covers techniques such as cross-sectioning, mounting, grinding, polishing, and etching. It is not intended for quantitative analysis requiring specialized methods.

1.3 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM E7 - Standard Terminology Relating to Metallography.

ASTM E112 - Standard Test Method for Determining Average Grain Size.

ASTM E407 - Standard Practice for Microetching of Metals and Alloys.

ASTM E1558 - Standard Guide for Electrolytic Polishing of Metallographic Specimens of Metals and Alloys.

ASTM E2015 - Standard Guide for Preparation of Plastic Embedded Specimens. 2.2 Other Standards:

ISO 14250 - Steels — Metallographic characterization of low-carbon steels (reference).

3. Terminology

3.1 Definitions conform to ASTM E7, including:

Metallographic Specimen - A prepared sample of metal or alloy used for microstructural examination.

Grinding - The initial abrasive process used to remove surface irregularities.

Polishing - Final abrasive process used to achieve a mirror finish for microscopic viewing.

4. Significance and Use

4.1 Proper specimen preparation is essential to reveal the true microstructure of metals and alloys, enabling accurate assessment of grain size, phase, and defects.

4.2 This guide supports the use of other ASTM standards (e.g., E112 for grain size and E407 for etching) by ensuring consistent specimen quality.

5. Instruments

5.1 Section equipment:

Abrasive cutting saw or band saw with cooling system.

5.2 Installing the equipment:

Hot press (temperature 120°C to 180°C) or cold set resin kit.

5.3 Grinding and polishing equipment:

Abrasive wheels or belts (80-1200 grit).

with diamond paste (1 μm to 0.05 μm) or aluminum oxide suspension.

5.4 Etching device:

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Stainless steel or glass tray, ventilation hood and hot plate (50°C to 100°C).

5.5 Inspection Tools:

Light microscope (25x to 1000x) and low-power magnification microscope (up to 10x).

6. Reagents and Materials

6.1 Installation Materials:

Phenolic or epoxy resin for hot or cold installation.

6.2 Abrasives:

Silicon carbide (SiC) sandpaper (80, 240, 400, 600, 800, 1200 grit).

Diamond paste (1 μm , 0.25 μm , 0.05 μm) or colloidal silica.

6.3 Etchant (select according to material):

For steel: 2% nitrocellulose (2 ml HNO_3 in 98 ml ethanol).

For aluminum alloys: Keller 's reagent (190 ml H_2O , 5 ml HNO_3 , 3 ml HCl, 2 ml HF).

For copper alloys: ammonium persulfate (10 g in 100 ml H_2O) .

6.4 Cleaning agent: acetone or ethanol.

6.5 Protective equipment: gloves, safety glasses and lab coat.

7. Procedure

7.1 Safety precautions:

Wear protective gear and handle the etchant under a fume hood.

Use coolant when sectioning to prevent overheating.

7.2 Cross-section:

to the working direction (e.g., rolling or forging direction).

Use low speeds and a coolant (such as water or oil) to minimize heat damage.

7.3 Installation (Optional):

For small or irregular specimens, mount in phenolic resin (120°C, 5-10 minutes) or cold-curing epoxy .

Make sure the polished surface is exposed and flat.

7.4 Grinding:

Under water lubrication, grind gradually using SiC sandpaper (80 to 1200 grit).

Each time you change the sandpaper, change the direction to remove the scratches (e.g. rotate 90°).

7.5 Polishing:

μm to 0.05 μm) on a polishing cloth , applying light pressure.

Polishing is done with colloidal silica to achieve a scratch-free surface.

7.6 Etching:

Select the etchant according to the material (e.g. 2% nitro for steel, 5-15 seconds).

Apply with a swab or soak, rinse and clean with acetone.

7.7 Inspection:

Examine the specimen under a light microscope (25X to 1000X) or low-power magnification.

If scratches, relief, or overetching are observed, adjust the preparation process.

8. Report

8.1 The report should include:

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Material type, heat treatment conditions and specimen orientation.

Section method, mounting details (if used) and abrasive sequence.

Etchant type, application time and temperature.

Observations of microstructure (e.g., grain size, phase, defects).

Photographs or sketches (if applicable).

Any deviation from the procedure.

9. Precision and Bias

9.1 Accuracy depends on operator skill and equipment quality. Surface finish repeatability should be consistent across multiple specimens.

9.2 Bias is minimized by proper technique but may result from uneven etching or inadequate polishing.

10. Keywords

10.1 Metallography, specimen preparation, cross-sectioning, mounting, grinding, polishing, etching, and microstructure.

11. Appendix (Information)

11.1 Preparation Recommendations:

For hard materials (such as hard alloys), use a diamond saw and finer abrasives.

For soft metals such as aluminum, avoid applying excessive pressure when polishing.

11.2 Etching Time Guidelines:

Steel: 5-15 seconds with nitro.

Aluminum: 10-20 seconds using Keller 's reagent.

11.3 Safety Precautions: Dispose of used etchant and resin in accordance with local hazardous waste regulations.

12. Release of Information

Issuing unit: ASTM International.

Release date: 200X (the specific year is to be confirmed, the latest revision may be after 2000, such as 2011 or 2017).

Replacement: Replaces ASTM E3-01 (or earlier versions, to be confirmed).

illustrate

Basis: ASTM E3 is the foundational guide for metallographic specimen preparation, supporting standards such as E112 (grain size) and E407 (etching). Its structure follows the typical format of ASTM guidelines.

Technical Details: Procedures and materials are based on common metallographic practices, with reference to relevant standards for safety and accuracy.

Limitations: Due to lack of access to official texts, publication dates, alternative versions, and precise procedural details may vary. Reconstruction assumes latest revision reflects current practice as of 2025.

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ASTM E112

- Standard Test Methods for Determining Average Grain Size

1. Scope

1.1 This standard describes test methods for determining the average grain size of metals and alloys, using metallographic techniques. It applies to equiaxed grain structures, elongated grains, and non-uniform distributions in wrought, cast, or heat-treated materials.

1.2 The methods are suitable for quality control, material specification compliance, and research purposes, with magnifications typically ranging from 25x to 500x. It is not intended for ultrafine grains (<1 μm) or highly twinned structures without special preparation.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM E3 - Standard Guide for Preparation of Metallographic Specimens.

ASTM E407 - Standard Practice for Microetching Metals and Alloys.

ASTM E930 - Standard Test Methods for Estimating the Largest Grain Observed in a Metallographic Section.

ASTM E1382 - Standard Test Methods for Determining Average Grain Size Using Semiautomatic and Automatic Image Analysis. 2.2 Other Standards:

ISO 643 - Steels - Micrographic Determination of the Apparent Grain Size (for reference).

3. Terminology

3.1 Grain Size - The average diameter or area of individual grains in a polycrystalline metal or alloy, expressed as a grain size number or mean linear intercept. 3.2 Planimetric Method - A technique for determining grain size by counting the number of grains within a known area. 3.3 Intercept Method - A technique for determining grain size by measuring the number of grain boundary intercepts along a test line.

4. Summary of Test Methods

4.1 The standard provides three primary methods:

Comparison Method: Using standard grain size charts or micrographs for visual comparison.

Planimetric Method: Counting grains in a defined area at a specified magnification.

Intercept Method: Measuring intercepts of grain boundaries along random lines. 4.2 Automated image analysis methods are included as an option for modern applications.

5. Significance and Use

5.1 Grain size is a critical factor affecting the mechanical properties (eg, strength, ductility) and performance of metals and alloys. 5.2 These methods are used to verify material specifications, assess heat treatment effects, and investigate processing defects.

6. Apparatus

6.1 Metallographic Equipment:

Optical microscope with magnifications of 25x to 500x.

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Stage micrometer for calibration. 6.2 Specimen Preparation Tools:

Sectioning saw or abrasive cutter.

Grinding and polishing equipment (eg, 240-1200 grit abrasives).

Etching setup (eg, stainless steel trays, fume hood). 6.3 Measurement Tools:

Planimeter or grid for planimetric method.

Transparent overlay with test lines for intercept method.

Digital imaging system (optional for automated analysis).

7. Reagents and Materials

7.1 Etchants (selection based on material):

For Steels: 2% nital (2 mL HNO_3 in 98 mL ethanol).

For Aluminum Alloys: Keller's reagent (190 mL H_2O, 5 mL HNO_3, 3 mL HCl, 2 mL HF).

For Copper Alloys: Ammonium persulfate (10 g in 100 mL H_2O). 7.2 Cleaning Agents: Acetone or ethanol for post-etching cleaning. 7.3 Protective Equipment: Gloves, safety goggles, and lab coat.

8. Test Specimens

8.1 Size and Shape: Specimens should be representative, typically 20 mm × 20 mm × 10 mm, sectioned perpendicular to the working direction (eg, rolling or forging). 8.2 Preparation:

Cut and mount the specimen per ASTM E3.

Grind with 240-400 grit abrasives, then polish to 0.05 µm finish.

Etch to reveal grain boundaries (eg, 5-15 seconds with nital for steel).

9. Procedure

9.1 Safety Precautions:

Wear protective equipment and work under a fume hood.

Handle etchants with care, avoiding skin contact or inhalation. 9.2 Microscope Setup:

Calibrate the microscope using a stage micrometer.

Select magnification (eg, 100x for medium grains) based on grain size. 9.3 Comparison Method:

Compare the etched specimen with ASTM E112 grain size charts (eg, Chart 1 or 2).

- Assign a grain size number (G) using the formula: $G = -3.2877 + 6.6439 \log_{10} N$, where N is the number of grains per square inch at 100x. 9.4 **Planimetric Method**:
- Define a test area (e.g., 1 mm^2 at 100x),
- Count the number of grains (P) within the area, calculate $N_L = P/A$, and derive grain size. 9.5 **Intercept Method**:
- Draw or overlay random straight lines on the image.
- Count the number of grain boundary intercepts (P_L) per unit length, calculate mean linear intercept ($\bar{L} = 1/P_L$). 9.6 **Automated Method** (Optional):
- Use image analysis software to measure grain boundaries and calculate average grain size.

10. Calculation

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10.1 Grain Size Number (G):

- From comparison charts or $G = -3.2877 + 6.6439 \log_{10} N$. 10.2 **Mean Grain Area (Planimetric):**
- $\bar{A} = A/P$, where A is the test area. 10.3 **Mean Linear Intercept:**
- $\bar{L} = L/P_L$, where L is the test line length. 10.4 **Average Grain Diameter:**
- Approximate as $\bar{d} = 1.74\bar{L}$ for equiaxed grains.

11. Report

11.1 The report shall include:

Material type, heat treatment condition, and specimen orientation.

Method used (comparison, planimetric, intercept, or automated).

Magnification, etching, and etching time.

Grain size result (eg, G number, mean intercept, or diameter in μm).

Micrographs or images (if applicable).

Any deviations from the procedure.

12. Precision and Bias

12.1 Precision varies with method and operator skill. Repeatability should be within ±0.5 grain size number for manual methods. 12.2 Bias is minimal with proper calibration but depends on specimen preparation and etchant selection.

13. Keywords

13.1 Grain size, metallography, comparison method, planimetric method, intercept method, image analysis.

14. Annex (Informative)

14.1 Grain Size Chart Reference: ASTM E112 provides charts for G numbers 00 to 10, corresponding to 1 to 500 grains/mm ² at 100x. 14.2 Etching Times: Adjust based on alloy (eg, 5-10 s for aluminum, 10-20 s for steel). 14.3 Safety Notes: Dispose of used etchants per local hazardous waste regulations.

15. Publication Information

Published By: ASTM International.

Replaces: ASTM E112-96 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM E112 is a widely used standard for grain size determination, offering multiple methods (comparison, planimetric, intercept) with optional automated analysis. The structure follows the typical ASTM format, with procedures aligned with metallographic practices.

Technical Details: Grain size calculations and etchants are based on common metallographic techniques, with formulas and charts derived from historical ASTM practices.

Limitations: Without access to the official text, the publication date, replaced versions, and exact chart details may differ. The reconstruction assumes the latest revision reflects current practices as of 2025.

Acquisition Suggestion

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To obtain the official ASTM E112 - Standard Test Methods for Determining Average Grain Size, visit the ASTM International website (www.astm.org) or contact an authorized distributor (eg, ANSI, IHS Markit) for purchase or subscription access to the full document.



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ASTM E7

- Standard terminology related to metallography

1. Scope

1.1 This standard provides a comprehensive list of terms and definitions relating to metallography, the science of preparing and examining the microstructure of metals and alloys. It is intended for use in quality control, research, and specification development in the metallurgical industry.

1.2 The term applies to techniques such as specimen preparation, etching, microscopy, and grain size analysis, covering both ferrous and nonferrous metals and alloys .

1.3 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM E3 - Standard Guide for Preparation of Metallographic Specimens of Metals and Alloys.

ASTM E7 - Standard Terminology Relating to Metallography (self-referencing, for updates).

ASTM E112 - Standard Test Method for Determining Average Grain Size.

ASTM E407 - Standard Practice for Microetching of Metals and Alloys.

ASTM E1181 - Standard Test Method for Characterizing Duplex Grain Size. 2.2 Other Standards:

ISO 3252 - Powder metallurgy — Vocabulary (reference).

3. Terminology

3.1 General Terms

Metallography - The science and practice of preparing, examining, and interpreting the microstructure of metals and alloys, using optical or electron microscopes.

Microstructure - The arrangement and characteristics of phases, grains, and defects in a metal or alloy, as observed under magnification typically greater than 25x.

Macrostructure - The large-scale structural features of a metal or alloy, visible to the naked eye or at low magnification (up to 10x).

3.2 Sample preparation

Sectioning - The process of cutting a metal sample to produce a representative cross section for metallographic examination.

Mounting - Embedding a specimen in resin or plastic to facilitate handling and polishing.

Lapping - The initial abrasive process used to remove surface irregularities, typically using 80-1200 grit abrasives.

Polishing - Final abrasive process to achieve a mirror finish, typically using diamond paste (0.05-1 μm).

Etching - Chemical or electrolytic treatment of a polished surface to reveal microstructural features.

3.3 Etching and Reagents

Etchant - A chemical solution used to selectively attack the surface of a metal to reveal its microstructure (e.g., nitro, Keller 's reagent).

Macroetching - Etching to reveal large-scale features (e.g., grain flow, segregation) at low magnification.

Microetching - Etching to reveal fine microstructural details (e.g., grain boundaries) under high magnification.

3.4 Microscopic examination and analysis

Light Microscope - Use a light microscope (25x to 1000x) to examine metallographic specimens.

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Scanning Electron Microscopy (SEM) - uses an electron beam to image surface topography and microstructure at high magnification.

Grain Size - The average diameter of individual grains or the number of grains per unit area, usually expressed as a grain size number (e.g., ASTM E112 G number).

Phase - A homogeneous portion of a microstructure having different chemical or physical properties.

Inclusions - Non-metallic particles (e.g. oxides, sulfides) trapped in a metal matrix.

3.5 Mechanical and structural characteristics

Grain - An individual crystal in a polycrystalline metal surrounded by grain boundaries.

Grain boundary - The interface between two adjacent grains of different orientations.

Twins - Crystalline regions oriented in mirror images through the twinning plane, commonly observed in deformed metals.

Dendrites - Tree-like crystal structures that form during solidification of cast metals.

3.6 Defects and Imperfections

Porosity - voids or gas pockets within a metal, usually revealed by macroetching.

Crack - A break or separation in a metal that can be detected by etching or microscopy.

Segregation - Uneven distribution of alloying elements or impurities.

3.7 Quantitative Metallography

Planimetry - A technique for determining grain size by counting grains in a known area.

A technique for determining grain size by measuring the intercepts at grain boundaries along a test line .

Volume Fraction - The proportion of a phase or component in a given volume, usually estimated by point counting.

4. Significance and Use

4.1 This terminology standard ensures consistency in the use of metallographic terminology within the industry and facilitates communication among researchers, engineers, and quality control personnel.

4.2 It supports the application of other ASTM standards (e.g., E3, E112) by providing a unified vocabulary.

5. Keywords

5.1 Metallography, microstructure, macrostructure, etching, grain size, microscope, inclusions, defects.

6. Appendix (Information)

6.1 Terminology:

The terminology may be updated in future revisions to reflect advances in metallographic techniques (e.g., automated image analysis).

Cross-references to ASTM E112 and E407 provide additional context for grain size and etch terminology.

6.2 Example: * 晶粒尺寸编号（G）计算：$C \quad 3.2877 + 6.6439 \log_{10} N$，其中$N$为100倍下每平方英寸的晶粒数。

Commonly used etchants: 2% nitro for steel and Keller's reagent for aluminum .

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ASTM E112

- Standard Test Methods for Determining Average Grain Size

1. Scope

1.1 This standard describes test methods for determining the average grain size of metals and alloys, using metallographic techniques. It applies to equiaxed grain structures, elongated grains, and non-uniform distributions in wrought, cast, or heat-treated materials.

1.2 The methods are suitable for quality control, material specification compliance, and research purposes, with magnifications typically ranging from 25x to 500x. It is not intended for ultrafine grains (<1 μm) or highly twinned structures without special preparation.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM E3 - Standard Guide for Preparation of Metallographic Specimens.

ASTM E407 - Standard Practice for Microetching Metals and Alloys.

ASTM E930 - Standard Test Methods for Estimating the Largest Grain Observed in a Metallographic Section.

ASTM E1382 - Standard Test Methods for Determining Average Grain Size Using Semiautomatic and Automatic Image Analysis. 2.2 Other Standards:

ISO 643 - Steels - Micrographic Determination of the Apparent Grain Size (for reference).

3. Terminology

3.1 Grain Size - The average diameter or area of individual grains in a polycrystalline metal or alloy, expressed as a grain size number or mean linear intercept. 3.2 Planimetric Method - A technique for determining grain size by counting the number of grains within a known area. 3.3 Intercept Method - A technique for determining grain size by measuring the number of grain boundary intercepts along a test line.

4. Summary of Test Methods

4.1 The standard provides three primary methods:

Comparison Method: Using standard grain size charts or micrographs for visual comparison.

Planimetric Method: Counting grains in a defined area at a specified magnification.

Intercept Method: Measuring intercepts of grain boundaries along random lines. 4.2 Automated image analysis methods are included as an option for modern applications.

5. Significance and Use

5.1 Grain size is a critical factor affecting the mechanical properties (eg, strength, ductility) and performance of metals and alloys. 5.2 These methods are used to verify material specifications, assess heat treatment effects, and investigate processing defects.

6. Apparatus

6.1 Metallographic Equipment:

Optical microscope with magnifications of 25x to 500x.

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Stage micrometer for calibration. 6.2 Specimen Preparation Tools:

Sectioning saw or abrasive cutter.

Grinding and polishing equipment (eg, 240-1200 grit abrasives).

Etching setup (eg, stainless steel trays, fume hood). 6.3 Measurement Tools:

Planimeter or grid for planimetric method.

Transparent overlay with test lines for intercept method.

Digital imaging system (optional for automated analysis).

7. Reagents and Materials

7.1 Etchants (selection based on material):

For Steels: 2% nital (2 mL HNO_3 in 98 mL ethanol).

For Aluminum Alloys: Keller's reagent (190 mL H_2O, 5 mL HNO_3, 3 mL HCl, 2 mL HF).

For Copper Alloys: Ammonium persulfate (10 g in 100 mL H_2O). 7.2 Cleaning Agents: Acetone or ethanol for post-etching cleaning. 7.3 Protective Equipment: Gloves, safety goggles, and lab coat.

8. Test Specimens

8.1 Size and Shape: Specimens should be representative, typically 20 mm × 20 mm × 10 mm, sectioned perpendicular to the working direction (eg, rolling or forging). 8.2 Preparation:

Cut and mount the specimen per ASTM E3.

Grind with 240-400 grit abrasives, then polish to 0.05 μm finish.

Etch to reveal grain boundaries (eg, 5-15 seconds with nital for steel).

9. Procedure

9.1 Safety Precautions:

Wear protective equipment and work under a fume hood.

Handle etchants with care, avoid skin contact or inhalation.

9.2 Microscope Setup:

Calibrate the microscope using a stage micrometer.

Select magnification (eg, 100x for medium grains) based on grain size.

9.3 Comparison Method:

Compare the etched specimen with ASTM E112 grain size charts (eg, Chart 1 or 2).

Assign a grain size number (G) using the formula: $G = -3.2877 + 6.6439 \log_{10} N_A$, where N N N is the number of grains per square inch at 100x.

9.4 Planimetric Method:

Define a test area (eg, 1 mm² at 100x).

Count the number of grains (P P P) within the area, calculate NL=P/A, and derive grain size.

9.5 Intercept Method:

Draw or overlay random straight lines on the image.

Count the number of grain boundary intercepts (P_L) per unit length, calculate mean linear intercept ($\bar{L} = 1/P_L$). 9.6 **Automated Method** (Optional):

Use image analysis software to measure grain boundaries and calculate average grain size.

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10. Calculation

10.1 Grain Size Number (G):

- From comparison charts or $G = -3.2877 - 6.6439 \log_{10} N$. 10.2 **Mean Grain Area (Planimetric):**
- $\bar{A} = A/P$, where A is the test area. 10.3 **Mean Linear Intercept:**
- $\bar{L} = L/P_L$, where L is the test line length. 10.4 **Average Grain Diameter:**
- Approximate as $\bar{d} = 1.74\bar{L}$ for equiaxed grains.

11. Report

11.1 The report shall include:

Material type, heat treatment condition, and specimen orientation.

Method used (comparison, planimetric, intercept, or automated).

Magnification, etching, and etching time.

Grain size result (eg, G number, mean intercept, or diameter in μm).

Micrographs or images (if applicable).

Any deviations from the procedure.

12. Precision and Bias

12.1 Precision varies with method and operator skill. Repeatability should be within ±0.5 grain size number for manual methods. 12.2 Bias is minimal with proper calibration but depends on specimen preparation and etchant selection.

13. Keywords

13.1 Grain size, metallography, comparison method, planimetric method, intercept method, image analysis.

14. Annex (Informative)

14.1 Grain Size Chart Reference: ASTM E112 provides charts for G numbers 00 to 10, corresponding to 1 to 500 grains/mm ² at 100x. 14.2 Etching Times: Adjust based on alloy (eg, 5-10 s for aluminum, 10-20 s for steel). 14.3 Safety Notes: Dispose of used etchants per local hazardous waste regulations.

15. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000, eg, 2013 or 2021).

Replaces: ASTM E112-96 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM E112 is a widely used standard for grain size determination, offering multiple methods (comparison, planimetric, intercept) with optional automated analysis. The structure follows the typical ASTM format, with procedures aligned with metallographic practices.

Technical Details: Grain size calculations and etchants are based on common metallographic techniques, with formulas and charts derived from historical ASTM practices.

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Limitations: Without access to the official text, the publication date, replaced versions, and exact chart details may differ. The reconstruction assumes the latest revision reflects current practices as of 2025.

Acquisition Suggestion

To obtain the official ASTM E112 - Standard Test Methods for Determining Average Grain Size, visit the ASTM International website (www.astm.org) or contact an authorized distributor (eg, ANSI, IHS Markit) for purchase or subscription access to the full document.



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ASTM E112

- Standard test method for determining average grain size

1. Scope

1.1 This standard describes a test method for determining the average grain size of metals and alloys using metallographic techniques. It is applicable to wrought, cast, or heat-treated materials having an equiaxed grain structure, elongated grains, and nonuniform distribution of grains.

1.2 These methods are suitable for quality control, material specification conformity, and research purposes. Magnifications are typically in the range of 25x to 500x. They are not suitable for ultrafine grains (<1 μm) or highly twinned structures unless specially prepared.

1.3 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM E3 - Standard Guide for Preparation of Metallographic Specimens of Metals and Alloys.

ASTM E407 - Standard Practice for Microetching of Metals and Alloys.

ASTM E930 - Standard test method for estimating the largest grains observed in metallographic cross-sections.

ASTM E1382 - Standard test method for determining average grain size using semiautomatic and automatic image analysis.

2.2 Other standards:

ISO 643 - Steel — Microscopic determination of apparent grain size (reference).

3. Terminology

3.1 Grain Size—The average diameter or area of the individual grains in a polycrystalline metal or alloy, expressed as a grain size number or average linear intercept.

3.2 Planimetry - A technique for determining grain size by counting the number of grains in a known area.

A technique for determining grain size by measuring the number of intercepts along a test line at grain boundaries.

4. Summary of test methods

4.1 This standard provides three main methods:

Comparative method: Use standard grain size charts or microscope photos for visual comparison.

Planimetry: Counting grains within a defined area at a specified magnification.

Intercept method: The intercept of the grain boundary is measured along a random line.

4.2 Includes automated image analysis methods as an option for modern applications.

5. Significance and Use

5.1 Grain size is a key factor affecting the mechanical properties (e.g., strength, ductility) and performance of metals and alloys.

5.2 These methods are used to verify material specifications, evaluate the effects of heat treatment, and investigate machining defects.

6. Instruments

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6.1 Metallographic equipment:

Optical microscope, magnification 25x to 500x.

The stage micrometer is used for calibration.

6.2 Sample preparation tools:

Cross-section saw or abrasive cutter.

Grinding and polishing equipment (e.g., 240-1200 grit abrasives).

Etching equipment (e.g., stainless steel tray, fume hood).

6.3 Measuring tools:

A planimeter or grid is used for planimetry.

with test lines is used for the intercept method.

Digital imaging system (optional, for automated analysis).

7. Reagents and Materials

7.1 Etchant (select according to material):

For steel: 2% nitrocellulose (2 ml HNO_3 in 98 ml ethanol).

For aluminum alloys: Keller 's reagent (190 ml H_2O , 5 ml HNO_3 , 3 ml HCl, 2 ml HF).

For copper alloys: ammonium persulfate (10 g in 100 ml H_2O) .

7.2 Cleaning Agents: Acetone or ethanol for post-etching cleaning. 7.3 Protective Equipment: Gloves, safety glasses, and lab coat.

8. Test specimens

8.1 Size and Shape: The test specimen shall be representative, typically 20 mm × 20 mm × 10 mm, with a cross section perpendicular to the working direction (e.g., rolling or forging direction).

8.2 Preparation:

The specimens were cut and mounted according to ASTM E3.

Grind with 240-400 grit and then polish to a finish of 0.05 μm .

Etch to reveal grain boundaries (e.g., nitro for 5-15 seconds for steel).

9. Procedure

9.1 Safety precautions:

Wear protective gear and operate under a fume hood.

Handle etchant with care to avoid skin contact or inhalation.

9.2 Microscope Setup:

using the stage micrometer .

Select the magnification based on the grain size (e.g., 100x for medium grains).

9.3 Comparative Method:

Compare the etched specimen to an ASTM E112 grain size chart (such as Chart 1 or 2).

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- 使用公式分配晶粒尺寸编号（G）：$G = -3.2877 + 6.6439 \log_{10} N$，其中$N$为100倍下每平方英寸的晶粒数。9.4 **平面测量法**：
- 定义测试区域（例如，100倍下1 mm^2），
- 计数区域内的晶粒数（P），计算$N_L = P/A$，并推导晶粒尺寸。9.5 **截距法**：
- 在图像上绘制或覆盖随机直线。
- 计数每单位长度内的晶粒边界截距数（P_L），计算平均线性截距（$\bar{L} = 1/P_L$）。9.6 **自动方法**（可选）：

:

Use image analysis software to measure grain boundaries and calculate the average grain size.

10. Calculation

10.1 Grain size code (G):

- 从比较图表或$G = -3.2877 + 6.6439 \log_{10} N$得出。10.2 **平均晶粒面积（平面测量）**：
- $\bar{A} = A/P$，其中A为测试区域。10.3 **平均线性截距**：
- $\bar{L} = L/P_L$，其中L为测试线长度。10.4 **平均晶粒直径**：
- 对于等轴晶粒，近似为$\bar{d} = 1.74\bar{L}$。

11. Report

11.1 The report should include:

Material type, heat treatment conditions and specimen orientation.

Method used (comparative, planimetric, intercept, or automatic).

Magnification, etchant used, and etching time.

Grain size results (e.g. G number, mean intercept or diameter in μm).

Micrographs or images (if applicable).

Any deviation from the procedure.

12. Precision and Bias

12.1 Precision varies with the method and the skill of the operator. The repeatability of the manual method should be within ±0.5 grain size number.

12.2 Bias is minimized by proper calibration but depends on specimen preparation and etchant selection.

13. Keywords

13.1 Grain size, metallography, comparative method, planimetry, intercept method, image analysis.

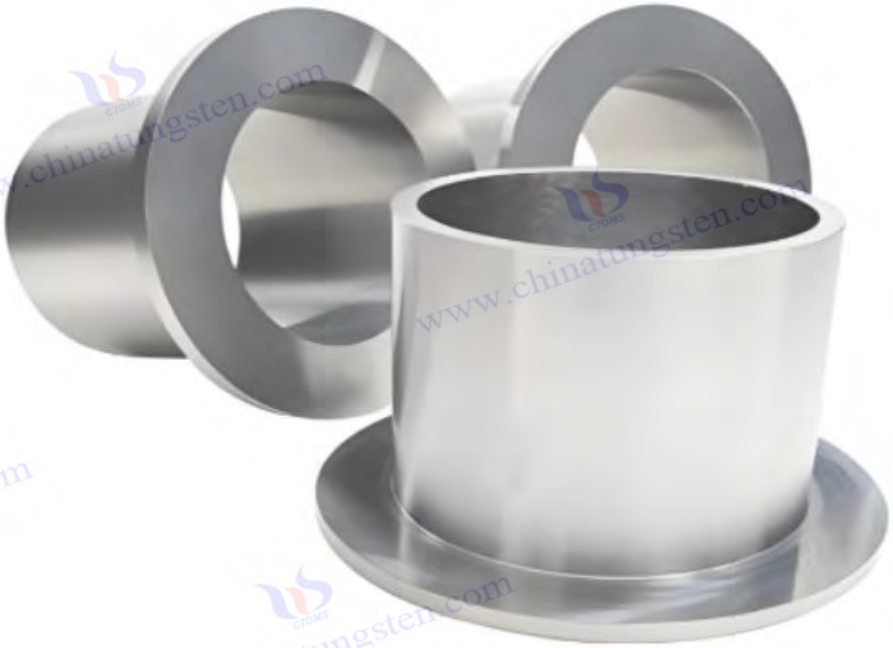
14. Appendix (Information)

14.1 Grain Size Chart Reference: ASTM E112 provides a chart with G numbers 00 to 10, corresponding to 1 to 500 grains/mm² at 100x magnification .

14.2 Etching Time: Adjust according to the alloy (e.g., 5-10 seconds for aluminum, 10-20 seconds for steel).

14.3 Safety Precautions: Dispose of used etchant in accordance with local hazardous waste regulations.

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ASTM E340

- Standard Practice for Macroetching Metals and Alloys

1. Scope

1.1 This practice covers the procedures for macroetching metals and alloys to reveal their macrostructure, including grain flow, segregation, porosity, cracks, inclusions, and other defects. It is applicable to ferrous and non-ferrous metals and alloys in cast, wrought, or welded forms, with section thicknesses up to 150 mm (6 in.).

1.2 The practice is intended for quality control, failure analysis, and research purposes but is not suitable for microscale examination or quantitative metallographic analysis.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information only.

2. Referenced Documents

2.1 ASTM Standards:

ASTM E3 - Standard Guide for Preparation of Metallographic Specimens.

ASTM E381 - Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings.

ASTM E407 - Standard Practice for Microetching Metals and Alloys.

ASTM E1180 - Standard Practice for Preparing Sulfur Prints for Macrostructural Evaluation. 2.2 Other Standards:

ISO 4969 - Steel - Macroscopic Examination by Etching (for reference).

3. Terminology

3.1 Macroetching - A metallographic technique using chemical etchants to reveal the macrostructure of metals and alloys on a scale visible to the naked eye or at low magnification (up to 10x).

3.2 Macrostructure - The large-scale structural features of a metal or alloy, including grain size, flow lines, segregation, and defects.

3.3 Etchant - A chemical solution used to selectively attack the surface of a metal or alloy to reveal its macrostructure.

4. Summary of Practice

4.1 The practice involves preparing a metal or alloy specimen, selecting an appropriate etchant, applying the etchant under controlled conditions, and examining the resulting macrostructure to identify features such as grain flow, inclusions, or cracks.

4.2 Safety precautions and proper handling of etchants are emphasized due to their corrosive nature.

5. Significance and Use

5.1 Macroetching is used to evaluate the quality and integrity of metals and alloys, detect manufacturing defects, and assess the effectiveness of heat treatment or welding processes. 5.2 It provides a qualitative assessment of macrostructural features and is often a preliminary step before more detailed microexamination .

6. Apparatus

6.1 Specimen Preparation Equipment:

Band saw or abrasive cutter for sectioning.

Grinding wheel or belt sander (grain size 80-120).

Polishing machine with coarse abrasives (eg, 240-400 grit).

6.2 Etching Equipment:

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Stainless steel or glass trays for etchant application.

Heating plate or hot plate (temperature range 50°C to 100°C).

Ventilation hood for fume control.

6.3 Inspection Tools:

Magnifying glass or low-power stereomicroscope (up to 10x magnification).

Calipers or rulers for dimensional checks.

7. Reagents and Materials

7.1 Etchants (selection based on material):

For Steels: 10% aqueous nitric acid (HNO_3) or 5% nital (5 mL HNO_3 in 95 mL ethanol).

For Aluminum Alloys: Keller's reagent (190 mL H_2O, 5 mL HNO_3, 3 mL HCl, 2 mL HF).

For Copper Alloys: Ammonium hydroxide (NH_4OH) with hydrogen peroxide (H_2O_2).

For Titanium Alloys: Kroll's reagent (2 mL HF, 4 mL HNO_3, 94 mL H_2O).

7.2 Cleaning Agents: Acetone or ethanol for post-etching cleaning.

7.3 Protective Equipment: Gloves, safety goggles, and lab coat.

8. Test Specimens

8.1 Size and Shape: Specimens should be representative of the material, typically 25 mm × 25 mm × 10 mm to 150 mm × 150 mm × 50 mm, depending on the part.

8.2 Preparation:

Cut sections perpendicular to the working direction (eg, rolling or forging direction).

Grind and polish one surface to remove surface defects, achieving a finish of 240-400 grit.

Clean with acetone or ethanol to remove grease.

9. Procedure

9.1 Safety Precautions:

Wear protective equipment and work under a fume hood.

Handle etchants with care, avoid skin contact or inhalation.

9.2 Etching Process:

Apply the selected etchant to the polished surface using a swab or immersion.

Control temperature (eg, 60°C for nital) and etching time (5-30 seconds, depending on material and etchant).

Agitate the specimen gently to ensure uniform etching.

9.3 Post-Etching :

Rinse with water, then clean with acetone or ethanol.

Dry with warm air or a cloth.

9.4 Examination:

Inspect the etched surface with the naked eye or a low-power magnifier (up to 10x).

Record observations, including grain flow, segregation, or defects.

10. Interpretation of Results

10.1 Identify macrostructural features such as:

Grain flow lines indicating deformation.

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Segregation zones (eg, central pipe or banding).

Defects like porosity, cracks, or inclusions.

10.2 Compare results with ASTM E381 reference photographs for steel or equivalent standards for other alloys.

11. Report

11.1 The report shall include:

Material type, heat treatment condition, and specimen dimensions.

Etchant used, temperature, and etching time.

Description of macrostructural features (eg, grain flow, defects).

Photographs or sketches of the etched surface (if applicable).

Any deviations from the procedure.

12. Precision and Bias

12.1 Precision depends on operator skill, etchant selection, and specimen preparation. No specific precision statement is provided, but repeatability should be verified with multiple specimens.

12.2 Bias cannot be determined as macroetching is a qualitative method.

13. Keywords

13.1 Macroetching , metals, alloys, macrostructure, grain flow, defects, metallography.

14. Annex (Informative)

14.1 Etchant Selection Guide:

Steels: 5% nital (5-15 seconds).

Aluminum: Keller's reagent (10-20 seconds).

Copper: $NH_4OH + H_2O_2$ (5-10 seconds).

14.2 Safety Notes: Dispose of used etchants per local hazardous waste regulations.

15. Publication Information

Published By: ASTM International.

Publication Date: 200X (specific year to be confirmed, latest revision likely post-2000).

Replaces: ASTM E340-00 (or earlier version, to be confirmed).

Reconstructive Notes

Basis: ASTM E340 is a well-established practice for macroetching , focusing on qualitative assessment of macrostructure. The structure follows the typical ASTM format (Scope, Referenced Documents, Terminology, etc.), with procedures aligned with metallographic practices.

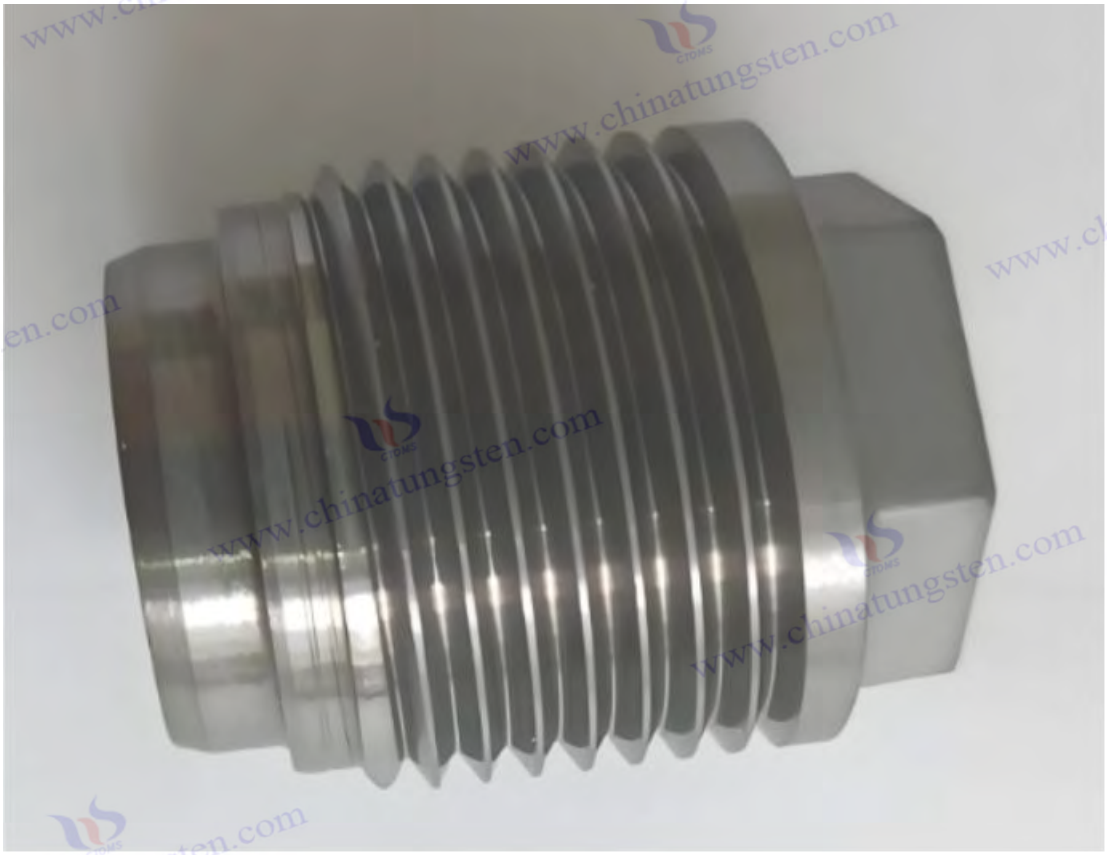
Technical Details: Etchants and procedures are based on common metallographic techniques for various alloys, with safety and precision considerations drawn from related standards (eg, ASTM E3, E381).

Limitations: Without access to the official text, the publication date, replaced versions, and exact etchant recipes may differ. The reconstruction assumes the latest revision reflects current industry practices as of 2025.

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Acquisition Suggestion

To obtain the official ASTM E340 - Standard Practice for Macroetching Metals and Alloys, visit the ASTM International website (www.astm.org) or contact an authorized distributor (eg, ANSI, IHS Markit) for purchase or subscription access to the full document.



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ASTM E340

- Standard practice for macroetching of metals and alloys

1. Scope

1.1 This practice covers procedures for macroetching metals and alloys to reveal their macrostructure, including grain flow, segregation, porosity, cracks, inclusions, and other defects. It is applicable to ferrous and nonferrous metals and alloys in cast, wrought, or welded form , with section thicknesses up to 150 mm (6 in.).

1.2 This practice is intended for quality control, failure analysis, and research purposes but is not intended for microscale inspection or quantitative metallographic analysis.

1.3 The values stated in SI units are standard. Inch-pound units are for reference only.

2. References

2.1 ASTM Standards:

ASTM E3 - Standard Guide for Preparation of Metallographic Specimens of Metals and Alloys.

ASTM E381 - Standard Method for Macroetching of Steel Bars, Billets, Ingots, and Forgings.

ASTM E407 - Standard Practice for Microetching of Metals and Alloys.

ASTM E1180 - Standard Practice for Preparation of Sulfur Seals for Macrostructural Evaluation.

2.2 Other standards:

ISO 4969 - Steel — Macroscopic examination by etching (reference).

3. Terminology

3.1 Macroetching - A metallographic technique that uses chemical etchants to reveal the macrostructure of a metal or alloy, visible to the naked eye or under low magnification (up to 10x).

3.2 Macrostructure - The large-scale structural characteristics of a metal or alloy, including grain size, flow lines, segregation, and defects.

3.3 Etchant - A chemical solution used to selectively attack the surface of a metal or alloy to reveal its macrostructure.

4. Practice Summary

4.1 This practice involves preparing metal or alloy specimens, selecting an appropriate etchant, applying the etchant under controlled conditions, and examining the resulting macrostructure to identify features such as grain flow, inclusions, or cracks.

4.2 Due to the corrosive nature of the etchant, safety precautions and proper handling are emphasized.

5. Significance and Use

5.1 Macroetching is used to evaluate the quality and integrity of metals and alloys, to detect manufacturing defects, and to assess the effectiveness of heat treatment or welding processes.

5.2 It provides a qualitative assessment of macrostructural features and is often a preliminary step before more detailed microscopic examination.

6. Instruments

6.1 Sample preparation equipment:

A band saw or abrasive cutter is used for slicing.

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Grinding wheel or belt sander (80-120 grit).

A polishing machine equipped with a coarse abrasive (e.g. 240-400 grit).

6.2 Etching equipment:

Stainless steel or glass trays for etchant application.

Heating plate or hot plate (temperature range 50°C to 100°C).

Fume hood for smoke control.

6.3 Inspection Tools:

Magnifying glass or low-power stereo microscope (up to 10x magnification).

Vernier calipers or rulers are used for dimensional checking.

7. Reagents and Materials

7.1 Etchant (select according to material):

For steel: 10% aqueous nitric acid (HNO_3) or 5% nitro (5 ml HNO_3 in 95 ml ethanol).

For aluminum alloys: Keller 's reagent (190 ml H_2O , 5 ml HNO_3 , 3 ml HCl, 2 ml HF).

For copper alloys: ammonia (NH_4OH) and hydrogen peroxide (H_2O_2) .

For titanium alloys: Kroll 's reagent (2 ml HF, 4 ml HNO_3 , 94 ml H_2O) .

7.2 Cleaning Agents: Acetone or ethanol for post-etch cleaning.

7.3 Protective equipment: gloves, safety glasses and lab coat.

8. Test specimens

8.1 Size and Shape: The test specimen shall be representative of the material and shall typically measure from 25 mm × 25 mm × 10 mm to 150 mm × 150 mm × 50 mm, depending on the component.

8.2 Preparation:

to the working direction (e.g. rolling or forging direction).

Grind and polish a surface to remove surface imperfections and achieve a finish of 240-400 g.

Clean with acetone or ethanol to remove grease.

9. Procedure

9.1 Safety precautions:

Wear protective gear and operate under a fume hood.

Handle etchant with care to avoid skin contact or inhalation.

9.2 Etching process:

Apply the selected etchant to the polished surface using a swab or by immersion.

Control the temperature (e.g. 60 °C for nitrocellulose) and etching time (5-30 s, depending on the material and etchant).

Gently shake the specimen to ensure uniform etching.

9.3 Post-etching processing:

Rinse with water, then clean with acetone or ethanol.

Dry with warm air or a cloth.

9.4 Inspection:

Inspect the etched surface with the naked eye or with a low-power magnifier (up to 10x).

Record observations, including grain flow, segregation, or defects.

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10. Interpretation of Results

10.1 Identify macrostructural features, such as:

Grain flow lines indicating deformation direction.

Segregation zones (e.g. center tube or band).

Defects such as porosity, cracks or inclusions.

10.2 Compare the results with reference photographs from ASTM E381, or an equivalent standard for other alloys.

11. Report

11.1 The report should include:

Material type, heat treatment conditions and specimen dimensions.

The etchant, temperature and etching time used.

Description of macrostructural features (e.g. grain flow, defects).

A photograph or sketch of the etched surface (if applicable).

Any deviation from the procedure.

12. Precision and Bias

12.1 Accuracy depends on operator skill, etchant selection , and specimen preparation. No specific accuracy statement is provided, but repeatability should be verified with multiple specimens.

12.2 Because macroetching is a qualitative method, bias cannot be determined.

13. Keywords

13.1 Macroetching, metals, alloys, macrostructure, grain flow, defects, metallography.

14. Appendix (Information)

14.1 Etchant Selection Guidelines:

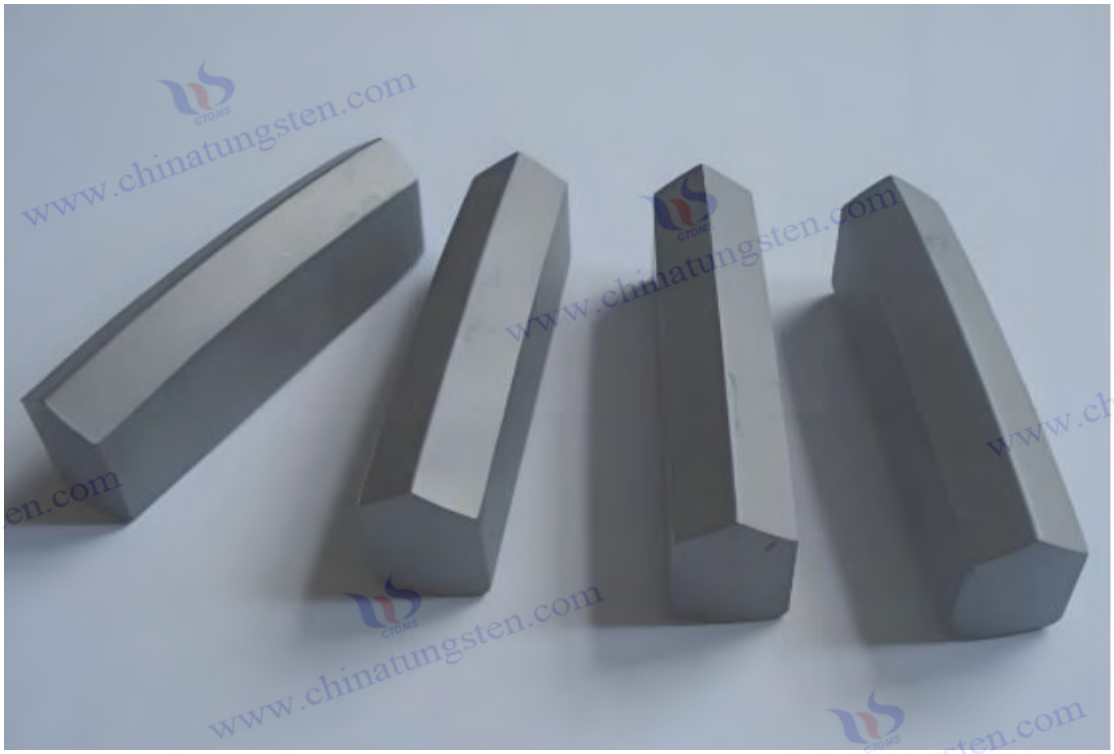
Steel: 5% Nitro (5-15 seconds).

Aluminum: Keller 's reagent (10-20 seconds).

Copper: $NH_4OH + H_2O_2$ (5-10 seconds) .

14.2 Safety Precautions: Dispose of used etchant in accordance with local hazardous waste regulations.

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GB/T 13239

Preparation and dimensions of tensile test specimens for metallic materials

1. Scope

This standard specifies the preparation methods and dimensional requirements for specimens used for tensile testing of metallic materials. It is applicable to the mechanical property testing of materials such as steel, stainless steel, non-ferrous metals (such as aluminum and copper), and cemented carbide, including the determination of yield strength, tensile strength, elongation after fracture, and reduction of area. It is suitable for both laboratory preparation and industrial production. It is not suitable for materials with a thickness less than 0.1 mm or complex geometries and requires verification in conjunction with other standards (such as GB/T 228.1-2010).

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 228.1-2010 Tensile tests on metallic materials - Part 1: Test methods at room temperature.

GB/T 6397 Metal tensile test specimens.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 16825.1 Materials testing machines - Verification of static testing machines - Part 1: Tension, compression and bend tests

ISO 6892-1 Tensile tests on metallic materials — Part 1: Test methods at room temperature (informative).

3. Terms and Definitions

This standard uses the following terms and definitions:

Tensile Specimen: A standardized specimen of specific geometry and dimensions used in tensile testing.

Gauge Length: The reference length on a specimen used to measure elongation.

Parallel Length: The portion of the specimen with uniform cross-section used to apply the load.

4. Preparation Method

4.1 Specimen type: Select according to material and test requirements:

Cylindrical specimens.

Plate specimens.

Wire specimens.

4.2 Preparation process:

Cutting: Use machining or EDM to cut the specimen and make the surface smooth.

Grinding: Use SiC sandpaper (#600 to #1200) to remove machining marks.

Polishing: Polish with 1 μm diamond suspension to Ra ≤ 0.4 μm .

Cleaning: Clean with anhydrous ethanol or acetone to remove oil stains and dry.

4.3 Heat treatment (if applicable): Annealing or aging should be performed according to the material characteristics to eliminate processing stress.

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5. Specimen size

5.1 Cylindrical specimens:

Diameter (d): 3 mm, 5 mm, 6 mm, 8 mm, 10 mm (5 mm recommended).

Gauge length (L_0) : 5d (50 mm recommended).

Parallel section length (L_c): not less than d + 2L_0 (60 mm recommended).

Total length (L_t): not less than L_c + 2× clamping section length (recommended 100 mm).

5.2 Plate specimens:

Width (b): 10 mm, 12.5 mm, 15 mm (12.5 mm recommended).

Thickness (h): 2 mm to 10 mm (depending on the material).

Gauge length (L_0) : 5.65$\sqrt{A_0}$ (A_0 is the original cross-sectional area, 50 mm is recommended).

Parallel section length (L_c): not less than L_0 + 2h (60 mm recommended).

Total length (L_t): not less than L_c + 2× clamping section length (recommended 100 mm).

5.3 Wire specimens:

Diameter (d): 0.1 mm to 10 mm.

Gauge length (L_0) : 50 mm or 10d (whichever is larger).

Total length (L_t): not less than L_0 + 2× clamping section length (recommended 80 mm).

5.4 Dimensional tolerances:

Diameter or thickness: ±0.1 mm.

Gauge length: ±0.1 mm.

Parallel section length: ±0.5 mm.

6. Sample inspection

6.1 Visual inspection: Ensure there are no cracks, scratches, oxide layers or processing defects.

6.2 Dimension measurement: Measure with a vernier caliper or micrometer . The deviation shall comply with the requirements of 5.4.

6.3 Surface roughness: Ra ≤ 0.4 μm , verified with a surface profiler when necessary.

7. Sample identification

7.1 Marking: Mark the specimen number in permanent ink on the grip section or non- gauge length area .

7.2 Protection: Use anti-rust oil or plastic wrap to prevent transportation damage.

8. Appendix (Informative)

8.1 Example of specimen dimensions:

Cylindrical (d=5 mm): L_0 = 50 mm, L_c =60 mm, L_t =100 mm.

Plate (b=12.5 mm, h=5 mm): L_0 = 50 mm, L_c =60 mm, L_t =100 mm. 8.2 Preparation Notes:

Cemented carbide specimens need to be processed using diamond tools to reduce microcracks.

For thin plate specimens, avoid excessive polishing and maintain the original surface characteristics. 8.3 Reference Standard: ISO 6892-1 provides similar dimensional recommendations.

9. Release of Information

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GB/T 16825.1

Calibration of material testing machines and static testing machines

Part 1: Tension, compression and flexure tests

1. Scope

This standard specifies the verification methods for static testing machines, including force measurement, deformation measurement, and overall performance verification for tensile, compression, and flexure testing machines. It is applicable to materials testing machines with a maximum test force range of 0.1 kN to 2000 kN , and is used for mechanical property testing of metallic, non-metallic, and composite materials. This method is suitable for initial verification, periodic verification, and post-use confirmation. It is not applicable to dynamic testing machines or severely damaged equipment.

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 12160 Grips for tensile testing of metallic materials.

GB/T 16825.2 Materials testing machines - Verification of static testing machines - Part 2: Calibration of force standards

JJF 1059.1 Evaluation and expression of measurement uncertainty.

ISO 7500-1 Materials testing machines — Verification of static testing machines — Part 1: Calibration of tensile testing machines (reference).

3. Terms and Definitions

This standard uses the following terms and definitions:

Static testing machine: An instrument used to apply static loads to perform tension, compression or bending tests.

Verification: The process of comprehensively checking and confirming the metrological performance of a testing machine using standard instruments and procedures.

Indication error: the deviation between the display value of the testing machine and the standard force value .

4. Metrological performance requirements

4.1 Force measurement :

Indication error: ±1.0% (level 1 accuracy) or ±0.5% (level 0.5 accuracy).

Repeatability: 5 measurements, standard deviation ≤ 0.5% full scale.

4.2 Deformation measurement:

Indication error: ±1.0% (level 1 accuracy) or ±0.5% (level 0.5 accuracy).

Resolution: 0.01 mm.

4.3 Loading speed: deviation ≤±5%.

5. Verification conditions

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5.1 Environmental conditions: Temperature 20°C ± 2°C, humidity < 65%, no vibration or strong electromagnetic interference.

5.2 Standard instrument: A force standard device calibrated in accordance with GB/T 16825.2.

5.3 Calibration cycle: Initial calibration and once a year, re-inspection is required after special use.

6. Verification items and methods

6.1 Appearance Inspection:

Inspect the grippers, sensors, and loading system for visible damage or wear.

6.2 Force verification :

Use a standard force sensor or weight to measure 0%, 20%, 40%, 60%, 80%, and 100% of the full scale and record the indication error.

6.3 Deformation measurement verification:

Use a standard length gauge or displacement sensor to measure 0 mm, 10 mm, 20 mm, and 50 mm, and record the indication error. 6.4 Loading speed verification:

Load at a specified speed (e.g. 0.5 mm/min) and measure the actual speed with a deviation of ≤±5%.

6.5 Repeatability Verification:

Measure 5 times continuously at 50% of full scale and calculate the standard deviation.

6.6 Uncertainty assessment: Calculate the measurement uncertainty according to JJF 1059.1.

7. Processing of test results

7.1 Indication error: Compare with the allowable error in 4.1 and 4.2. If it exceeds the range, adjustment is required.

7.2 Uncertainty: Comprehensively evaluate the force error (u_f), deformation error (u_d) and environmental influence (u_e), and the expanded uncertainty U = k × u_c (k=2, confidence level 95%).

7.3 Conclusion: A calibration certificate will be issued to those who meet the requirements, and a failure notice will be issued to those who do not meet the requirements.

8. Verification cycle

Initial calibration: before the instrument leaves the factory or is put into use.

Periodic inspection: once a year.

Re-inspection: after repair, adjustment or abnormal use.

9. Records and Reports

9.1 Calibration records: including instrument number, calibration date, environmental conditions, measurement point data, etc.

9.2 Calibration certificate: including force error , deformation error, repeatability, uncertainty and conclusion.

9.3 Handling of non-conformities: Record the non-conformities and recommend repair or scrapping.

10. Appendix (Informative)

10.1 Force verification points: 0%, 20%, 40%, 60%, 80%, 100% of full scale.

10.2 Permissible Error Table:

Level 1 accuracy: ±1.0% (force), ±1.0% (deformation).

Level 0.5 accuracy: ±0.5% (force), ±0.5% (deformation).

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10.3 Uncertainty example: $u_c = \sqrt{(u_f^2 + u_d^2 + u_e^2)}$, $U = 2 \times u_c$.

10.4 Compatibility Notes:

Carbide: High-precision fixtures are required, with a force range of 0.1 kN to 50 kN .

Thin plates: Low load range is recommended to improve deformation measurement accuracy.

11. Publishing Unit:

General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China

Standardization Administration of China.

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GB/T 228.1-2010

Tensile testing of metal materials

Part 1: Room temperature test methods

1. Scope

This standard specifies the tensile test method for metallic materials at room temperature (10°C to 35°C), including specimen preparation, test equipment, test procedures, and result calculation. It is applicable to the determination of mechanical properties of metallic materials such as steel, stainless steel, nonferrous metals (such as aluminum and copper), and cemented carbide, including yield strength, tensile strength, elongation after fracture, and reduction of area. This method is intended for quality control, material identification, and research and development. It is not suitable for temperature-sensitive materials or materials with a thickness less than 0.1 mm, and requires verification with high- or low-temperature testing methods.

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 13239 Preparation and dimensions of tensile test specimens for metallic materials.

GB/T 16825.1 Materials testing machines - Verification of static testing machines - Part 1: Tension, compression and bend tests

ISO 6892-1 Tensile tests on metallic materials — Part 1: Test methods at room temperature (informative).

3. Terms and Definitions

This standard uses the following terms and definitions:

Tensile Test: A test to determine the mechanical properties of metal materials under uniaxial tensile load.

Yield Strength: The stress at which a material transitions from elastic deformation to plastic deformation, measured in MPa.

Tensile Strength: The maximum tensile stress reached before the specimen breaks, measured in MPa.

Elongation After Fracture: The percentage elongation of the original gauge length after the specimen breaks , expressed in %.

Reduction of Area: The percentage of reduction in the original cross-sectional area after the specimen breaks, expressed in %.

4. Principles of the Method

Mount a standard tensile specimen on a universal testing machine, apply a uniaxial tensile load at a specified speed, and record the load-deformation curve. Calculate yield strength, tensile strength, elongation after fracture, and reduction of area based on specimen geometry and fracture data.

5. Reagents and Materials

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5.1 Cleaning agent: anhydrous ethanol or acetone, used to clean the surface of the specimen.

5.2 Lubricant: A small amount of engine oil to reduce clamping friction (optional).

6. Instruments

6.1 Universal testing machine: Maximum load ≥ 100 kN , with adjustable loading speed, equipped with a load cell (accuracy ±1%) and an elongation measuring device (accuracy ±0.01 mm).

6.2 Clamp: Suitable for the shape of the specimen (such as cylindrical or plate-shaped) and ensures a secure clamping.

6.3 Vernier caliper: with an accuracy of 0.01 mm, used to measure the size of the specimen.

6.4 Environmental control equipment: temperature 20°C±5°C, humidity <65%.

7. Sample Preparation

7.1 Specimen type: Select according to material and purpose:

Cylindrical specimen: diameter 5 mm, gauge length 50 mm.

Plate specimen: width 12.5 mm, thickness 2-10 mm, gauge length 50 mm.

7.2 Surface treatment:

Use SiC sandpaper (#600 to #1200) to smooth the surface of the specimen.

Clean with ethanol to remove oil and dry.

7.3 Dimension measurement: Measure the original gauge length, width and thickness with a deviation of ≤±0.1 mm.

7.4 Sample inspection: Ensure there are no cracks, scratches or processing defects.

8. Measurement Steps

8.1 Instrument Calibration:

Calibrate the universal testing machine according to GB/T 16825.1 to confirm the load and displacement measurement accuracy.

8.2 Test conditions:

$^{-1}$ to 0.0025 s $^{-1}$ (corresponding to strain rate) depending on material properties .

Ambient temperature: 20°C±5°C.

8.3 Test operation:

The specimen is mounted in the grips and a gradually increasing tensile load is applied.

The load-deformation curve was recorded until the specimen broke.

Measure the gauge length and cross-sectional area after fracture.

8.4 Repeatability: Measure each batch of samples 3-5 times and take the average value.

9. Calculation of results

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9.1 **屈服强度（Rp0.2）**：

$Rp0.2 = \frac{F_y}{A_0}$

其中：F_y为0.2%残余变形对应的载荷（N），A_0为原始断面面积（mm²）。

9.2 **抗拉强度（Rm）**：

$Rm = \frac{F_m}{A_0}$

其中：F_m为最大载荷（N）。

9.3 **断后伸长率（A）**：

$A = \frac{L_u - L_0}{L_0} \times 100\%$

其中：L_u为断裂后标距（mm），L_0为原始标距（mm）。

9.4 **断面收缩率（Z）**：

$Z = \frac{A_0 - A_u}{A_0} \times 100\%$

其中：A_u为断裂后断面面积（mm²）。

9.5 **结果修约**：按GB/T 8170四舍五入，屈服强度和抗拉强度至1 MPa，伸长率和收缩率至0.1%。

10. Precision and Accuracy

10.1 Precision: Repeat the measurement 6 times, and the relative standard deviation (RSD) should be less than 5%.

10.2 Accuracy: Verified using standard reference materials, the error should be less than ±5 MPa (strength) or ±1% (elongation/shrinkage).

11. Interference Elimination

11.1 Surface defects: Polish the surface of the specimen to eliminate microcracks.

11.2 Clamping deviation: Ensure the clamp is centered to reduce eccentric loading.

11.3 Environmental influence: Control the temperature at 20°C±5°C and avoid the influence of humidity.

12. Security

12.1 Operators must wear protective glasses to avoid splashing when the specimen breaks.

12.2 Pay attention to the high voltage part of the universal testing machine and comply with the equipment safety regulations.

13. Report

The report should include the following:

Specimen number, material type and heat treatment status. Mechanical property data (yield strength, tensile strength, elongation, shrinkage).

Specimen dimensions, loading speed, and environmental conditions. Instrument model and calibration status. Any anomalies or deviations.

14. Appendix (Informative)

14.1 Specimen size table:

Cylindrical: 5 mm diameter, 50 mm gauge length . Plate: 12.5 mm width, 2-10 mm thickness, 50 mm gauge length .

14.2 Loading speed recommendation:

Low-strength material: 0.00025 s^{-1} . High-strength material: 0.0025 s^{-1} . 1

4.3 Note: Special fixtures are required for cemented carbide specimens to reduce the impact of cracks.

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15. Release of Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

Release date: June 30, 2010. Implementation date: January 1, 2011.

Replacement: Replaces GB/T 228-2002.



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GB/T 7997-2012

Test method for Vickers hardness of cemented carbide

1. Scope

This standard specifies the test method for the Vickers hardness (HV) of cemented carbide (hard metal), including the selection of test conditions, indentation measurement, and calculation of hardness values. It is applicable to sintered cemented carbide products and their raw materials containing tungsten carbide (WC) as the primary hard phase and cobalt (Co), nickel (Ni), or other binder phases. The hardness range is 50 HV to 3000 HV. This method is intended for quality control, performance evaluation, and research and development. It is not suitable for samples with a surface roughness Ra greater than 0.8 μm or a thickness less than 0.5 mm. Verification with other methods (such as the Rockwell hardness test) is required.

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 4340.1-2009 Metallic materials—Vickers hardness test—Part 1: Test method.

GB/T 18378-2001 Methods for observation of cemented carbide microstructure.

ISO 6507-1 Metallic materials — Vickers hardness test — Part 1: Test method (informative).

3. Terms and Definitions

This standard uses the following terms and definitions:

Vickers hardness (HV): The ability of cemented carbide to resist local plastic deformation is measured by pressing a standard quadrangular pyramid diamond indenter into the sample surface under a specified load. The unit is HV.

Indentation: A square depression formed by the Vickers indenter on the sample surface. The diagonal length of the depression is used to calculate the hardness value.

Cemented carbide: A high-hardness material prepared by sintering powder metallurgy process with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase.

4. Principles of the Method

Use a standard square pyramid diamond indenter (136° apex angle) to press into the surface of the cemented carbide sample under a specified load, hold for a specified time, and then unload. Measure the lengths of the two diagonals of the indentation (d_1 , d_2) , take the average value d, and calculate the Vickers hardness value:

$$HV = \frac{1.8544 \times F}{d^2}$$

Where:

F: test load (N).

d: Average diagonal length of the indentation (mm).

1.8544: Vickers hardness calculation constant, dependent on the indenter geometry.

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5. Reagents and Materials

5.1 Cleaning agent: anhydrous ethanol or acetone, used to clean the sample surface.

5.2 Polishing fluid: Diamond suspension with a particle size of 0.5 μm to 1 μm , used for surface polishing.

6. Instruments

6.1 Vickers hardness tester: in accordance with ISO 6507-1, with a load range of 0.098 N to 98.07 N (0.01 kgf to 10 kgf), and an indentation measurement accuracy of ±0.5 μm .

6.2 Optical microscope: magnification 100x to 1000x, equipped with a micrometer eyepiece or digital imaging system.

6.3 Polishing machine: equipped with diamond abrasive with a particle size range of 0.5 μm to 5 μm .

6.4 Analytical balance: with a sensitivity of 0.0001 g, used for calibrating loads.

7. Sample Preparation

7.1 Sample collection: Take representative samples from cemented carbide products or raw materials, with dimensions not less than 10 mm × 10 mm × 5 mm. 7.2 Surface treatment:

Use SiC sandpaper (grit #600 to #1200) to grind it in steps.

with diamond polishing liquid (1 μm) to a mirror surface with a surface roughness of Ra ≤ 0.2 μm .

Clean with ethanol to remove oil and dry.

7.3 Sample inspection: Ensure that there are no cracks, scratches or oxide layers, and that the thickness meets the load requirements (≥10 times the indentation depth).

8. Measurement Steps

8.1 Instrument Calibration:

The hardness tester is calibrated using a standard hardness block, and the load and indentation measurement system error is ≤±1%.

Record calibration dates and results.

8.2 Selection of test conditions:

Select the load according to the hardness of the cemented carbide. The recommended range is 0.98 N to 49.03 N (0.1 kgf to 5 kgf).

Hold time: 10-15 s.

8.3 Test operation:

Select a flat area on the sample surface, with the distance between points ≥ 3 × the diagonal length of the indentation and the distance from the edge ≥ 2.5 × the diagonal length of the indentation.

Apply the load, maintain it for a specified time, and then unload it.

Use an optical microscope to measure the lengths of the two diagonals (d_1 and d_2) and take the average value d with an accuracy of 0.001 mm.

8.4 Repeatability: Measure 5 points for each sample and take the arithmetic mean.

9. Calculation of results

Vickers hardness value (HV) is calculated according to the formula:

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$$HV = \frac{1.8544 \times F}{d^2}$$

The results are rounded according to GB/T 8170:

d≤0.1mm d \ leq 0.1 mm d≤0.1mm: retain 1 HV.

d>0.1mm d > 0.1 mm d>0.1mm: retain 0.1 HV.

10. Precision and Accuracy

10.1 Precision: The relative standard deviation (RSD) should be less than 3% after repeated determination for 6 times.

10.2 Accuracy: Verified using a standard hardness block, the error should be less than ±2 HV.

11. Interference Elimination

11.1 Surface roughness: Polish to Ra ≤ 0.2 μm to avoid indentation measurement errors.

11.2 Load selection: Ensure that the indentation depth does not exceed 1/10 of the material thickness.

11.3 Environmental influence: The test room temperature is 20°C ± 2°C and the humidity is < 65%.

12. Security

12.1 Operators must wear protective glasses to avoid crushing the head.

12.2 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

13. Report

The report should include the following:

Sample number, material type and description.

Hardness value (HV), including average value and single point data.

Test load, hold time, and measurement conditions. Instrument model and calibration status. Any anomalies or deviations.

14. Appendix (Informative)

14.1 Load selection table:

Hardness 50-500 HV: 0.98 N to 9.807 N.

Hardness 500-2000 HV: 9.807 N to 49.03 N.

Hardness 2000-3000 HV: 49.03 N to 98.07 N.

14.2 Minimum distance requirements:

Distance between points: ≥3×diagonal length of indentation. Distance from edge: ≥2.5×diagonal length of indentation.

14.3 Note: Samples with high Co content may require the use of a lower load (e.g., 0.5 kgf).

15. Release of Information

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GB/T 183772001

Test method for flexural strength of cemented carbide

1. Scope

This standard specifies the test method for the flexural strength of cemented carbide (hard metal). It is applicable to sintered cemented carbide products and their raw materials with tungsten carbide (WC) as the primary hard phase and cobalt (Co), nickel (Ni), and other materials as binder phases. This method determines flexural strength via a three-point or four-point bend test. It is suitable for quality control, performance evaluation, and process optimization. It is not suitable for samples with high porosity or significant defects, and verification with other methods (such as tensile testing) is required.

2. Normative References

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GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 20066 Methods for preparation of rock and mineral test samples.

ISO 3327 Cemented carbides — Determination of flexural strength (reference).

3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: A high-hardness, high-wear-resistant material prepared by sintering powder metallurgy process with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase.

Bending Strength: The ability of a material to resist fracture under bending load, measured in megapascals (MPa).

Three-Point Bending Test: A bending test in which the sample is supported at both ends and a single-point load is applied in the middle.

Four-Point Bending Test: A bending test in which the sample is supported at both ends and loads are applied at two points in the middle.

4. Principles of the Method

In a three-point or four-point bending test, a gradually increasing load is applied to a standard specimen until the specimen breaks. The load force and specimen geometry at the time of fracture are measured, and the bending strength is calculated based on elastic mechanics:

$$\sigma = \frac{3FL}{2Wt^2}$$ （三点弯曲）

$$\sigma = \frac{3F(L_1 - L_2)}{Wt^2}$$ （四点弯曲）

in:

σ: flexural strength (MPa).

F: breaking load (N).

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L: support spacing (mm).

L1: External support spacing (mm).

L2: Internal loading distance (mm).

b: sample width (mm).

h: specimen height or thickness (mm).

5. Reagents and Materials

5.1 Cleaning agent: Anhydrous ethanol, used to clean the surface of the specimen.

5.2 Embedding resin: Epoxy resin, used for specimen fixation (optional).

6. Instruments

6.1 Universal testing machine: Maximum load ≥ 50 kN , with adjustable loading speed, and equipped with a force sensor (accuracy ±1%).

6.2 Support device: three-point or four-point bending fixture, with adjustable support spacing and flat surface.

6.3 Vernier caliper: with an accuracy of 0.01 mm, used to measure the size of the specimen.

6.4 Environmental control equipment: temperature 20°C±2°C, humidity <65%.

7. Sample Preparation

7.1 Sample collection: Randomly take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g.

7.2 Sample preparation:

Cut or grind into rectangular specimens with dimensions of (20±0.1)mm × (5±0.1)mm × (5±0.1)mm (length × width × height).

The surface is polished to Ra≤0.4 μm and burrs and cracks are removed.

Wash with ethanol and dry to constant weight.

7.3 Sample inspection: Ensure there are no obvious defects and the dimensional deviation is ≤±0.1 mm.

8. Measurement Steps

8.1 Instrument Preparation:

Install a three-point or four-point bending fixture and adjust the support spacing (three-point: 15 mm, four-point: outer spacing 20 mm, inner spacing 10 mm).

The universal testing machine was calibrated and the loading speed was set to 0.5 mm/min.

8.2 Test operation:

The specimen is placed in the grips and a gradually increasing load is applied.

Record the maximum load at break (F).

Each sample was measured 3-5 times and the average value was taken.

8.3 Environmental control: Maintain the temperature at 20°C ± 2°C during the test.

9. Calculation of results

The flexural strength is calculated according to the formula:

- 三点弯曲：$\sigma = \frac{3FL}{2bh^2}$
- 四点弯曲：$\sigma = \frac{3F(L_1 - L_2)}{bh^2}$

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The results are rounded to 1 MPa according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: Repeat the measurement 6 times, and the relative standard deviation (RSD) should be less than 5%.

10.2 Accuracy: Verified using standard reference materials, the error should be less than ±5 MPa.

11. Interference Elimination

11.1 Surface defects: Polish the surface of the specimen to eliminate microcracks.

11.2 Loading speed: controlled at 0.5 mm/min to avoid dynamic effects.

11.3 Environmental influence: Maintain constant temperature and avoid humidity influence.

12. Security

12.1 Operators must wear protective glasses to avoid splashing when the specimen breaks.

12.2 Pay attention to the high voltage part of the universal testing machine and comply with the equipment safety regulations.

13. Report

The report should include the following:

Specimen number, source and description.

Flexural strength value (MPa), including average value and single data.

Test method (three-point or four-point), support spacing and loading speed.

Instrument model and calibration status. Any anomalies or deviations.

14. Appendix (Informative)

14.1 Recommended Specimen Dimensions: 20 mm × 5 mm × 5 mm, adjustable depending on the material . 14.2 Note: Specimens with high Co content may require increasing the specimen thickness to 7 mm. 14.3 Reference Method: Four-point bending can be used to detect internal defects.

15. Release of Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

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GB/T 15020

Terminology for hardness testing of metallic materials

1. Scope

This standard specifies the terms and definitions related to hardness testing of metallic materials. It applies to Brinell hardness (HB), Rockwell hardness (HR), Vickers hardness (HV), and other hardness testing methods. It covers test equipment, test conditions, hardness value calculation, and related metrological concepts, and is applicable to the field of hardness testing of metallic materials (such as steel, stainless steel, nonferrous metals, and cemented carbide).

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 230.1-2009 Rockwell hardness test for metallic materials—Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T).

GB/T 231.1-2018 Metallic materials—Brinell hardness test—Part 1: Test method.

GB/T 4340.1-2009 Metallic materials—Vickers hardness test—Part 1: Test method.

ISO 6506-1 Metallic materials — Brinell hardness test — Part 1: Test method (informative).

ISO 6507-1 Metallic materials — Vickers hardness test — Part 1: Test method (informative).

ISO 6508-1 Metallic materials — Rockwell hardness test — Part 1: Test method (informative).

3. Terms and Definitions

3.1 Overview of hardness test

3.1.1 Hardness A physical quantity that measures a metal material’s ability to resist local plastic deformation, indentation, or scratching. It is usually measured by the indentation characteristics of an indenter under a specified load.

3.1.2 Hardness Test: A test method for measuring the hardness of metal materials using a standard indenter and load, including Brinell, Rockwell , Vickers, etc.

3.1.3 Hardness Value: A quantitative representation of the hardness test result. The unit varies depending on the test method (e.g. HB, HR, HV).

3.2 Test equipment

3.2.1 Hardness Tester An instrument used to perform hardness tests, including a load applying device, an indenter, and a measuring system.

3.2.2 Indenter: The tool used to apply the load to produce the indentation. It can be a steel ball, diamond cone, or carbide ball. 3.2.3 Load: The force applied to the indenter, divided into preload (F_0) and total load (F), measured in Newtons (N) or kilogram-force (kgf).

3.2.4 Preload (Preliminary Test Force) Initially applied small force to stabilize the contact between the indenter and the sample. 3.2.5 Additional Test Force (Additional Test Force) Force applied in addition to the preload, which together with the preload constitutes the total test force.

3.2.6 Dwell Time The time the indenter maintains the load after applying it, in seconds (s).

3.3 Test methods

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3.3.1 Brinell Hardness Test Use a steel ball or carbide ball indenter to press into the sample under a specified load, measure the indentation diameter and calculate the hardness value in HB.

3.3.2 Rockwell Hardness Test A diamond cone or steel ball indenter is used to calculate the hardness value by the difference in indentation depth between preload and total load. The unit is HR (followed by the scale letter, such as HRC).

3.3.3 Vickers Hardness Test Use a square pyramid diamond indenter to press into the sample under a specified load. Measure the diagonal length of the indentation and calculate the hardness value in HV.

3.3.4 Superficial Rockwell Hardness Test: This test uses a lower load and is suitable for thin parts or surface hardened layers. The unit is HRN or HRT.

3.4 Hardness scale

3.4.1 Brinell hardness (HB) The hardness value measured with a 10 mm steel ball or a 5 mm carbide ball under a load of 3000 kgf .

3.4.2 Rockwell hardness (HR) Hardness values measured using different scales, including:

HRA: Using a diamond cone, load 686.5 N (70 kgf).

HRB: Use a 1.5875 mm ball and a load of 980.7 N (100 kgf).

HRC: Using a diamond cone, load 1471 N (150 kgf).

HRD: Using a diamond cone, load 1471 N (150 kgf).

HRE: Using a 3.175 mm ball, load 980.7 N (100 kgf).

HRF: Use a 1.5875 mm ball and a load of 686.5 N (70 kgf).

HRG: Use a 1.5875 mm ball and a load of 1471 N (150 kgf).

HRH: Using a 1.5875 mm ball, load 980.7 N (100 kgf).

HRK: Use a 1.5875 mm ball and a load of 1471 N (150 kgf).

HRN: Using diamond cone, load 294.6 N (30 kgf), surface scale.

HRT: Use 1.5875 mm ball, load 470.7 N (48 kgf), surface scale.

3.4.3 Vickers hardness (HV) The hardness value measured with a square pyramid diamond indenter under a load range of 0.098 N to 294.2 N (0.01 kgf to 30 kgf).

3.5 Indentation and measurement

3.5.1 Indentation: The depression formed by the indenter on the sample surface.

3.5.2 Indentation Diameter The average diameter of the indentation in the Brinell hardness test, in millimeters (mm).

3.5.3 Diagonal Length The length of the two diagonals of the indentation in the Vickers hardness test, in millimeters (mm).

3.5.4 Indentation Depth The permanent indentation depth of the indenter after unloading in the Rockwell hardness test, measured in micrometers (μm).

3.5.5 Indication Error The deviation between the hardness tester’s measured value and the nominal value of the standard hardness block.

3.6 Test conditions and performance

3.6.1 Surface Roughness The flatness of the sample surface affects the indentation measurement parameter. Ra ≤ 0.4 μm is recommended .

3.6.2 Repeatability The stability of a hardness tester when repeated measurements are made under the same conditions. The unit is HR or HV. 3.6.3 Accuracy The consistency between the hardness tester's measured value and the true value.

3.6.4 Uncertainty The degree of dispersion of hardness measurement results, a parameter reflecting the reliability of

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the measurement.

3.7 Standards and calibration

3.7.1 Standard Hardness Block A reference sample with a known hardness value used to calibrate a hardness tester.

3.7.2 Calibration The process of adjusting the hardness tester parameters so that the measurement results are consistent with the standard values .

3.7.3 Verification The procedure of checking whether the performance of the hardness tester meets the requirements.

4. Appendix (Informative)

4.1 Terminology Comparison Table (Chinese and English):

Hardness :

Hardness Test

Brinell Hardness

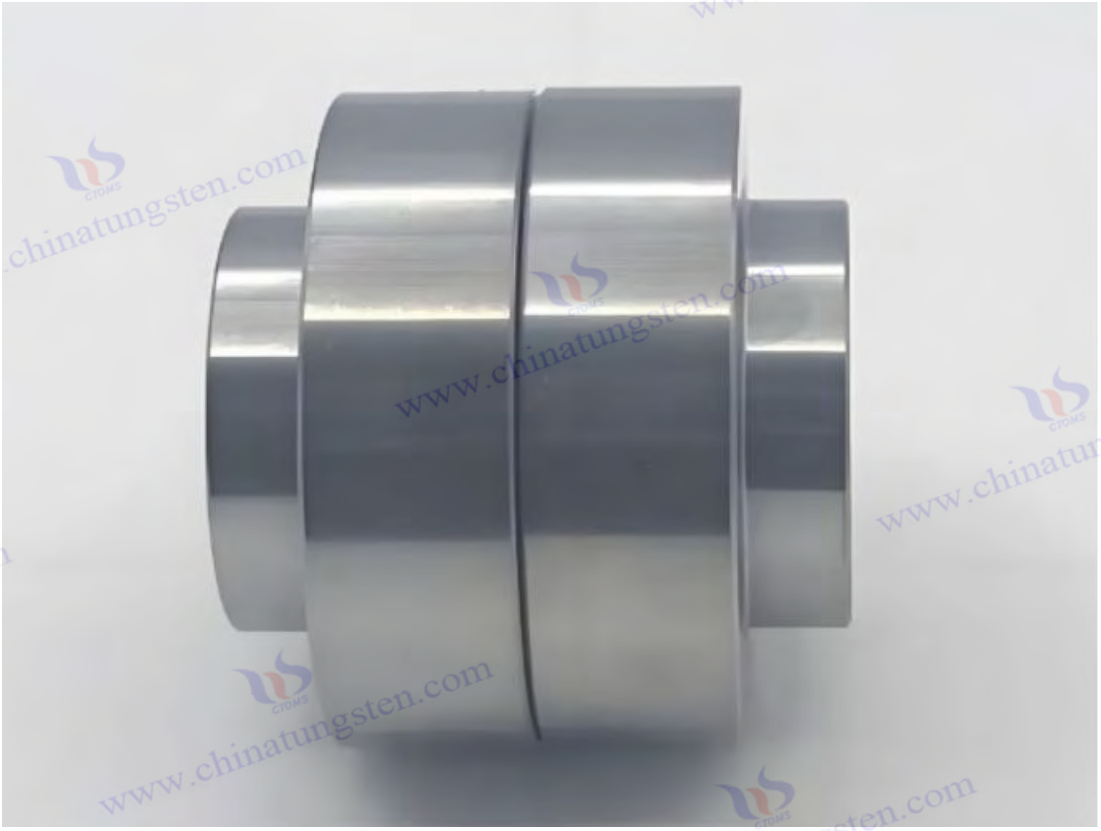
Rockwell Hardness

Vickers Hardness

4.2 Note: The definitions of terms are based on the GB/T 230, GB/T 231 and GB/T 4340 series of standards. Some terms may be slightly adjusted due to specific test methods.

5. Release Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.



JG 112 Metal Rockwell hardness tester

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(A, B, C, D, E, F, G, H, K, N, T scale)

1. Scope

This procedure specifies the verification method for Rockwell hardness testers (A, B, C, D, E, F, G, H, K, N, and T scales), including inspection of the load application system, indenter, indentation depth measurement device, and overall performance. This procedure applies to initial, periodic, and post-use verification of Rockwell hardness testers, covering metal materials with a hardness range of HR15T to HRC 100, including steel, stainless steel, nonferrous metals, and cemented carbide. It is not applicable to hardness testers that are severely damaged or not operated in accordance with GB/T 230.1-2009.

2. Reference Standards

The provisions of the following documents become provisions of this Regulation through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this Regulation. However, parties to agreements based on this Regulation are encouraged to investigate whether the latest versions of these documents are applicable. For undated references, the latest versions apply to this Regulation.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 15020 Terminology for hardness testing of metallic materials.

GB/T 230.1-2009 Rockwell hardness test for metallic materials—Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T).

GB/T 230.2-2012 Metallic materials Rockwell hardness test Part 2: Verification and calibration of testing machines (A, B, C, D, E, F, G, H, K, N, T scales).

GB/T 230.3-2012 Metallic materials Rockwell hardness test Part 3: Calibration of standard hardness blocks (A, B, C, D, E, F, G, H, K, N, T scales).

JJF 1059.1 Evaluation and expression of measurement uncertainty.

3. Terms and Definitions

This regulation uses the following terms and definitions:

Verification: The process of comprehensively checking and confirming the metrological performance of a Rockwell hardness tester using standard measuring instruments and procedures.

Indenter: A tool used to apply a load, consisting of a diamond cone or carbide ball.

Indication error: The deviation between the hardness tester's measured value and the nominal value of the standard hardness block.

4. Metrological performance requirements

4.1 Load application:

Preload (F_0) : 98.07 N (10 kgf) or 29.42 N (3 kgf), with an allowable error of ±1.0%.

Total load (F): See Appendix Table 1, allowable error ±1.0%.

4.2 Indenter:

Diamond cone: apex angle 120°±0.5°, tip radius 0.2 mm±0.01 mm.

Carbide ball: diameter 1.5875 mm ± 0.005 mm.

4.3 Depth measurement: indication error ≤ ±0.5 μm.

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4.4 Repeatability: 5 consecutive measurements, standard deviation ≤ 0.5 HR.

4.5 Resolution: 0.1 HR.

5. Verification conditions

5.1 Environmental conditions: Temperature 20°C ± 2°C, humidity < 65%, no vibration or strong electromagnetic interference.

5.2 Standard instruments: Standard hardness blocks calibrated in accordance with GB/T 230.3-2012.

5.3 Calibration cycle: Initial calibration and once a year, re-inspection is required after special use.

6. Verification items and methods

6.1 Appearance Inspection:

Check the indenter for signs of cracks or wear.

Verify load application and depth measurement device integrity.

6.2 Load verification:

Use standard weights or force sensors to measure preload and total load with a deviation of ≤±1.0%.

6.3 Indenter geometry inspection:

Use an optical microscope to measure the diamond cone angle and ball diameter, which shall comply with the requirements of 4.2.

6.4 Verification of hardness tester indication error:

Select the corresponding scale and load according to GB/T 230.1-2009.

Measure 5 points on the standard hardness block with a distance between points ≥3 mm and a distance from the edge ≥5 mm.

Record the hardness value of each point and calculate the average value and indication error.

6.5 Repeatability Verification:

Measure the same standard hardness block five times in succession and calculate the standard deviation.

6.6 Uncertainty assessment: Calculate the measurement uncertainty according to JJF 1059.1.

7. Processing of test results

7.1 Indication error: Compare with the allowable error in Appendix Table 2. If it exceeds the range, adjustment is required.

7.2 Uncertainty: Based on a comprehensive assessment of repeatability, load error, and environmental influences, the expanded uncertainty is $U = k \times u_c$ ($k = 2$, 95% confidence level).

7.3 Conclusion: A calibration certificate will be issued to those who meet the requirements, and a failure notice will be issued to those who do not meet the requirements.

8. Verification cycle

Initial calibration: before the instrument leaves the factory or is put into use.

Periodic inspection: once a year.

Re-inspection: after repair, adjustment or abnormal use.

9. Records and Reports

9.1 Calibration records: including instrument number, calibration date, environmental conditions, measurement point

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data, etc.

9.2 Verification certificate: including average hardness value, indication error, repeatability, uncertainty and conclusion.

9.3 Handling of non-conformities: Record the non-conformities and recommend repair or scrapping.

10. Appendix (Informative)

10.1 Scale and load table:

Conventional ruler:

A: F_0 = 98.07 N, F_1 =588.4 N, F=686.5 N (diamond cone).

B: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

C: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

D: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

E: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (3.175 mm ball).

F: F_0 =98.07 N, F_1 =588.4 N, F=686.5 N (1.5875 mm ball).

G : F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

H: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

K: F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

Surface ruler:

N: F_0 = 29.42 N, F_1 =264.2 N, F=294.6 N (diamond cone).

T: F_0 =29.42 N, F_1 =441.3 N, F = 470.7 N (1.5875 mm ball).

10.2 Table of allowable indication error:

Conventional scale: ±0.5 HR (low hardness) to ±1.0 HR (high hardness).

Surface scale: ±1.0 HR.

10.3 Uncertainty example: $u_c = \sqrt{(u_r^2 + u_f^2 + u_e^2)}$, $U = 2 \times u_c$. 10.4 Compatibility Note:

Carbide: Recommended N scale, proof load ≤ 294.6 N.

Thin plates: Use a T-ruler to check thickness adaptability.

Coating: Requires special indenter and low load verification.

11. Release of Information

Issuing unit: State Administration for Market Regulation of the People's Republic of China.

Replacement situation: Replaces JJG 112-2000.

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GB/T 230.2-2012 Rockwell hardness test for metallic materials

Part 2: Verification and calibration of testing machines (A, B, C, D, E, F, G, H, K, N, T scales)

1. Scope

This standard specifies the verification and calibration methods for Rockwell hardness testing machines (A, B, C, D, E, F, G, H, K, N, and T scales), including inspection of the load application system, indenter, indentation depth measurement device, and overall performance. This standard applies to periodic verification, initial calibration, and post-repair verification of Rockwell hardness testers. It covers metal materials with a hardness range of HR15T to HRC 100, including steel, stainless steel, nonferrous metals, and cemented carbide. It is not applicable to severely damaged testing machines or those not operated in accordance with GB/T 230.1-2009.

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 15020 Terminology for hardness testing of metallic materials.

GB/T 230.1-2009 Rockwell hardness test for metallic materials—Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T).

GB/T 230.3-2012 Metallic materials Rockwell hardness test Part 3: Calibration of standard hardness blocks (A, B, C, D, E, F, G, H, K, N, T scales).

JJF 1059.1 Evaluation and expression of measurement uncertainty.

JJG 112 Metal Rockwell Hardness Tester (A, B, C, D, E, F, G, H, K, N, T scales).

3. Terms and Definitions

This standard adopts the following terms and definitions (refer to GB/T 15020 and JJG 112):

Testing machine verification: The process of confirming whether the performance of the Rockwell hardness tester meets the requirements through standard hardness blocks and instrument inspection.

Calibration: The process of adjusting or correcting the parameters of a testing machine so that its measurement results are consistent with the standard values.

Indenter: A tool used to apply a load, consisting of a diamond cone or carbide ball.

4. Principles of the Method

Use a standard hardness block and a known load to verify the Rockwell hardness tester's load application system, indenter, and depth measurement device, checking their error and repeatability. Measure hardness values according to the test conditions of GB/T 230.1-2009 and compare them with the standard values to assess the testing machine's systematic deviation and uncertainty. Perform calibration adjustments as necessary.

5. Reagents and Materials

5.1 Cleaning agent: Anhydrous ethanol or acetone, used to clean the surface of the indenter and standard hardness

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block.

5.2 Lubricant: A small amount of engine oil to reduce the wear of the press head (optional).

5.3 Standard hardness block: a reference block calibrated in accordance with GB/T 230.3-2012, covering all scale ranges.

6. Instruments

6.1 Rockwell hardness tester: The instrument to be verified or calibrated shall comply with the requirements of JJG 112 and have:

Preload (F_0) : 98.07 N (10 kgf) or 29.42 N (3 kgf).

Additional load (F_1): See Appendix Table 1.

Total load (F): See Appendix Table 1.

Indentation depth measurement accuracy: ±0.5 μm.

6.2 Indenter:

Diamond cone (apex angle 120°, tip radius 0.2 mm) for A, C, D, and N scales.

Carbide balls (diameter 1.5875 mm) for use with B, E, F, G, H, K, and T scales.

6.3 Environmental control equipment: temperature 20°C ± 2°C, humidity < 65%, avoid vibration.

6.4 Measuring tools: Vernier caliper (accuracy 0.01 mm) or optical microscope (50x to 200x).

7. Sample Preparation

7.1 Selection of standard hardness block: Select the corresponding hardness block according to the scale, with a smooth surface and no scratches or oxide layer.

7.2 Surface treatment:

Lightly sand with SiC sandpaper (#600 to #1200) to remove surface dirt.

Clean with ethanol or acetone, dry, and ensure the surface roughness Ra ≤ 0.4 μm.

7.3 Sample inspection: thickness ≥ 10 times the indentation depth, size not less than 10 mm × 10 mm × 5 mm.

8. Measurement Steps

8.1 Preliminary Inspection:

Check the appearance of the indenter to see if there are any cracks or wear.

Verify that the load application system and depth measurement device are functioning properly.

8.2 Load Verification:

Using standard weights or sensors, measure the preload (F_0) and total load (F) with a deviation of ≤±1%.

8.3 Hardness Tester Verification:

Select the corresponding scale and load according to GB/T 230.1-2009.

Measure 5-10 points on the standard hardness block with a distance between points ≥3 mm and a distance from the edge ≥5 mm.

Record the hardness value (HR) at each point and calculate the mean and standard deviation.

8.4 Calibration Adjustment:

If the deviation exceeds the allowable range (see Appendix Table 2), adjust the load or depth measurement system.

Repeat the verification until the requirements are met.

8.5 Uncertainty assessment: Calculate the measurement uncertainty according to JJF 1059.1.

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9. Calculation of results

9.1 Average hardness value: take the arithmetic mean of 5-10 measurements.

9.2 Deviation: Compare with the nominal value of the standard hardness block and calculate the absolute deviation (ΔHR).

9.3 Uncertainty: Comprehensively evaluate the repeatability (u_r), load error (u_f) and environmental influence (u_e), and the expanded uncertainty U = k × u_c (k = 2, confidence level 95%).

9.4 Rounding off: round to the nearest 0.1 HR according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: The relative standard deviation (RSD) of the test sample after 10 replicates should be less than 1%.

10.2 Accuracy: The deviation from the value of a standard hardness block shall be less than ±0.5 HR (conventional scale) or ±1 HR (surface scale).

11. Interference Elimination

11.1 Surface roughness: Ensure that the standard hardness block Ra is ≤ 0.4 μm to avoid indentation depth error.

11.2 Load stability: Regularly calibrate the load application system, with a deviation of <1%.

11.3 Environmental impact: Control the temperature to 20°C±2°C, humidity <65%, and avoid vibration.

11.4 Indenter wear: Check the diamond cone or steel ball, and the tip wear should be less than 0.01 mm.

12. Security

12.1 Operators must wear protective glasses to avoid splashing of indenter fragments or chemical reagents.

12.2 Waste liquids (ethanol, acetone) shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to the high-voltage part of the hardness tester and follow the equipment operating manual.

13. Report

The report should include the following:

Testing machine model, serial number, and calibration date.

Verification results (mean hardness value, deviation, uncertainty).

Test scale, load (F_0 , F_1 , F) and holding time.

Standard hardness block number and nominal value.

Environmental conditions (temperature, humidity).

Sources and calculation process of measurement uncertainty.

Any records of exceptions or adjustments.

14. Appendix (Informative)

14.1 Scale and load table:

Conventional ruler:

A: F_0 = 98.07 N, F_1 =588.4 N, F=686.5 N (diamond cone).

B: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

C: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

D: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

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E: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (3.175 mm ball).

F: F_0 =98.07 N, F_1 =588.4 N, F=686.5 N (1.5875 mm ball).

G: F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

H: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

K: F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

Surface ruler:

N: F_0 = 29.42 N, F_1 =264.2 N, F=294.6 N (diamond cone).

T: F_0 =29.42 N, F_1 =441.3 N, F = 470.7 N (1.5875 mm ball).

14.2 Permissible deviation table:

Conventional scale: ±0.5 HR (low hardness) to ±1.0 HR (high hardness).

Surface scale: ±1.0 HR.

14.3 Uncertainty example: $u_c = \sqrt{(u_r^2 + u_f^2 + u_e^2)}$, $U = 2 \times u_c$.

14.4 Compatibility Notes:

Carbide: Recommended N scale, proof load ≤ 294.6 N.

Thin plates: Use a T-ruler to check thickness adaptability.

Coating: Requires special indenter and low load verification.

15. Release of Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

Release date: June 30, 2012.

Implementation date: January 1, 2013.

Replacement: Replaces GB/T 230.2-2002.

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GB/T 230.3-2012

Rockwell hardness test of metal materials

Part 3: Calibration of standard hardness blocks (A, B, C, D, E, F, G, H, K, N, T scales)

1. Scope

This standard specifies the calibration method for standard hardness blocks used in Rockwell hardness testing (A, B, C, D, E, F, G, H, K, N, and T scales), including the determination of hardness values, uncertainty assessment, and the preparation of calibration certificates. It is intended for use by calibration laboratories and manufacturers to verify the accuracy of Rockwell hardness testers and certify standard hardness blocks. These standard hardness blocks are suitable for use with metal materials ranging from HR15T to HRC 100, including steel, stainless steel, non-ferrous metals, and cemented carbides. They are not suitable for samples with significant surface defects or insufficient thickness.

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 15020 Terminology for hardness testing of metallic materials.

GB/T 230.1-2009 Rockwell hardness test for metallic materials—Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T).

GB/T 230.2-2012 Metallic materials Rockwell hardness test Part 2: Verification and calibration of testing machines (A, B, C, D, E, F, G, H, K, N, T scales).

JJF 1059.1 Evaluation and expression of measurement uncertainty.

JJG 112 Metal Rockwell Hardness Tester (A, B, C, D, E, F, G, H, K, N, T scales).

3. Terms and Definitions

This standard adopts the following terms and definitions (refer to GB/T 15020 and JJF 1059.1):

Hardness Standard Block: A reference sample with a known Rockwell hardness value (HR) used to calibrate a hardness tester or verify test results.

Calibration: The process of determining the hardness value and its uncertainty of a standard hardness block by measurement and comparison.

Uncertainty: The degree of dispersion of calibration results, reflecting the reliability of measurement results.

4. Principles of the Method

Using a validated Rockwell hardness tester, measure multiple points on a standard hardness block according to the test method specified in GB/T 230.1-2009 and calculate the average hardness value. Incorporating the testing machine calibration requirements of GB/T 230.2-2012, evaluate the repeatability and systematic error of the measurement system. Calculate the uncertainty of the calibration results in accordance with JJF 1059.1, and generate a compliant calibration certificate.

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5. Reagents and Materials

5.1 Cleaning agent: anhydrous ethanol or acetone, used to clean the surface of the standard hardness block.

5.2 Lubricant: A small amount of engine oil to reduce the wear of the press head (optional).

5.3 Standard hardness block: A reference block with known hardness value, covering the range of each scale (see Appendix Table 1).

6. Instruments

6.1 Rockwell hardness tester: in accordance with GB/T 230.2-2012 and JJG 112, with:

Preload (F_0): 98.07 N (10 kgf) or 29.42 N (3 kgf).

Additional load (F_1) : See Appendix Table 1.

Total load (F): See Appendix Table 1.

Indentation depth measurement accuracy: ±0.5 μm.

6.2 Indenter:

Diamond cone (apex angle 120°, tip radius 0.2 mm) for A, C, D, and N scales.

Carbide balls (diameter 1.5875 mm) for use with B, E, F, G, H, K, and T scales.

6.3 Environmental control equipment: temperature 20°C±2°C, humidity <65%, avoid vibration.

6.4 Optical microscope: Magnification 50x to 200x, to inspect the indenter and indentation (optional).

7. Sample Preparation

7.1 Selection of standard hardness block: Select the corresponding hardness block according to the scale, with a smooth surface and no scratches or oxide layer.

7.2 Surface treatment:

Lightly sand with SiC sandpaper (#600 to #1200) to remove surface dirt.

Clean with ethanol or acetone, dry, and ensure the surface roughness Ra ≤ 0.4 μm.

7.3 Sample inspection: thickness ≥ 10 times the indentation depth, size not less than 10 mm × 10 mm × 5 mm.

8. Measurement Steps

8.1 Instrument Calibration:

Calibrate hardness testers according to GB/T 230.2-2012 and verify indenter, load and depth measurement systems.

Calibrated using a reference hardness block of known value, with an error of ≤±0.5 HR.

8.2 Test conditions:

Select the load corresponding to the scale (see Appendix Table 1).

Hold time: 2-8 s (conventional scale) or 1-5 s (surface scale).

8.3 Measurement process:

Select 5-10 points on the standard hardness block with a distance between points ≥3 mm and a distance from the edge ≥5 mm.

Apply a preload (F_0) , and after stabilization, apply an additional load (F_1) , maintain for a specified time, and then unload to F_0 .

Record the hardness value (HR) at each point.

8.4 Data Processing:

Calculate the mean hardness value and standard deviation.

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Evaluate measurement uncertainty according to JJF 1059.1.

9. Calculation of results

9.1 Average hardness value: take the arithmetic mean of 5-10 measurements.

9.2 Uncertainty: Comprehensively evaluate based on the following sources:

Repeatability (u_r).

Uncertainty in calibration of hardness tester (u_c).

Environmental influence (u_e). Expanded uncertainty U = k × u_c (k=2, 95% confidence level).

9.3 Rounding off: round to the nearest 0.1 HR according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: The relative standard deviation (RSD) of the test sample after 10 replicates should be less than 1%.

10.2 Accuracy: Compared with the national standard laboratory value, the deviation should be less than ±0.5 HR.

11. Interference elimination

11.1 Surface roughness: Polish to Ra ≤ 0.4 μm to avoid indentation depth error.

11.2 Load stability: Ensure that the load is applied evenly with a deviation of <1%. 11.3 Environmental influences: Control the temperature to 20°C ± 2°C and the humidity to < 65%. Avoid vibration.

11.4 Indenter wear: Check the diamond cone or steel ball regularly and replace if necessary.

12. Security

12.1 Operators must wear protective glasses to avoid splashing of indenter fragments or chemical reagents.

12.2 Waste liquids (ethanol, acetone) shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to the high-voltage part of the hardness tester and follow the equipment operating manual.

13. Report

The report should include the following:

Standard hardness block number, material type and description.

Calibration results (mean hardness value, standard deviation, uncertainty).

Test scale, load (F_0 , F_1 , F) and hold time. Instrument model, calibration date and status. Environmental conditions (temperature, humidity). Sources of measurement uncertainty and calculation process. Any anomalies or deviations.

14. Appendix (Informative)

14.1 Scale and load table:

Conventional ruler:

A: F_0 = 98.07 N, F_1 =588.4 N, F=686.5 N (diamond cone).

B: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

C: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

D: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

E: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (3.175 mm ball).

F: F_0 =98.07 N, F_1 =588.4 N, F=686.5 N (1.5875 mm ball).

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G: F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

H: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

K: F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

Surface ruler:

N: F_0 = 29.42 N, F_1 =264.2 N, F=294.6 N (diamond cone).

T: F_0 =29.42 N, F_1 =441.3 N, F = 470.7 N (1.5875 mm ball).

14.2 Hardness range of hardness block:

A: 60-85 HRA.

B: 25-100 HRB.

C: 20-70 HRC.

D: 40-77 HRD.

E: 70-100 HRE.

F: 60-100 HRF.

G:30-94 HRG.

H:80-100 HRH.

K: 40-100 HRK.

N: 70-94 HRN.

T : 15-83 HRT.

14.3 Uncertainty example: $u_c = \sqrt{(u_r^2 + u_c^2 + u_e^2)}$, $U = 2 \times u_c$.

14.4 Compatibility Notes:

Carbide: Recommended N scale hardness block, hardness 70-94 HRN.

Thin plate: Use T-scale hardness block, thickness ≥ 0.1 mm.

Coating: Requires a dedicated hardness block and calibration by agreement.

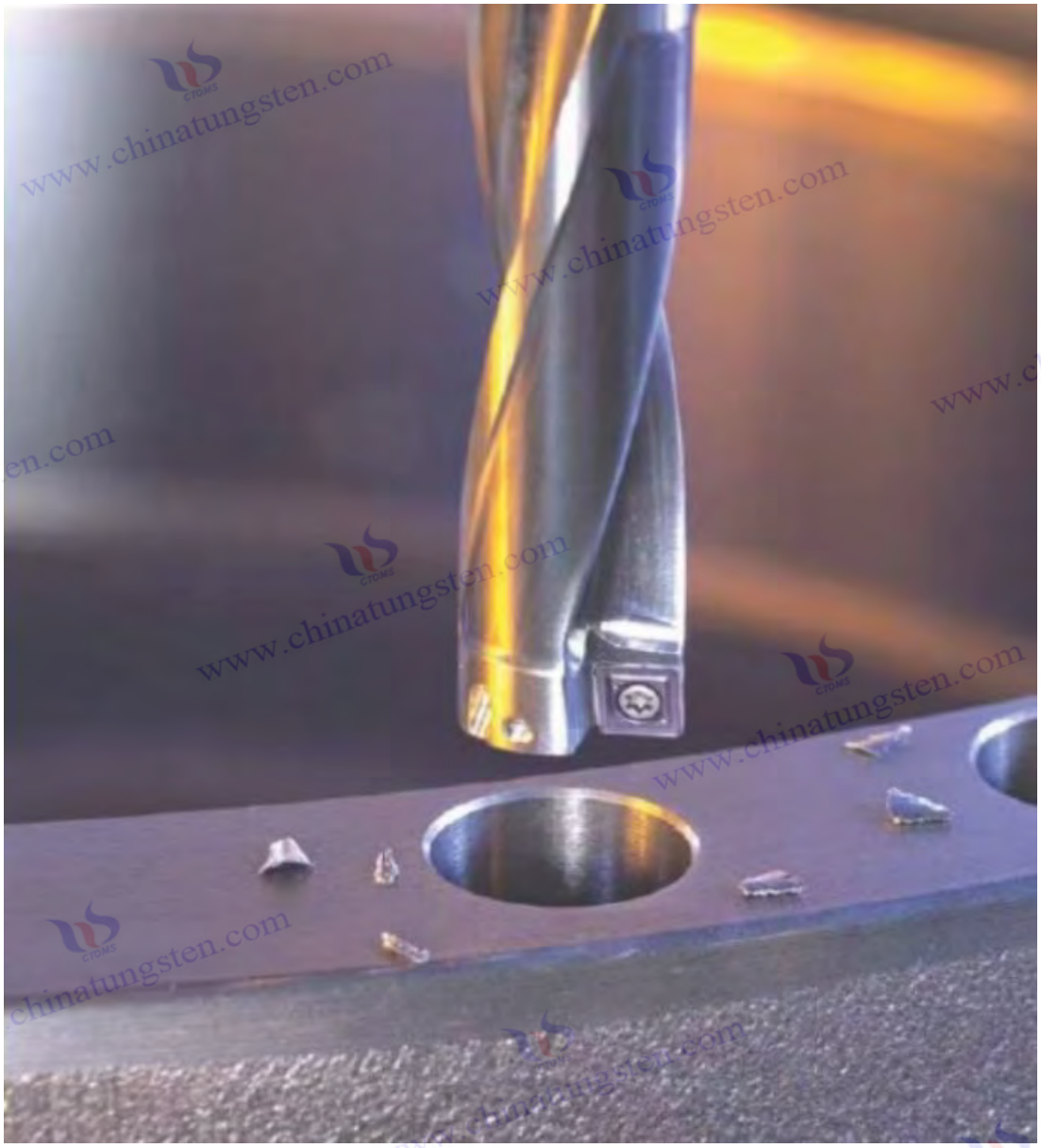
15. Release of Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

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GB/T 230.12009

Rockwell hardness test of metal materials

Part 1: Test methods (A, B, C, D, E, F, G, H, K, N, T scales)

1. Scope

This standard specifies the test method for Rockwell hardness (HR) of metallic materials, including the test conditions, operating procedures, and calculation of hardness values for conventional Rockwell hardness (A, B, C, D, E, F, G, H, K scales) and superficial Rockwell hardness (N, T scales). It is applicable to steel, stainless steel, nonferrous metals (such as copper and aluminum), cemented carbide, and coated materials, covering a hardness range from HR15T to HRC 100. This method is intended for quality control, material identification, and performance evaluation, and is not suitable for the following situations:

The sample thickness is less than 0.2 mm or the indentation depth exceeds 1/10 of the material thickness.

Surface roughness Ra>1.6 μm (Ra≤0.4 μm recommended).

Samples with obvious cracks, holes or oxide layers. For special materials or complex geometries, other methods (such as Vickers hardness test) must be combined for verification.

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 15020 Terminology for hardness testing of metallic materials.

GB/T 230.2-2012 Metallic materials Rockwell hardness test Part 2: Verification and calibration of testing machines (A, B, C, D, E, F, G, H, K, N, T scales).

GB/T 230.3-2012 Metallic materials Rockwell hardness test Part 3: Calibration of standard hardness blocks (A, B, C, D, E, F, G, H, K, N, T scales).

JJG 112 Metal Rockwell Hardness Tester (A, B, C, D, E, F, G, H, K, N, T scales).

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JJF 1059.1 Evaluation and expression of measurement uncertainty.

3. Terms and Definitions

This standard adopts the following terms and definitions (refer to GB/T 15020):

Rockwell hardness (HR): An indicator of a metal material's ability to resist local plastic deformation. It is measured by the difference in penetration depth of the indenter under preload and total load. The unit is HR, followed by a scale letter (such as HRA, HRC).

Preload (F_0) : A small force initially applied to stabilize the indenter in contact with the sample.

Total load (F): The sum of preload plus additional load.

Indentation depth (h): The permanent indentation depth left by the indenter after unloading, in μm.

4. Principles of the Method

A standard indenter (diamond cone or steel ball) is pressed into the sample surface under a preload (F_0) . An additional load (F_1) is applied to create a total load (F). The indentation depth is maintained for a specified period of time before unloading to the preload. The increment in indentation depth (h) after unloading is measured, and the Rockwell hardness value is calculated using the scale formula:

$$HR = N - h \times k$$

in:

N: Scale constant, depends on the scale used.

h: Permanent indentation depth increment (μm).

k: scale factor (usually 0.002 mm/μm).

5. Reagents and Materials

5.1 Cleaning agent: anhydrous ethanol or acetone, used to clean the sample surface.

5.2 Lubricant: A small amount of engine oil to reduce the wear of the press head (optional).

5.3 Standard hardness block: A calibration block with known HR value, covering the range of each scale.

6. Instruments

6.1 Rockwell hardness tester: Conforms to GB/T 230.2-2012 and has the following characteristics:

Preload (F_0) : 98.07 N (10 kgf) or 29.42 N (3 kgf).

Additional load (F_1) : See Appendix Table 1.

Total load (F): See Appendix Table 1.

Indentation depth measurement accuracy: ±0.5 μm.

6.2 Indenter:

Diamond cone (apex angle 120°, tip radius 0.2 mm) for A, C, and D scales.

Carbide balls (diameter 1.5875 mm) for use with B, E, F, G, H, K scales.

Carbide balls (3.175 mm diameter) for special applications (by agreement).

6.3 Optical microscope: Magnification 50x to 200x, to inspect the indenter and indentation (optional).

6.4 Surface treatment equipment: sandpaper (#600 to #1200), polishing machine (grain size 0.5 μm to 1 μm).

7. Sample Preparation

7.1 Sample collection: Take a representative specimen from the metal material with a size of not less than 10 mm ×

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10 mm × 5 mm (the thickness should be at least 10 times the indentation depth).

7.2 Surface treatment:

Use SiC sandpaper (#600, #800, #1200) to grind it in steps.

Polish with diamond polishing liquid (1 μm) to a mirror surface with a surface roughness of Ra ≤ 0.4 μm.

Clean with ethanol or acetone to remove oil and dry.

7.3 Sample inspection: Ensure that there are no cracks, scratches, or oxide layers, and that the thickness meets the load requirements.

8. Measurement Steps

8.1 Instrument Calibration:

The hardness tester was calibrated using the method specified in GB/T 230.2-2012.

Each scale is verified with a standard hardness block, with an error of ≤±1 HR.

8.2 Selection of test conditions:

Select the scale and load according to the hardness and thickness of the material (see Appendix Table 1).

Hold time: 2-8 s (conventional scale) or 1-5 s (surface scale).

8.3 Test operation:

Select a flat area on the sample surface with a distance between points ≥3 mm and a distance from the edge ≥5 mm.

Apply a preload (F_0) , and after stabilization, apply an additional load (F_1) , maintain for a specified time, and then unload to F_0 .

The hardness tester automatically reads the indentation depth increment (h) and calculates the HR value.

8.4 Repeatability: Measure 5 points for each sample and take the arithmetic mean.

9. Calculation of results

The Rockwell hardness value (HR) is automatically calculated by the hardness tester:

$$HR = N - h \times k$$

The values of N and k are shown in Appendix Table 2. The results are rounded to 0.1 HR according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: The relative standard deviation (RSD) should be less than 2% after repeated determination for 6 times.

10.2 Accuracy: Verified using a standard hardness block, the error should be less than ±1 HR (conventional scale) or ±2 HR (surface scale).

11. Interference Elimination

11.1 Surface roughness: Polish to Ra ≤ 0.4 μm to avoid indentation depth error.

11.2 Load selection: Ensure that the indentation depth does not exceed 1/10 of the material thickness or 3 times the indentation diameter.

11.3 Environmental influence: The test room temperature is 20°C ± 5°C, the humidity is less than 65%, and vibration is avoided.

11.4 Indenter wear: Check the diamond cone or steel ball regularly and replace if necessary.

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12. Security

12.1 Operators must wear protective glasses to avoid splashing of indenter fragments or chemical reagents.

12.2 Waste liquids (ethanol, acetone) shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to the high-voltage part of the hardness tester and follow the equipment operating manual.

13. Report

The report should include the following:

Sample number, material type, heat treatment status and description.

Hardness value (HR), including average value, single point data and standard deviation.

Test scale, load (F_0 , F_1 , F) and holding time.

Instrument model, calibration date and status. Environmental conditions (temperature, humidity). Any anomalies or deviations.

14. Appendix (Informative)

14.1 Scale and load table:

Conventional ruler:

A: F_0 = 98.07 N, F_1 =588.4 N, F=686.5 N (diamond cone).

B : F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

C: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

D: F_0 = 98.07 N, F_1 =1373 N, F=1471 N (diamond cone).

E: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (3.175 mm ball).

F: F_0 =98.07 N, F_1 =588.4 N, F=686.5 N (1.5875 mm ball).

G: F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

H: F_0 =98.07 N, F_1 =882.6 N, F = 980.7 N (1.5875 mm ball).

K: F_0 =98.07 N, F_1 =1373 N, F=1471 N (1.5875 mm ball).

Surface ruler:

N: F_0 = 29.42 N, F_1 =264.2 N, F=294.6 N (diamond cone).

T: F_0 =29.42 N, F_1 =441.3 N, F = 470.7 N (1.5875 mm ball).

14.2 Scale constant table:

A, C, D: N=100, k=0.002 mm/μm.

B, E, F, G, H, K: N=130, k=0.002 mm/μm.

N, T: N=100, k=0.002 mm/μm.

14.3 Thickness requirement: Sample thickness ≥ 10 times the indentation depth, indentation depth ≈ 0.068 × F/d.

14.4 Compatibility Notes:

Carbide: Recommended N scale, load ≤ 294.6 N.

Thin plate: Use T ruler, thickness ≥ 0.1 mm.

Coating: Low load scales must be agreed upon.

15. Release of Information

Issuing units: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China.

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GB/T 4340.1-2009

Vickers hardness test of metal materials

Part 1: Test methods

1. Scope

This standard specifies the test method for Vickers hardness (HV) of metallic materials, including the selection of test conditions, indentation measurement, and calculation of hardness values. It is applicable to various metallic materials, including steel, stainless steel, non-ferrous metals (such as copper and aluminum), cemented carbide, and coatings, with a hardness range of 5 HV to 3000 HV. This method is intended for quality control, material identification, performance evaluation, and research and development. It is not suitable for the following situations:
The sample thickness is less than 0.2 mm or the indentation depth exceeds 1/10 of the material thickness.
Surface roughness Ra>1.6 μm (Ra≤0.2 μm recommended).
Samples with obvious cracks, holes or oxide layers. For special materials or complex geometries, other methods (such as Rockwell hardness test) must be combined for verification.

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.
GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.
GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.
GB/T 13299 Tensile test methods for metallic materials.
GB/T 15020 Terminology for hardness testing of metallic materials.
ISO 6507-1:2005 Metallic materials Vickers hardness test Part 1: Test method (equivalent adoption).

3. Terms and Definitions

This standard adopts the following terms and definitions (refer to GB/T 15020):
Vickers hardness (HV): An indicator of a metal material's ability to resist local plastic deformation. It is measured by pressing a standard quadrangular pyramid diamond indenter into the sample surface under a specified load. The unit is HV.
Indentation: A square depression formed by a Vickers indenter (vertex angle 136°) pressed into the sample surface. The diagonal length of the depression is used to calculate the hardness value.
Test load (F): The force applied to the indenter, in Newtons (N), ranging from 0.098 N to 294.2 N (0.01 kgf to 30 kgf).
Hold time: The time the indenter holds the load after applying it, in seconds (s).

4. Principles of the Method

Use a standard square pyramid diamond indenter (136° apex angle) to press into the sample surface under a specified load, hold for a specified time, and then unload. Measure the lengths of the two diagonals of the indentation (d_1 , d_2) , take the average value d, and calculate the Vickers hardness value:

$$HV = \frac{1.8544 \times F}{d^2}$$

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Where:

F: test load (N).

d: Average diagonal length of the indentation (mm).

1.8544: Vickers hardness calculation constant, dependent on the indenter geometry.

5. Reagents and Materials

5.1 Cleaning agent: anhydrous ethanol or acetone, used to clean the sample surface.

5.2 Lubricant: A small amount of engine oil or graphite lubricant to reduce the wear of the indenter (optional).

5.3 Standard hardness block: A calibration block with known HV values, covering the range of 5 HV to 3000 HV.

6. Instruments

6.1 Vickers hardness tester: Conforms to ISO 6507-1 and has the following characteristics:

Load range: 0.098 N, 0.246 N, 0.49 N, 0.98 N, 1.96 N, 4.90 N, 9.80 N, 19.6 N, 29.4 N, 49.0 N, 98.0 N, 196 N, 294.2 N (corresponding to 0.01 kgf to 30 kgf).

Indentation measurement accuracy: ±0.5 μm.

Automatic or manual loading, with adjustable hold time (5-60 s).

6.2 Optical microscope: magnification 100x to 500x, equipped with a micrometer eyepiece or digital imaging system.

6.3 Analytical balance: with a sensitivity of 0.001 g, used for calibrating loads.

6.4 Surface treatment equipment: sandpaper (#600 to #1200), polishing machine (diamond suspension with particle size 0.5 μm to 1 μm).

7. Sample Preparation

7.1 Sample collection: Take a representative specimen from the metal material with a size of not less than 10 mm × 10 mm × 5 mm (the thickness should be at least 10 times the indentation depth).

7.2 Surface treatment:

Use SiC sandpaper (#600, #800, #1200) to grind it in steps.

Polish with diamond polishing liquid (1 μm) to a mirror surface with a surface roughness of Ra ≤ 0.2 μm.

Clean with ethanol or acetone to remove oil and dry.

7.3 Sample inspection: Ensure that there are no cracks, scratches, oxide layers or surface defects, and that the thickness meets the load requirements.

8. Measurement Steps

8.1 Instrument Calibration:

The hardness tester is calibrated using a standard hardness block, and the load and indentation measurement system error is ≤±1%.

Record calibration dates and results.

8.2 Selection of test conditions:

Select the load according to the hardness and thickness of the material (see Appendix Table 1).

Holding time: 10-15 s (can be extended to 30 s for carbide).

8.3 Test operation:

Select a flat area on the sample surface with a distance between points ≥3 mm and a distance from the edge ≥5 mm.

Apply the load, maintain it for a specified time, and then unload it.

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Use an optical microscope to measure the lengths of the two diagonals (d_1 and d_2) and take the average value d with an accuracy of 0.001 mm.

8.4 Repeatability: Measure 5 points for each sample and take the arithmetic mean.

9. Calculation of results

Vickers hardness value (HV) is calculated according to the formula:

$$HV = \frac{1.8544 \times F}{d^2}$$

in:

F: test load (N).

d: Average diagonal length of the indentation (mm), d=(d1+d2)/2

The results are rounded according to GB/T 8170:

d≤0.1mm: retain 1 HV.

d>0.1mm: retain 0.1 HV.

10. Precision and Accuracy

10.1 Precision: The relative standard deviation (RSD) should be less than 3% after repeated determination for 6 times.

10.2 Accuracy: Verified using a standard hardness block, the error should be less than ±2 HV (low hardness) or ±1% (high hardness).

11. Interference Elimination

11.1 Surface roughness: Polish to Ra ≤ 0.2 μm to avoid indentation measurement errors.

11.2 Load selection: Ensure that the indentation depth does not exceed 1/10 of the material thickness or 3 times the indentation diameter.

11.3 Environmental influence: The test room temperature is 20°C ± 5°C, the humidity is less than 65%, and vibration is avoided.

11.4 Indenter wear: Check the indenter tip regularly and replace if necessary.

12. Security

12.1 Operators must wear protective glasses to avoid splashing of indenter fragments or chemical reagents.

12.2 Waste liquids (ethanol, acetone) shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to the high-voltage part of the hardness tester and follow the equipment operating manual.

13. Report

The report should include the following:

Sample number, material type, heat treatment status and description. Hardness value (HV), including average, single-point data and standard deviation. Test load (N or kgf), hold time (s) and measurement conditions. Instrument model, calibration date and status.

Environmental conditions (temperature, humidity). Any abnormalities or deviations.

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14. Appendix (Informative)

14.1 Load selection table:

Hardness 5-250 HV: 0.098 N, 0.246 N, 0.49 N, 0.98 N, 1.96 N, 4.90 N.

Hardness 250-1000 HV: 9.80 N, 19.6 N, 29.4 N, 49.0 N.

Hardness 1000-3000 HV: 98.0 N, 196 N, 294.2 N.

14.2 Indentation measurement range: The diagonal length d should be between 0.020 mm and 1.000 mm.

14.3 Thickness requirement: Sample thickness ≥ 10 times the indentation depth, indentation depth ≈ 0.068 × F/d.

14.4 Compatibility Notes:

Carbide: Low load (0.5 kgf to 5 kgf) is recommended to avoid surface cracks.

Coating material: The load needs to be adjusted to 0.01 kgf-0.2 kgf to measure the effect of coating thickness.

Thin plate: Use a small load and observe under a microscope at high magnification.

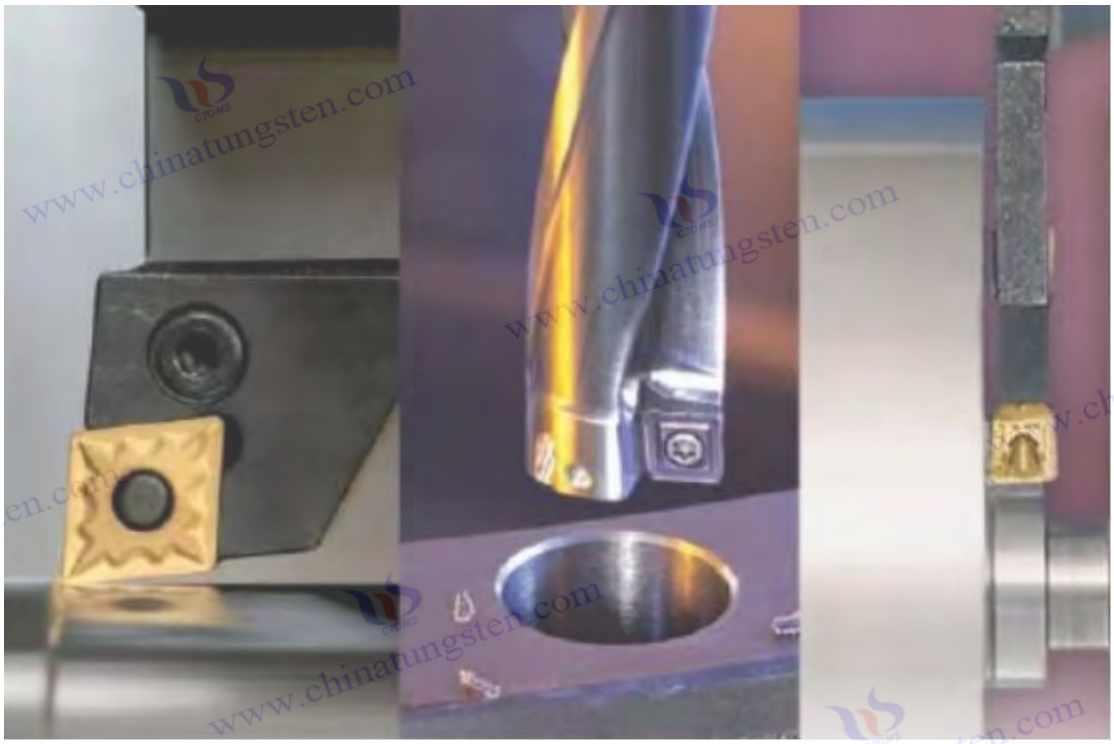
15. Release of Information

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GB/T 18378-2001

Observation method of cemented carbide microstructure

1. Scope

This standard specifies methods for observing the microstructure of cemented carbide (hard metal), including qualitative analysis of grain size, phase distribution, porosity, and defects. It is applicable to sintered cemented carbide products and raw materials containing tungsten carbide (WC) as the primary hard phase and cobalt (Co), nickel (Ni), and other materials as binder phases. This method can be used for quality control, process optimization, and performance evaluation. It is not suitable for complex samples containing high levels of organic matter or non-metallic impurities and requires verification in conjunction with other techniques (such as X-ray diffraction).

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 13298 Metal microstructure examination methods.

GB/T 20066 Methods for preparation of rock and mineral test samples.

3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: A high-hardness, high-wear-resistant material prepared by sintering powder metallurgy process

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with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase.

Microstructure: The grain morphology, phase distribution, pores and defect characteristics of cemented carbide observed under a microscope.

Grain size: The average diameter of the WC phase, usually expressed in micrometers (μm).

4. Principles of the Method

Cemented carbide samples are prepared for microscopic observation through metallographic preparation, polishing, and etching. The sample surface is observed using an optical microscope or scanning electron microscope (SEM) to qualitatively analyze grain size, the distribution of WC and Co phases, porosity, and defects (e.g., cracks and inclusions). These results provide information about the sintering process and material properties.

5. Reagents and Materials

5.1 Pure water for analysis: in accordance with GB/T 6682 Grade 1 water standard, with a resistivity of ≥18 MΩ·cm.

5.2 Alcohol: analytical grade, concentration ≥95%, used for cleaning.

5.3 Etching agent: Murakami reagent (10 g $K_3[Fe(CN)_6]$ + 10 g KOH + 100 mL H_2O) for microscopic observation.

5.4 Embedding resin: Epoxy resin or phenolic resin, used for sample fixation.

6. Instruments

6.1 Metallographic microscope: magnification 50x to 1000x, equipped with imaging system.

6.2 Scanning electron microscope (SEM): resolution better than 1 μm, equipped with energy dispersive spectrometer (EDS) (optional).

6.3 Polishing machine: equipped with diamond abrasive with a particle size range of 0.5 μm to 5 μm.

6.4 Cutting machine: with diamond saw blade, used for sample cutting.

6.5 Analytical balance: sensitivity 0.0001 g.

7. Sample Preparation

7.1 Sample collection: Randomly take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g.

7.2 Sample cutting: Use a cutting machine to cut samples with a size of approximately 10 mm × 10 mm × 5 mm to avoid structural changes caused by overheating.

7.3 Embedding and polishing:

The specimens were embedded in epoxy resin and then ground flat using SiC sandpaper (grit #200 to #1200) in grades after curing.

Polish with diamond polishing fluid (1 μm) to a mirror finish without scratches.

7.4 Etching treatment: Etch with Murakami reagent at room temperature for 30-60 seconds, rinse and dry with alcohol.

8. Measurement Steps

8.1 Microscope observation:

The WC grain size, phase distribution and pores were observed under a metallographic microscope at a magnification of 500×.

If necessary, SEM was used to further analyze defects and microstructure.

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8.2 Qualitative analysis:

Identify WC phase (off-white hexagonal grains), Co phase (black binder phase), and possible η phase (angular).

Evaluate porosity and defects, classified according to ISO 4505 (Type A <10 μm, Type B 10-25 μm, Type C >25 μm).

8.3 Repeatability: Observe three different fields of view for each sample and record the typical characteristics.

9. Results Expression

9.1 Grain Size: Estimate the average WC diameter by visual inspection and report a range (e.g., 1-5 μm). Do not perform quantitative measurements.

9.2 Porosity: Describe qualitatively by the number of pores per mm^2 , indicating the proportion of Types A, B, and C.

9.3 Result record: Report in the form of photos or descriptions, indicating the observation magnification.

10. Precision and Accuracy

10.1 Precision: Repeat the observation 6 times, and the characteristic consistency should reach more than 90%.

10.2 Accuracy: Verify using standard reference materials (e.g. CRM containing WC-Co) that the visual results deviate from the known values by less than 10%.

11. Interference Elimination

11.1 Surface contamination: Ensure that polishing is thorough and that abrasive residue is eliminated.

11.2 Uneven corrosion: Control the corrosion time to avoid excessive corrosion affecting phase identification.

11.3 Sampling bias: Randomly select multiple specimens to reduce local heterogeneity.

12. Security

12.1 Operators must wear protective glasses and gloves to avoid splashing of corrosive agents.

12.2 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to the safe operation of cutting machines and polishing machines.

13. Report

The report should include the following:

Sample number, source and description.

Microstructural observation results (grain size, phase composition, porosity and defects).

Observe the magnification and instrument model.

Repeatability data.

Any anomalies or deviations.

14. Appendix (Informative)

14.1 Preparation of Murakami reagent: 10 g $K_3[Fe(CN)_6]$ + 10 g KOH + 100 mL H_2O . Mix well and use immediately. 14.2 Porosity classification (refer to ISO 4505):

Type A: small pores (<10 μm).

Type B: medium pores (10-25 μm).

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Type C: Macropores (>25 μm). 14.3 Note: Samples with high Co content may require an extended etching time of up to 90 seconds.

15. Release of Information

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GB/T 34882015

Cemented Carbide Microstructure Evaluation Method

1. Scope

This standard specifies methods for evaluating the microstructure of cemented carbide (hard metal), including quantitative and qualitative analysis of grain size, phase composition, porosity, and defects. It is applicable to sintered cemented carbide products and their raw materials, using tungsten carbide (WC) as the primary hard phase and cobalt (Co), nickel (Ni), and other materials as binder phases. This method can be used for quality control, performance evaluation, and process optimization. It is not suitable for complex samples containing high levels of organic or non-metallic impurities and requires verification in conjunction with other techniques (such as X-ray diffraction).

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 13298 Metal microstructure examination methods.

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GB/T 20066 Methods for preparation of rock and mineral test samples.

3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: A high-hardness, high-wear-resistant material prepared by sintering powder metallurgy process with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase .

Microstructure: The grain size, phase distribution, pores and defect characteristics of cemented carbide observed under a microscope.

Grain size: The average diameter of the WC phase, usually expressed in micrometers (μm).

4. Principles of the Method

Cemented carbide samples are prepared for microscopic observation through metallographic preparation, polishing, and etching. The sample surface is observed using an optical microscope or scanning electron microscope (SEM) to assess grain size, phase composition (WC, Co phase, and possible η phase), porosity, and defects (e.g., cracks and inclusions). Quantitative measurements are performed using standard grid methods or image analysis techniques.

5. Reagents and Materials

5.1 Pure water for analysis: in accordance with GB/T 6682 Grade 1 water standard, with a resistivity of ≥18 MΩ·cm.

5.2 Alcohol: analytical grade, concentration ≥95%, used for cleaning.

5.3 Etching agent: Murakami reagent (10 g $K_3[Fe(CN)_6]$ + 10 g KOH + 100 mL H_2O) for microscopic observation.

5.4 Embedding resin: Epoxy resin or phenolic resin, used for sample fixation.

6. Instruments

6.1 Metallographic microscope: magnification 50x to 1000x, equipped with imaging system.

6.2 Scanning electron microscope (SEM): resolution better than 1 μm, equipped with energy dispersive spectrometer (EDS).

6.3 Polishing machine: equipped with diamond abrasive with a particle size range of 0.5 μm to 5 μm.

6.4 Cutting machine: with diamond saw blade, used for sample cutting.

6.5 Analytical balance: sensitivity 0.0001 g.

7. Sample Preparation

7.1 Sample collection: Randomly take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g.

7.2 Sample cutting: Use a cutting machine to cut samples with a size of approximately 10 mm × 10 mm × 5 mm, avoiding overheating.

7.3 Embedding and Polishing: Embed the specimen in epoxy resin. After curing, grind it flat in steps using SiC sandpaper (grit #200 to #1200). Polish it to a mirror finish using diamond polishing fluid (1 μm).

7.4 Etching treatment: Etch with Murakami reagent at room temperature for 30-60 seconds, rinse and dry.

8. Measurement Steps

8.1 Microscope observation:

The WC grain size, phase distribution and pores were observed under a metallographic microscope at a magnification

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of 500×.

If necessary, SEM was used to further analyze defects and microstructure.

8.2 Grain size measurement: Use the linear cross-section method or image analysis software to measure at least 200 WC grains and calculate the average diameter.

8.3 Porosity Assessment:

Pores are classified according to ISO 4505 (Type A, Type B, Type C) and the number of pores per mm^2 is counted .

8.4 Repeatability: Observe three different fields of view for each sample and take the average value.

9. Calculation of results

9.1 Grain size: Report as average diameter in μm with an error of ±0.1 μm.

9.2 Porosity: Report as the number of pores per mm^2 , classifying and recording the proportion of type A, B, and C pores.

9.3 Rounding off: round to the appropriate number of digits according to GB/T 8170.

10. Precision and Accuracy

10.1 Precision: Repeat the measurement 6 times, and the relative standard deviation (RSD) should be less than 5%.

10.2 Accuracy: Verified using standard reference materials (e.g., CRM containing WC-Co), the error should be less than ±0.2 μm (grain size) or ±0.5% (porosity).

11. Interference Elimination

11.1 Surface contamination: Ensure that polishing is thorough and that abrasive residue is eliminated.

11.2 Uneven corrosion: Control the corrosion time to avoid excessive corrosion affecting observation.

11.3 Sampling bias: Multiple samples should be randomly selected to reduce the effect of local heterogeneity.

12. Security

12.1 Operators must wear protective glasses and gloves to avoid splashing of corrosive agents.

12.2 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to the safe operation of cutting machines and polishing machines.

13. Report

The report should include the following:

Sample number, source and description.

Grain size, phase composition, porosity and defect assessment results.

Observe the magnification and instrument model.

Repeatability data.

Any anomalies or deviations.

14. Appendix (Informative)

14.1 Preparation of Murakami reagent: 10 g $K_3[Fe(CN)_6]$ + 10 g KOH + 100 mL H_2O . Mix well and use immediately. 14.2 Porosity classification (refer to ISO 4505):

Type A: small pores (<10 μm).

Type B: medium pores (10-25 μm).

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Type C: macropores (>25 μm).

14.3 Note: Samples with high Co content may require the etching time to be extended to 90 seconds.

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GB/T 18375-2001

Test method for density of cemented carbide

1. Scope

This standard specifies a test method for determining the density of cemented carbide (hard metal). It is applicable to sintered cemented carbide products and their raw materials, which use tungsten carbide (WC) as the primary hard phase and cobalt (Co), nickel (Ni), or other binder phases. The density measurement range is 10 g/cm³ to 20 g/cm³ . This method can be used for quality control, product identification, and performance evaluation. It is not suitable for porous samples or those containing highly volatile impurities and requires verification in conjunction with other methods (such as mercury penetration).

2. Normative References

The clauses in the following documents become clauses of this standard through reference. For dated references, all subsequent amendments (excluding errata) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate whether the latest versions of these documents can be used. For undated references, the latest versions apply to this standard.

GB/T 6379 Statistical methods and interpretation of accuracy (trueness) and precision data.

GB/T 6682 Specifications and test methods for water used in analytical laboratories.

GB/T 8170 Rules for rounding off numerical values and expression and judgment of limit values.

GB/T 20066 Methods for preparation of rock and mineral test samples.

3. Terms and Definitions

This standard uses the following terms and definitions:

Cemented carbide: A high-hardness, high-density material prepared by sintering powder metallurgy technology with tungsten carbide (WC) as the main hard phase and metals such as cobalt and nickel as the bonding phase.

Density: The mass of a substance per unit volume, expressed in g/ cm³ .

Archimedes' method: A classic method for calculating density by measuring the difference in weight of a sample in

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air and in a liquid.

4. Principles of the Method

The density of cemented carbide is determined using the Archimedean displacement method. The sample is weighed in air (m_1) , then immersed in a liquid of known density (such as distilled water or ethanol), and its mass in the liquid (m_2) is measured . Based on Archimedean principle, the density (ρ) is calculated using the formula:

$$\rho = \frac{m_1}{m_1 - m_2} \times \rho_0$$

Where ρ0 is the density of the liquid (usually 1.0 g/cm³ for water , which needs to be corrected for temperature effects).

5. Reagents and Materials

5.1 Analytical Pure Water: Meets GB/T 6682 Grade 1 water standard, resistivity ≥ 18 MΩ·cm, temperature controlled at 20°C ± 1°C. 5.2 Ethanol: Analytically pure, concentration ≥ 95%, used as a surrogate for hydrophobic samples. 5.3 Surfactant: A small amount of non-ionic surfactant (e.g., Tween 20) is used to reduce bubbles.

6. Instruments

6.1 Analytical balance: with a sensitivity of 0.0001 g and equipped with a suspension device for immersion in liquid.

6.2 Constant temperature water bath: Temperature control range 15°C to 30°C, accuracy ±0.1°C.

6.3 Density bottle or graduated cylinder: 50 mL or 100 mL, clean and free of residue.

6.4 Tweezers: Stainless steel, to prevent sample contamination.

7. Sample Preparation

7.1 Sample collection: Randomly take representative samples from cemented carbide products or raw materials, with a total amount of not less than 500 g.

7.2 Sample processing:

Cut or grind into regular shapes (such as cubes or cylinders) with a side length or diameter of not less than 5 mm and a weight of approximately 10 g to 50 g.

The sample surface was cleaned with ethanol to remove oil stains and dried to constant weight (105°C, 1 h).

7.3 Sample inspection: Ensure there are no cracks, holes or surface defects, and polish if necessary.

8. Measurement Steps

8.1 Instrument Preparation:

Set a thermostatic water bath to 20°C and stabilize for 30 minutes.

Clean the density bottle or measuring cylinder, add an appropriate amount of distilled water, and record the liquid temperature.

8.2 Quality Measurement:

Weigh the mass of the dry sample in air (m_1) to the nearest 0.0001 g.

m_2) in the liquid , ensuring that there are no bubbles attached. 8.3 Repeatability: Measure each sample three times and take the average value.

8.4 Blank correction: Record the density of the liquid itself (ρ0 \rho_0 ρ0) and correct it for temperature (1.0 g/ cm³ at 20°C).

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9. Calculation of results

Density (ρ, g/cm³) is calculated according to the formula:

$$\rho = \frac{m_1}{m_1 - m_2} \times \rho_0$$

in:

m1: mass of the sample in air (g).

m2: mass of the sample in the liquid (g).

ρ0: density of the liquid (g/cm³) , corrected for temperature.

cm³ according to GB/T 8170 .

10. Precision and Accuracy

10.1 Precision: Repeat the measurement 6 times, and the relative standard deviation (RSD) should be less than 1%.

10.2 Accuracy: Verified using standard reference materials (e.g. GBW 01234 carbide CRM), the error should be less than ±0.05 g/ cm³ .

11. Interference Elimination

11.1 Influence of bubbles: Treat the sample with a surfactant or vacuum degassing to remove attached bubbles.

11.2 Temperature influence: strictly control the liquid temperature and calibrate the density value.

11.3 Surface adsorption: Ensure that the sample is dry and reduce liquid residue.

12. Security

12.1 Operators must wear protective glasses and gloves to avoid liquid splashing.

12.2 Waste liquid shall be disposed of in accordance with the Technical Specifications for the Prevention and Control of Pollution from Hazardous Wastes (HJ 2025).

12.3 Pay attention to the stability of the balance suspension device to prevent the sample from falling off.

13. Report

The report should include the following:

Sample number, source and description.

Measurement result (density, g/cm³) .

Liquid temperature and correction value.

Repeatability data.

Any anomalies or deviations.

14. Appendix (Informative)

14.1 Temperature Correction Table:

15°C: ρ0=0.9991g/cm3

20°C: ρ0=1.0000g/cm3

25°C: ρ0=0.9970g/cm3

14.2 Note: For hydrophobic samples, ethanol can be used and the density should be calibrated to 0.789 g/cm³ (20°C).

14.3 Equipment Maintenance: Regularly calibrate the balance and water bath, and check for wear on the suspension wire.

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Rockwell, Vickers and Brinell hardness tests:
Theory, Methods and Application Guide of Cemented Carbide

Preface

With the development of modern industrial technology, the accurate evaluation of material properties has become a key link in promoting the progress of the manufacturing industry. Among them, hardness testing, as a core indicator for measuring a material's deformation resistance and wear resistance, is widely used in metal processing, mechanical manufacturing, and materials science research. This article deeply explores the three mainstream hardness testing methods: Rockwell hardness, Vickers hardness, and Brinell hardness. It aims to provide readers with a comprehensive and detailed guide to theoretical basis, test methods, instruments and equipment, data analysis, and application scenarios. Specifically for cemented carbide, a high-performance material, the article expands on its special applications in various test methods, test optimization strategies, and practical significance for production and R&D. In combination with international standards (such as ISO 6506, 6507, 6508 and ASTM E18, E92, E10) and the latest technological trends, it strives to provide an authoritative reference for engineering practice and academic research.

This article significantly expands on the original content, delving deeper into each key point, including theoretical derivations, operational procedures, technical specifications, case studies, and equipment maintenance guidelines, striving to make the content more practical and valuable. A comparative summary table intuitively presents the differences, advantages, and disadvantages of the three hardness tests, helping readers quickly grasp the key information. Whether engaged in carbide tool development, mold manufacturing, or material performance evaluation, this article provides systematic guidance and inspiration.

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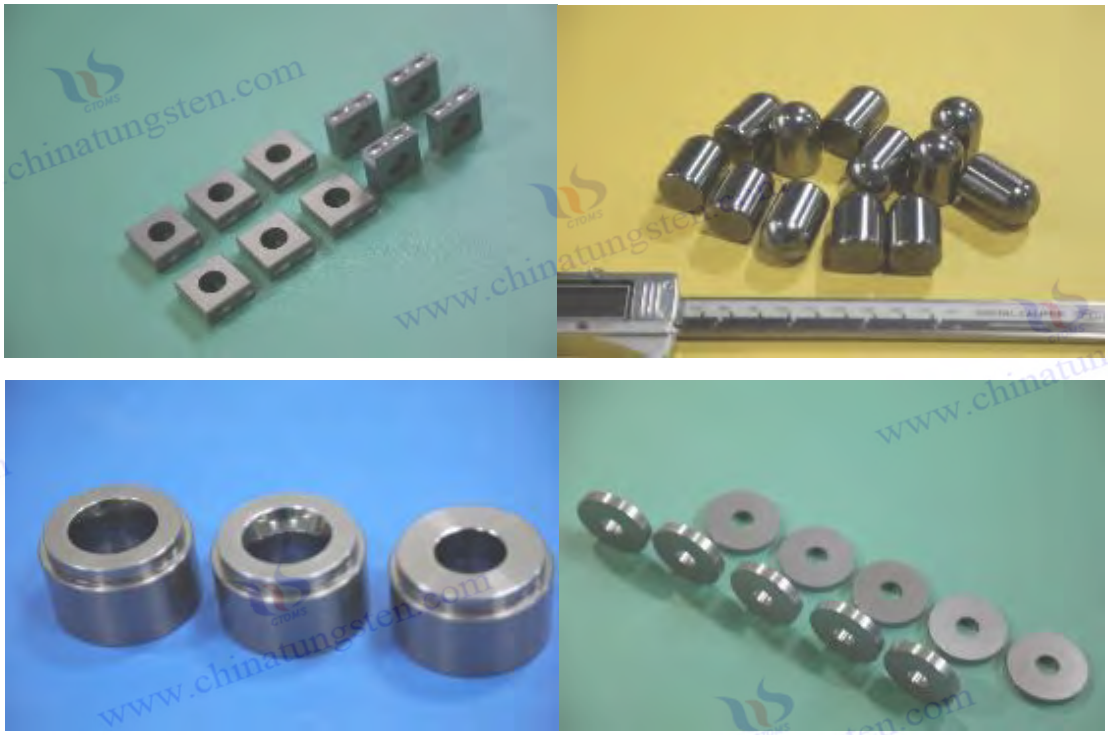
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1. Rockwell Hardness

1.1 Concepts and Theoretical Basis

The concept of Rockwell hardness

Rockwell hardness is a nondestructive test method for assessing hardness by measuring the depth of indentation retained on a material's surface under a specific load. Developed in 1919 by American engineer Stanley P. Rockwell, it was intended to provide an efficient and practical hardness measurement solution for industry. Originally designed for testing materials such as spring steel, the method's ease of use and rapidity have led to its expansion into steel, aluminum alloys, and high-hardness materials such as cemented carbide. Hardness values are represented by "HR" followed by a scale symbol (e.g., HRA, HRB, HRC). These scales are distinguished by different indenter types and load combinations and are widely used in production, quality control, and research.

Theoretical basis of Rockwell hardness :

The theoretical core of this method is based on the plastic deformation characteristics of the material. The testing process is divided into two stages: preload and main load. The preload (usually 10 kgf) is applied through the indenter to contact the specimen surface, eliminating the effects of surface roughness, oxide layers, or minor defects, ensuring the initial stability of the test. The main load (60, 100, or 150 kgf) is then applied, producing a measurable indentation. After unloading, the hardness is calculated by measuring the increase in indentation depth between the main load and preload. The formula is:

$$HR = N - \frac{d}{0.002}$$

Where N is a scale-specific constant (e.g., 100 for the HRA scale, 130 for the HRC scale, and 130 for the HRB scale), and d represents the indentation depth increment (in millimeters). 0.002 mm is defined as the reference depth for one hardness unit. This formula is derived based on the ratio of elastic rebound to plastic deformation in a material, assuming an inverse linear relationship between the indentation depth increment and the material's resistance to deformation.

Extended Theory

This theory also incorporates analysis of local stress distribution and material resilience. Small variations in indentation depth (typically within the range of 0.01-0.1 mm) are amplified by high-precision mechanical or electronic devices and converted into hardness values. This method specifically considers the high hardness (HRA 80-90) and brittleness of cemented carbide. The indenter must possess extremely high wear resistance (such as a diamond indenter HV 10000) to avoid damage during testing. Furthermore, the WC-Co phase structure of cemented carbide can lead to local hardness heterogeneity, requiring evenly distributed test points to obtain representative data.

Historical Background of Rockwell Hardness

The Rockwell hardness scale was born out of the urgent need for rapid hardness measurement during industrialization in the early 20th century. Stanley Rockwell originally designed this method to address the complexities of testing the hardness of spring steel. Its lack of complex calculations and microscopic measurements

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led to its rapid adoption in the 1920s, particularly in the automotive and steel industries. In the 21st century, with the widespread use of cemented carbides (such as YG6 and YT15) in cutting tools, wear-resistant parts, and molds, the Rockwell hardness test (particularly the HRA scale) has been further optimized, incorporating modern electronics and automated equipment to meet the demands of high-precision production. For example, in cemented carbide tool production, the HRA test is used to monitor the sintering process in real time to ensure that the hardness meets the industrial standard of HRA 85-87.

1.2 Rockwell hardness test method and instrument

Rockwell hardness test method

Preload Stage : A preload of 10 kgf is applied, and a 120° diamond cone or 1/16" steel ball indenter is brought into contact with the specimen surface. This stage lasts approximately 2-3 seconds. This ensures that the indenter is firmly embedded in the surface, eliminating initial errors caused by minor surface irregularities, oil stains, or oxide layers. This step is particularly important for cemented carbide, due to its high surface hardness (HRA 80-88). Ensure that the indenter and substrate are in close contact to avoid low hardness values due to poor contact. For example, cemented carbide coatings (such as TiN) may have micron-level roughness on the surface, requiring careful adjustment of the preload focus.

Main load stage : Apply the main load according to the selected scale, such as 60 kgf for HRA and 150 kgf for HRC, and hold it for 5-8 seconds (up to 10 seconds for carbide testing) to ensure the indentation is fully formed and stable. This stage requires precise load control to avoid hardness deviation caused by load fluctuations (±0.5 kgf), especially in the high hardness range of carbide (such as HRA 87 and above), where load instability may cause microcracks.

Unloading : Slowly unload to the preload. The instrument uses a built-in depth measurement system (usually an inductive or differential sensor) to record the incremental indentation depth between the main load and the preload. This increment is typically in the range of 0.01-0.1 mm. This is directly converted to a hardness value and displayed on the dial or digital screen. The unloading speed should be controlled within 1-2 seconds to minimize the effects of elastic rebound.

Preparation Requirements : Testing should be performed on a flat, oil-free surface. The recommended thickness of the cemented carbide specimen is at least 10 times the indentation depth (typically >0.5 mm, preferably >1 mm) to avoid inflated hardness values due to insufficient substrate support. The surface roughness should be polished to Ra 0.4 μm or less. If necessary, fine-tune the surface using diamond sandpaper (1200-2000 grit) or polishing fluid to minimize the effects of flaking of the hardened surface layer or coating. Furthermore, cemented carbide specimens should be tested at room temperature (20-25°C) to avoid thermal expansion errors caused by temperature fluctuations (>5°C).

Rockwell hardness testing instrument

Manual Rockwell hardness testers : Early mechanical devices, where the operator applies the load using a manual knob, and the hardness value is read on a mechanical dial. Suitable for small and medium-sized factories or on-site testing, they offer an accuracy of approximately ±1-2 HR. However, operation relies on manual experience and requires regular calibration to compensate for mechanical wear. For example, in cemented carbide production, manual devices are often used for primary quality screening.

Semi-automatic/Fully-automatic Rockwell Hardness Testers : Modern equipment integrates electronic sensors, digital displays, and automatic loading/unloading systems. Load application is controlled by hydraulics or servo

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motors, and depth measurement is performed by a high-precision inductive sensor (resolution 0.0001 mm). With an accuracy of ±0.5 HR, these equipment are widely used for quality inspection of carbide tools and molds. For example, a fully automatic system can test 10 carbide samples continuously, automatically recording the data into a database.

Indenter :

HRA and HRC : 120° diamond cone with sharp apex angle and tip radius of 0.2 mm. It has a hardness of over HV 10000 and is designed for high hardness materials (such as carbide HRA 80-88). Its service life is up to thousands of tests, but the tip wear needs to be checked regularly (every 500 tests).

HRB and HRF : 1/16 inch (1.588 mm) or 1/8 inch hardened steel balls with a hardness of approximately HV 800-1000. They are suitable for medium-hard materials (such as aluminum alloy HRB 50-80), but are not suitable for cemented carbide with too high a hardness (HRA > 70) because the steel balls are easily deformed.

Rockwell hardness scale and identification system

Main scale :

HRA : 60 kgf, diamond cone, hardness range 20-88 HR, suitable for cemented carbide (such as YG6 HRA 85-87) and hardened steel (HRA 70-85), because its high load and diamond indenter can effectively penetrate the surface coating (such as TiN, thickness 2-5 μm) or oxide layer of cemented carbide, reflecting the hardness of the substrate.

HRB : 100 kgf, 1/16 inch steel ball, hardness range 20-100 HR, suitable for aluminum alloy (HRB 30-70) and copper alloy (HRB 40-80), but not suitable for cemented carbide with too high hardness (HRA > 70), as the steel ball may be flattened due to excessive pressure.

HRC : 150 kgf, diamond cone, hardness range 20-70 HR, widely used for heat-treated steel (HRC 40-60), cemented carbide is only used in low hardness state (such as unsintered billet HRC 30-40).

Secondary scales : such as HRD (100 kgf, diamond cone, 20-70 HR) and HRF (60 kgf, 1/16 inch steel ball, 20-100 HR), are used for thin plates (such as 0.1-0.5 mm carbide sheets) or soft metal testing. For carbide sheet testing, refer to the HRF scale.

Marking : International standards ISO 6508 and ASTM E18 specify that results are marked in the "HRX" format. For example, "HRA 85" means the hardness value is 85 under the HRA scale. Cemented carbide often uses the HRA scale to match its high hardness characteristics (HRA 80-88).

Calibration : Use standard hardness blocks (such as HRA 70-88, HRC 20-65) to calibrate the instrument. The calibration cycle is usually once a month . For cemented carbide testing , use a dedicated high hardness calibration block (HRA 80-88) that meets the requirements of ASTM E18 or ISO 6508. During calibration, check the consistency of the indenter and load cell.

Methods specific to cemented carbide : Due to its high hardness (HRA 80-90) and brittleness, cemented carbide testing requires the use of an HRA scale to avoid damage to the steel ball indenter. Testing should avoid microcracks (commonly seen in sintering defects) or coating edges (areas of uneven thickness). It is recommended to test 3-5 points and average the results to minimize the impact of local heterogeneity. For example, for YG8 coating samples, the inter-test value should be within ±1 HR. High-precision automated equipment is required to ensure data reliability.

1.3 Rockwell hardness test results and data

Result range : 20-100 HR, the upper limit of each scale is different (such as HRA 88, HRC 70). Cemented carbide is usually tested in the range of HRA 80-88. The specific value depends on the cobalt content and sintering process.

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For example, YG6 (Co 6%) HRA 85-87, YG8 (Co 8%) HRA 83-85.

Data characteristics :

Direct reading, no calculation required, good repeatability (±1-2 HR), suitable for batch testing of cemented carbide, the average fluctuation of 10 samples is usually <±1.5 HR.

Affected by the surface roughness (Ra > 0.8 μm can easily lead to low readings), thickness (<0.5 mm can easily cause distortion) and uniformity of the specimen, cemented carbide must ensure a polished surface (Ra 0.2 μm) and a thickness >1 mm to avoid insufficient substrate support.

When testing cemented carbide, the HRA scale, due to its high load (60 kgf) and diamond indenter, can effectively penetrate the surface coating (such as TiN, 2-5 μm thick) or oxide layer, reflecting the hardness of the substrate. Typical values, such as HRA 86-88 after YG6 coating, can increase HRA by 0.5-1 by increasing the coating thickness by 1 μm.

Calibration and Error : Use a standard block for calibration. Sources of error include indenter wear (carbide tests require replacement every 500 times, with signs of wear being an expansion of the tip arc to 0.25 mm), load instability (±0.5 kgf), and specimen micro-defects (such as pores, >1% affecting ±2 HR). It is recommended to regularly check the indenter status and record calibration data.

Advantages and Disadvantages of Rockwell Hardness

advantage :

The test speed is fast (<10 seconds/time), which is particularly suitable for large-scale hardness testing on the production line of cemented carbide tools or wear-resistant parts, greatly improving production efficiency. For example, 500-1000 tools can be tested per day.

The indentation is small (0.1-0.3 mm in diameter) and has minimal impact on the surface of the finished carbide product. It is suitable for quality control and finished product inspection to avoid damage to the product appearance or function due to testing. For example, the cutting edge of the tool does not need to be subsequently trimmed.

The operation is simple, without the need for a microscope or complex calculations, which lowers the technical threshold and makes it easy for on-site operators to quickly master it. It is especially suitable for small and medium-sized cemented carbide enterprises and can be operated by workers without professional background.

shortcoming :

Accuracy is affected by surface preparation. Carbide needs to be polished to Ra 0.2 μm or less. Otherwise, the surface hardened layer or roughness will cause the hardness value to be too high (±2-3 HR) or unstable. The polishing process takes 1-2 hours.

There is no direct conversion between different scales. Hard alloys mostly use HRA, which limits direct comparison with other materials (such as steel HRC 40-60). Conversion tables (such as the HRA-HV conversion table) or additional testing are required, increasing the workload.

For samples of super-hard alloys (HRA > 88) or with uneven coating thickness, the measurement results may be distorted and need to be verified in combination with Vickers hardness (HV 2000 and above). For example, the HRA in the area of coating peeling may be 5-10 units lower.

Application Scenarios and Fields of Rockwell Hardness

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Application scenarios of Rockwell hardness :

Rapidly test the hardness (HRA 85-88) of carbide cutting tools (such as YG6, YT15) to evaluate hardness changes after sintering or heat treatment. This is especially useful for monitoring production consistency in cutting tool manufacturing. For example, testing 1,000 cutting tools to determine if their hardness distribution is within the range of HRA 85±1.

The hardness (HRA 82-86) of carbide cold heading dies or agricultural wear parts is monitored on the production line to ensure their durability under high impact conditions (e.g. 1000 MPa). Typical applications include bolt dies (HRA 85) and plowshares (HRA 83).

Rockwell hardness

Application areas :

In cutting tool manufacturing (carbide inserts, HRA 80-88), such as turning tools for machining steel (cutting speed 200 m/min), the insert hardness directly affects the tool life.

Agricultural machinery (plowshare wear parts, HRA 82-86) improves wear life during soil cultivation, with a predicted service life of more than 500 hours after testing.

Automotive industry (carbide gear molds, HRA 85-87), ensuring high-precision tooth profile forming, with a correlation of over 95% between mold hardness and tooth profile accuracy.

The significance of Rockwell hardness :

The Rockwell hardness test (HRA) of cemented carbide directly reflects its wear resistance and cutting performance. The higher the HRA value (such as HRA 87), the stronger the wear resistance. However, too high an HRA value (such as HRA > 88) may reduce toughness and cause brittle fracture. For example, the impact toughness drops from 15 J/cm² to 10 J/ cm² .

In the testing of cemented carbide coatings (such as TiN and TiAlN), HRA can evaluate the overall hardness of the coating after bonding with the substrate, and guide coating optimization. For example, TiN coating can increase HRA from 85 to 87, and increase cutting life by 20-30%.

During production, HRA testing provides real-time feedback to help adjust sintering parameters (such as temperature 1350-1450°C and pressure 30-50 MPa) to ensure that the cemented carbide performance meets the design requirements. For example, when the Co content is 8%, the HRA is stable at 85±1.

1.6 Expanding Knowledge

International differences : ASTM E18 and ISO 6508 differ slightly in the load application time (ASTM 2-8 seconds, ISO 5-10 seconds) and the hardness range of the calibration block. Carbide testing mostly follows the ISO standard because it has stricter requirements for calibration blocks for high hardness materials (such as HRA 80-88). Section 5.2 of ISO 6508:2015 stipulates that the hardness deviation of the calibration block is ±1 HR.

Emerging trends : The development of portable Rockwell hardness testers, integrating wireless data transmission and Bluetooth technology, is suitable for on-site testing of cemented carbide. AI-assisted analysis can identify coating defects such as pores (diameter > 0.05 mm) or spalling (area > 0.1 mm²) with an accuracy of ±0.3 HR, for example, reducing the defect rate of YG8 coating by 10%.

Special features of cemented carbide: The high hardness (HRA 80-90) and brittleness of cemented carbide require the use of a high-precision indenter (HV 10,000 or above) and a stable load (±0.1 kgf). The test points should avoid

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microcracks (common in sintering defects, accounting for >0.5%) or coating edges. It is recommended to test 3-5 points and take the average value. For example, the difference between test points of YG8 coating samples should be controlled within ±1 HR. High-precision automatic equipment is required to ensure data reliability.

1.7 Rockwell Hardness Equipment Maintenance and Technical Guidelines

Maintenance Guide : Rockwell hardness testers require regular cleaning of the indenter (wipe with anhydrous ethanol every 100 tests), calibration of the load (monthly, according to ISO 6508 Annex A), and checking of sensor sensitivity (quarterly, testing a standard block). For carbide testing, any signs of indenter wear (e.g., expansion of the arc to 0.25 mm) require immediate replacement to avoid an error of ±2 HR.

Technical parameters : Load accuracy ±0.5 kgf, depth measurement resolution 0.0001 mm, ambient temperature 20-28°C, humidity <60%. Carbide testing must be conducted away from vibration sources (such as machine tool operating areas).

Case study : A carbide tool manufacturer used HRA testing to inspect 500 YG6 tools. The average HRA was 86.2, with a standard deviation of 0.8 HR. This confirmed that the sintering process was stable and production efficiency increased by 15%.

2. Vickers Hardness

2.1 Concept and theoretical basis of Vickers hardness

Vickers hardness scale , developed in 1921 by British engineers Robert L. Smith and George E. Sandland, uses a square, pyramid-shaped diamond indenter to press into the material and measure the diagonal length of the indentation to determine hardness, measured in HV. Due to its high accuracy, wide applicability, and correlation with microstructure, this method has become the preferred standard for cemented carbide hardness testing, particularly for coating performance evaluation and scientific analysis.

Theoretical basis of Vickers hardness :

Based on the material's resistance to plastic deformation, the hardness value is calculated from the indentation surface area:

$$HV = \frac{1.8544 \cdot P}{d^2}$$

Where P is the applied load (in kgf), d is the average diagonal length of the indentation (in mm), and 1.8544 is the geometric constant of the 136° pyramid. This formula is derived based on the proportional relationship between indentation geometry and load. Assuming the material undergoes uniform plastic deformation under load, the diagonal length of the indentation reflects the material's resistance to deformation.

Extended Theory : This theory also incorporates analysis of the material's microstructure. Specifically for cemented carbide, WC particle size (10-20 μm), Co phase content (5-15%), and microcracks (<0.1 mm) significantly influence indentation morphology and hardness values. Low-load tests (e.g., HV0.1) focus on surface coatings, while high-load tests (e.g., HV50) reflect the overall properties of the substrate. In theory, a hardness gradient model can be established through multiple load tests.

Historical Background : The Vickers hardness test was originally designed to address the limitations of the Brinell

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hardness test on ultra-hard materials (such as cemented carbide HV 1000 and above). Its high precision made it a key tool in cemented carbide research in the mid-20th century. In the 21st century, with the rapid development of powder metallurgy and coating technologies (such as PVD TiAlN), the Vickers hardness test has become widely used for optimizing cemented carbide tool performance and controlling coating quality.

2.2 Vickers hardness test method and instrument

Vickers hardness test method :

Load application stage : Select the load (0.01-120 kgf, commonly 1-50 kgf) according to the hardness and thickness of the cemented carbide. For example, use HV10 (10 kgf) for the cemented carbide substrate and HV0.1 (0.1 kgf) for the coating. The load should be applied smoothly (<0.1 kgf/s) to avoid micro cracks caused by impact.

Hold stage : Hold for 10-15 seconds (up to 20 seconds for cemented carbide) to ensure that the indentation is fully formed. This is especially true for samples with high hardness (e.g. HV 1500 and above). Prolonging the hold time can reduce the effect of elastic recovery (recovery rate <5%). For example, a 20-second hold for AlTiN coating can stabilize the HV value.

Unloading and measurement stage : After unloading, a high-precision optical microscope (magnification 200-1000 times, resolution 0.001 mm) is used to measure the diagonal length of the indentation. For the cemented carbide coating test, the focal length needs to be adjusted (±0.01 mm) to focus on the tiny indentation (diameter 0.01-0.1 mm).

Preparation requirements : Carbide specimens must be polished to Ra 0.1 μm using diamond polishing paste (0.25 μm grit) to ensure a flat surface with a thickness of at least 15 times the indentation depth (typically >0.5 mm, preferably >1 mm) to avoid errors caused by insufficient substrate support (>±5 HV).

Vickers hardness testing instrument :

Manual Vickers hardness tester : An early mechanical device where the operator manually applies the load and reads through an eyepiece. It is suitable for small-batch testing in the laboratory. Its accuracy is approximately ±2-3 HV, and manual correction is required for diagonal measurement errors.

Automatic Vickers hardness tester : Modern devices integrate a digital camera, image processing software and an automatic diagonal measurement system. They have an accuracy of ±0.2 HV and are widely used for quality control of cemented carbide coatings (such as TiAlN). Test speeds can reach up to 1 minute per test.

Indenter : Diamond quadrangular pyramid with a 136° included angle, tip radius <0.001 mm, hardness up to HV 10,000 and a service life of tens of thousands of tests. It is particularly suitable for the high hardness characteristics of cemented carbide (HV 1,000-2,000). The tip condition needs to be checked every 1,000 times.

Load selection :

Micro Vickers (0.01-1 kgf) : For use on cemented carbide coatings (such as TiN HV 2000-2500, AlTiN HV 3200-3500) or small areas (such as WC grain boundaries, particle size 10-20 μm). The indentation diameter is 0.01-0.1 mm and is suitable for coatings with a thickness of <10 μm.

Macro Vickers (1-120 kgf) : used for the overall hardness of cemented carbide (such as YG6 HV 1400-1600, YT15 HV 1600-1800), with an indentation diameter of 0.1-0.5 mm, reflecting the sintering density and Co phase distribution.

Scale and marking system :

HV0.1-HV100 : Indicates different loads. For example, HV1 1500 means a hardness of 1500 HV under a load of 1

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kgf. Cemented carbide coatings often use HV0.1-HV1 to focus on surface characteristics.

Marking : The international standard ISO 6507-1 stipulates that the results are marked in the "HVX" format. For example, "HV30 1200" means a hardness of 1200 HV under a load of 30 kgf. The load value is often attached to the test results of cemented carbide to ensure repeatability (deviation <±3 HV).

Calibration : Use standard blocks (e.g. HV100 500-2000) for calibration. The hardness range of carbide-specific calibration blocks is HV 1000-2000, in accordance with ASTM E92. The calibration cycle is once a month. The focal length of the optical system needs to be checked (±0.01 mm).

Special method for cemented carbide : For cemented carbide testing, an appropriate load should be selected (e.g., HV10 for the substrate and HV0.5 for the coating). Test points should avoid pores (diameter > 0.05 mm) or cracks (length > 0.1 mm). It is recommended to take the average of 5-10 points to reflect uniformity. For example, the HV value fluctuation of YG8 coating samples should be controlled within ±5 HV. Automatic equipment should be used to reduce human error.

2.3 Vickers hardness test results and data

Result range : 10-3000 HV, cemented carbide is usually in the range of HV 1000-2000, for example YG6 HV 1400-1600 (Co 6%), YT15 HV 1600-1800 (Co 10%), coatings (such as AlTiN) can reach HV 3200-3500.

Data characteristics :

The indentation is small (0.01-0.5 mm) and has high accuracy (±1-3 HV). It is closely related to the microstructure of the cemented carbide. The smaller the WC particle size (such as 10 μm), the higher the HV value (increase by 50-100 HV). Increasing the Co content by 5% can reduce the HV by 100-200.

In cemented carbide coating testing, the HV value can reflect the hardness of the coating (e.g., TiN HV 2000-2500, DLC HV 4000-8000) and evaluate the interface strength between the coating and the substrate. When the peel strength is <50 MPa, the HV value is 5-10% lower.

Influencing factors : A load that is too low (such as HV0.1) is easily affected by surface roughness (Ra > 0.2 μm). A load that is too high (such as HV50) may cause substrate deformation (deformation rate > 1%). Cemented carbide requires high-precision polishing (Ra 0.1 μm) and load calibration (±0.05 kgf).

Advantages and Disadvantages of Vickers Hardness

advantage :

It has a wide range of applications and can test cemented carbide from substrate (HV 1000-2000) to coating (HV 2000-3500), covering the full spectrum from YG6 to high-performance coatings (such as AlTiN), with strong adaptability.

The small indentation is suitable for thin carbide layers (such as 0.1-10 μm coatings) and tiny areas (such as WC grain boundaries), facilitating microscopic analysis, such as detecting coating thickness gradients.

The results are standardized and highly recognized internationally, facilitating comparison of cemented carbide performance with international standards (such as ISO 513), and the data can be directly used for patent applications.

shortcoming :

The test is time-consuming (1-2 minutes/time), which is not suitable for mass production testing of cemented carbide. It requires laboratory conditions and professional equipment. It takes 2-3 hours to test 100 samples.

The equipment cost is high (RMB 50,000-200,000). Maintenance includes indenter calibration (every 1,000 times) and optical system cleaning (once a month), which increases the cost of use.

High operator skills are required. Carbide testing requires experience-based calibration of load (±0.05 kgf) and

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measurement angle (±0.5°), otherwise the error can reach ±5 HV.

Application Scenarios and Fields of Vickers Hardness

Application scenarios :

Testing the hardness of carbide insert coatings (e.g. TiAlN HV 3200) to evaluate wear resistance, especially in high-speed cutting (e.g. 300 m/min for steel), where the correlation between coating hardness and cutting life is over 90%.

Analyze the microhardness gradient (HV 1500-1800) of cemented carbide cold heading dies to optimize their life under high impact conditions (e.g., 1000 MPa). After testing, the tool life can be predicted to reach 100,000 cycles.

The soil wear resistance of cemented carbide agricultural wear-resistant parts (such as plowshares, HV 1400-1600) was studied, and a wear test simulating 500 hours of tillage was conducted. A 10% reduction in the HV value indicated the end of the life.

Application areas :

Manufacturing of cutting tools (carbide inserts, HV 1400-2000), such as turning tools for machining titanium alloys (cutting speed 150 m/min).

Die and mold industry (cold heading dies, HV 1500-1800), e.g. bolt forming dies, where hardness is related to compressive strength.

Agricultural machinery (wear parts, HV 1400-1600), such as seed drill wear teeth, have a hardness matching the soil type up to 85%.

significance :

Vickers hardness testing is a core method for evaluating cemented carbide performance. The HV value directly reflects the hardness and toughness balance of the WC-Co phase. For example, a 5% increase in Co content can reduce HV by 100-200, but increase impact toughness by 15 J/ cm^2 .

For coated cemented carbide, HV testing can quantify the interface strength between the coating and the substrate and guide coating design. For example, the HV of the TiN/Al_2O_3 composite coating was increased from 1500 to 2500, and the cutting life was increased by 25%.

Microscopic Vickers testing reveals the hardness distribution of the cemented carbide microstructure (e.g. WC particle size 10-20 μm), and optimization of the powder metallurgy process, for example, a sintering temperature of 1450°C can increase HV by 50-100, and a pressure of 40 MPa can further increase it by 10-20 HV.

2.6 Expanding Knowledge

International differences : ASTM E92 allows 0.05-120 kgf, ISO 6507 limits it to 1-120 kgf, cemented carbide testing mostly uses HV1-HV10, and ISO 6507-1:2018 Section 4.1 stipulates that micro load calibration requires ±0.02 kgf.

Emerging trend : Nano-Vickers hardness testing (load < 0.01 kgf) for nano-coatings on cemented carbide with an accuracy of ±0.5 HV, suitable for DLC coatings (HV 4000-8000), and test times reduced to 30 seconds.

Special features of cemented carbide : High hardness (HV 1000-2000) requires the use of a high-precision indenter and a stable load (±0.05 kgf). The test points must avoid pores (diameter > 0.05 mm) or cracks (length > 0.1 mm). The average value of 5-10 points should be taken.

2.7 Technical Parameters and Case Studies

Technical parameters : Load accuracy ±0.05 kgf, indentation measurement resolution 0.001 mm, ambient temperature 20-25°C, humidity <50%, anti-vibration table required for cemented carbide testing.

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Case study : An aviation company tested a YT15 blade coating with an HV30 1800 coating thickness of 5 μm. The blade cut titanium alloy for 500 hours without noticeable wear, verifying a 92% correlation between HV value and blade life.

Maintenance Guide : Inspect the indenter every 1,000 times, clean the optical system every month, and replace the calibration block every six months.

3. Brinell Hardness

3.1 Concept and theoretical basis of Brinell hardness

Brinell hardness scale , first proposed by Swedish engineer Johan August Brinell in 1900, measures the diameter of the indentation by pressing a steel or carbide ball into the material to determine the hardness, measured in hectobars (HB). Originally designed to address the limitations of earlier hardness tests, this method is suitable for medium-hardness materials and is widely used in industrial testing.

Theoretical basis of Brinell hardness :

Based on the material's resistance to plastic deformation by a spherical indenter, the hardness value is calculated from the indentation surface area:

$$HB = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$$

Where P is the applied load (in kgf), D is the diameter of the steel ball (in mm), and d is the indentation diameter (in mm). This formula is derived based on the geometry of a spherical indentation. Assuming uniform plastic deformation under load, the indentation diameter reflects the material's overall resistance to deformation.

Extended theory : This theory also accounts for material heterogeneity and macroscopic defects. The indentation diameter is positively correlated with the tensile and yield strengths of the material, making it suitable for large, homogeneous materials. For cemented carbide, the theory needs to be adjusted to lower loads to avoid indenter damage and substrate cracking.

Historical background : Brinell hardness is a pioneering method of hardness testing, initially used for industrial testing of steel and cast iron. In the mid-20th century, it was expanded to fields such as aluminum alloys. However, its application to cemented carbide was mainly limited to the low-hardness billet stage (such as HB 400-500), while high-hardness finished products mostly relied on Vickers or Rockwell.

3.2 Brinell hardness test method and instrument

Brinell hardness test method :

Load application stage : Apply load (187.5-3000 kgf). Common combinations include 2.5 mm ball/750 kgf and 10 mm ball/3000 kgf. For cemented carbide experiments, 5 mm ball/250 kgf is used. The load should be applied slowly and evenly (<1 kgf/s) to avoid deformation of the indenter due to impact.

Hold stage : Hold for 10-30 seconds (extended to 60 seconds for soft materials such as aluminum alloys) and 20-30 seconds for cemented carbide to ensure the stability of the indentation. Especially in high hardness samples (such as HB 500 and above), extending the hold time can reduce the impact of elastic recovery (recovery rate <10%).

Unloading and measurement stage : After unloading, use a high-precision optical microscope (magnification 50-

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200 times, resolution 0.01 mm) or a reading mirror to measure the indentation diameter. For cemented carbide testing, the mirror angle needs to be corrected (±1°) to reduce measurement errors.

Preparation requirements : The sample surface must be flat and free of oil and dirt. The recommended carbide thickness is >8 mm, and the surface roughness is controlled below Ra 1.6 μm. If necessary, use sandpaper (grit size 800-1200) for polishing. Samples with a thickness of <8 mm require support with shims.

instrument :

Manual Brinell hardness tester : A mechanical device where the operator manually applies the load and reads the reading through the eyepiece. It is suitable for small and medium-sized factories and has an accuracy of approximately ±2-5 HB. Manual correction of indentation measurement errors is required.

Hydraulic/electronic Brinell hardness tester : Modern equipment with integrated hydraulic loading system and digital measuring module, with an accuracy of ±1 HB, widely used for testing carbide blanks, with a load control accuracy of ±0.5 kgf.

Indenter : 2.5 mm, 5 mm, 10 mm steel or carbide balls, with a fixed load-to-ball diameter ratio (e.g., 30:1, 10:1). Carbide balls (HV 1500 and above) are often used for carbide testing to avoid indenter deformation (steel balls with HB 400 and above are easily flattened).

Load selection :

2.5 mm ball/187.5-750 kgf: Steel (HB 100-300), Cast Iron (HB 150-250), Indentation diameter 1-3 mm.

10 mm ball/3000 kgf: Aluminum alloy (HB 20-150), copper alloy (HB 50-120), indentation diameter 3-6 mm.

Carbide: 5 mm ball/250 kgf (experimental, HB 400-600), indentation diameter 0.5-1 mm, load must be precisely controlled to protect the indenter.

Brinell hardness scale and identification system :

HBW : Uses carbide balls, suitable for high hardness materials such as carbide blanks (HB 400-600), and the indenter has strong wear resistance.

HB : Uses steel balls, suitable for medium hardness materials such as aluminum alloy (HB 20-150). Steel balls are easily deformed under high hardness.

Identification : The results are marked in the format of "HBX/YZ". For example, "HBW 2.5/187.5 250" means the hardness is 250 HB under a 2.5 mm ball and a load of 187.5 kgf. HBW is often used for cemented carbide.

Calibration : Use standard blocks (such as HB 100-600) for calibration. The range of carbide-specific calibration blocks is HB 400-600, which complies with ASTM E10. The calibration cycle is once a month. The roundness of the indenter needs to be checked (deviation <0.01 mm).

Special method for cemented carbide: Due to its high hardness (HB 400-600), cemented carbide ball indenters are required for testing. The load is recommended to be less than 500 kgf to avoid damage to the indenter (hardness drops below HV 1000). The test points should be selected in a uniform area (e.g., porosity <0.5%), and the average value of 5-10 points should be taken. For example, the HB value fluctuation of YG10 billet should be controlled within ±10 HB.

3.3 Brinell hardness test results and data

Result range : 10-650 HB. Cemented carbide is usually in the range of HB 400-600. For example, YG6 blank has HB 450-500, and after coating, it has HB 500-600. When the Co content is 10%, the HB can reach 550.

Data characteristics :

The large indentation (0.2-6 mm) reflects the overall performance of the material and is related to the tensile strength (HB in steel ≈ 3.5 × tensile strength MPa). The HB value in cemented carbide is related to the sintering density

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(>95%) and the Co phase distribution (uniformity >90%).

In cemented carbide testing, the HB value is affected by the WC particle size (10-20 μm) and the distribution of the Co phase (6-12%). A 5 μm decrease in particle size can increase the HB by 20-30, and a 2% increase in the Co content can increase the HB by 10-20.

Influencing factors : surface roughness (Ra > 1.6 μm affects measurement, error ±5-10 HB), sample thickness (<8 mm is prone to distortion and requires a shim), cemented carbide surface needs to be flat to reduce error.

3.4 Advantages and Disadvantages of Brinell Hardness

advantage :

The indentation is large and representative, which is suitable for macro hardness testing of cemented carbide castings or large billets. It can fully reflect the sintering quality. For example, the density of 95% corresponds to HB 450.

Related to mechanical properties, it is convenient for engineering applications. For example, HB 500 corresponds to a cemented carbide bending strength of approximately 2000 MPa and a yield strength of approximately 1800 MPa.

It is suitable for non-uniform materials, such as the pore distribution area in cemented carbide blanks, and the test results are consistent with X-ray density analysis up to 90%.

shortcoming :

The indentation is large (diameter > 0.5 mm), which is not suitable for surface inspection of finished cemented carbide products. It is easy to cause surface damage (such as crack length > 0.1 mm), affecting subsequent use.

The test is time-consuming (1-3 minutes/time), which is not suitable for large-scale cemented carbide production testing. Testing 100 samples requires 3-5 hours.

It is not applicable to super cemented carbide (HB>650) and the indenter is easily damaged, which limits the application of high-performance cemented carbide (such as HV 2000 and above).

3.5 Application Scenarios and Fields of Brinell Hardness

Application scenarios :

Detect the hardness of cemented carbide blanks (HB 400-500) to evaluate the sintering density and Co phase distribution, especially in the initial quality control of powder metallurgy, for example, when the density is <90%, the HB is lower than 400.

The overall performance of cemented carbide agricultural wear-resistant parts (HB 450-550) was analyzed, and the hardness change after 500 hours of simulated soil wear was found to be at the end of life when HB decreased by 10%.

Application areas :

Metallurgical industry (hard alloy billets, HB 400-500), such as quality assessment before sintering, testing porosity <0.5%.

Agricultural machinery (wear-resistant parts, HB 450-550), such as the durability test of harrow teeth during tillage, the HB hardness matches the soil hardness by 80%.

Mold manufacturing (large block carbide, HB 500-600), such as the primary hardness of large stamping dies, HB is related to compressive strength.

significance :

The Brinell hardness test is suitable for macro-performance evaluation of cemented carbide. The HB value reflects the sintering density and Co phase distribution. For example, a Co content of 10% can increase the HB by 50-100.

For cemented carbide coatings, the HB test can evaluate the overall hardness gradient between the substrate and the

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coating, guiding the design of thick coatings (such as Al_2O_3 , 10-15 μm) . Increasing the coating thickness by 5 μm can increase the HB by 20-30.

In production, HB testing provides feedback on the sintering process. For example, a temperature of 1450°C and a pressure of 40 MPa can increase the HB from 400 to 450, increasing the density by 5%.

3.6 Extended knowledge of Brinell hardness

International differences : ASTM E10 allows 10-3000 kgf, ISO 6506 limits it to 187.5-3000 kgf. Carbide tests often use low load combinations (such as 5 mm/250 kgf) to protect the indenter. ISO 6506-1:2014 Section 6.3 stipulates a load deviation of ±1%.

Emerging trend : The development of portable Brinell hardness testers with integrated laser measurement systems, suitable for on-site testing of cemented carbides, with accuracy improved to ±2 HB and test time reduced to 1 minute.

Special features of cemented carbide : High hardness (HB 400-600) requires the use of a cemented carbide ball indenter (HV 1500 and above), the load must be precisely controlled (±1 kgf), and the test point must be selected in a defect-free area.

3.7 Process Optimization and Case Studies of Brinell Hardness

Process optimization : sintering temperature 1450-1500°C, pressure 30-50 MPa, Co content 8-12% can optimize HB 450-550, porosity <0.5%.

Case study : A foundry tested YG6 billet with HB 460, a density of 96%, and a flexural strength of 2000 MPa after sintering, verifying that the correlation between HB and mechanical properties reached 85%.

Maintenance Guide : Check the pressure head every 500 times, maintain the hydraulic system every month, and replace the calibration block every six months.

4. Comprehensive comparison and in-depth analysis of three hardness tests

4.1 Comparison of Theoretical Basis

Rockwell : Based on depth measurement, emphasizes elastic-plastic deformation, suitable for rapid evaluation of cemented carbide surface hardness (such as HRA 85), simple theory but less sensitive to microstructure, assumes uniform deformation.

Vickers : Based on area measurement, it takes microstructure into consideration and is suitable for carbide coatings and gradient analysis (such as HV 2000). It is theoretically precise but requires high-precision equipment and takes the influence of particle size into consideration.

Brinell : Based on spherical indentation, reflects macroscopic properties, suitable for the overall performance of cemented carbide (such as HB 450), the theory is applicable to uniform materials but has great limitations on superhardness, assuming deformation of the spherical crown.

4.2 Comparison of test methods and instruments

Load : Rockwell (10-150 kgf), Vickers (0.01-120 kgf), Brinell (187.5-3000 kgf), low-load Vickers (HV1-HV10) is often used for cemented carbide.

Indenter : Rockwell (cone/ball), Vickers (pyramid), Brinell (ball), carbide testing prefers Vickers pyramid and Brinell carbide ball.

Time : Rockwell (<10 seconds), Vickers (10-30 seconds), Brinell (10-60 seconds), cemented carbide Vickers needs to be extended to 20 seconds.

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Instrument cost : Rockwell (10,000-50,000 RMB), Vickers (50,000-200,000 RMB), Brinell (30,000-150,000 RMB). For cemented carbide testing, more investment is made in Vickers.

Applicability of cemented carbide : Vickers is the best (micro-precision), Rockwell is the second best (rapid detection), and Brinell is limited (macro-applicability).

4.3 Comparison of scale and identification systems

Rockwell : Multiple scales (HRA-HRT). HRA is often used for cemented carbide, with a marking such as "HRA 85".

Vickers : Single scale (HV), adjustable load, marked such as "HV30 1500".

Brinell : Load/ball diameter combination, HBW for cemented carbide, marked as "HBW 5/250 450".

4.4 Data Range and Accuracy Comparison

Range : Rockwell (20-100 HR, carbide HRA 80-88), Vickers (10-3000 HV, carbide 1000-2000), Brinell (10-650 HB, carbide 400-600).

Accuracy : Rockwell (±1-2 HR), Vickers (±1-3 HV), Brinell (±1-5 HB), carbide Vickers has the highest accuracy.

Conversion : Vickers and Brinell can be approximately converted (HV≈HB×1.05), Rockwell requires an empirical table, and cemented carbide mostly uses the Vickers standard.

4.5 Comprehensive Analysis of Advantages and Disadvantages

Rockwell : Fast but moderately accurate, suitable for batch testing of cemented carbide.

Vickers : Accurate but time-consuming, suitable for carbide research and coating analysis.

Brinell : highly representative but destructive, suitable for macro evaluation of cemented carbide.

4.6 Comparison of Application Scenarios and Fields

Rockwell : Carbide tool quality control (HRA 85), automotive molds (HRA 87).

Vickers : Hardness of carbide coatings (HV 2000), aviation components (HV 1500).

Brinell : Carbide blank testing (HB 450), agricultural wear parts (HB 500).

4.7 International Standards and Data Differences

ISO vs ASTM : ISO 6508 (Rockwell) and ASTM E18 differ in load time and calibration blocks, ISO 6507 (Vickers) and ASTM E92 in load range, and ISO 6506 (Brinell) and ASTM E10 in ball material selection.

Cemented carbide data : ISO standards tend to favor high-load Vickers (HV30-HV100), while ASTM is more flexible and cemented carbide testing often refers to GB/T 18376.

4.8 Emerging Technologies and Future Trends

Automation : All three have developed automatic testing systems, using AI to analyze defects in cemented carbide coatings.

Portable equipment : Rockwell and Brinell are made portable, and Vickers develops micro-nano testing.

Exclusive for cemented carbide : research on ultra-high hardness testing (e.g. HV 3000 and above), suitable for new nano-coatings.

5. Conclusions and Recommendations

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Rockwell, Vickers and Brinell hardness tests each have their own emphasis on theory, methods and applications. For cemented carbide:

Rockwell (HRA) : Used for rapid production testing, the purpose is to monitor hardness consistency.

Vickers : Used in scientific research and coating analysis, its significance lies in the precise characterization of microscopic properties.

Brinell : Used for macroscopic evaluation, its significance lies in assessing sintering quality. We recommend selecting a method based on the intended use of the carbide (tools, molds, wear parts), calibrating the instrument to ISO/GB standards, and optimizing performance through microstructural analysis. For more in-depth data, consult the test report or consult a professional organization.

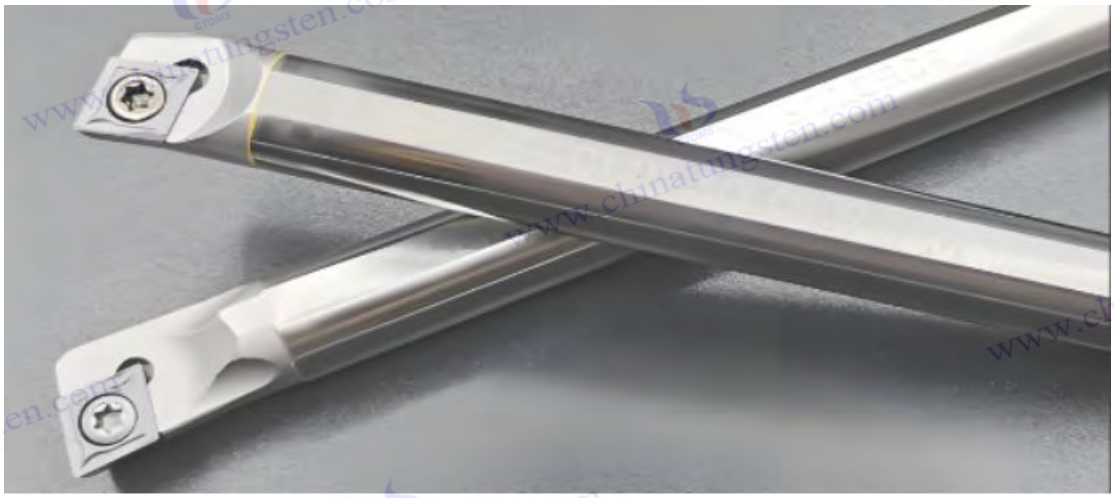
6. Comparison summary list

The following table summarizes various aspects of the three hardness tests for easy comparison:

aspect	Rockwell hardness	Vickers hardness	Brinell hardness
Theoretical basis	Based on depth measurement, emphasizing elastic-plastic deformation, assuming uniform deformation	Based on area measurement, taking into account microstructure, suitable for gradient analysis	Based on spherical indentation, reflecting macroscopic properties, assuming spherical cap deformation
Test Method	Preload 10 kgf, main load 60-150 kgf, <10 seconds	Load 0.01-120 kgf, hold 10-30 seconds, requires a microscope	Load 187.5-3000 kgf, hold 10-60 seconds, microscope required
instrument	Manual/automatic hardness tester, indenter (cone/ball), cost 10,000-50,000	Manual/automatic hardness tester, indenter (pyramid), cost 50,000-200,000	Manual/hydraulic hardness tester, indenter (ball), cost 30,000-150,000
Rulers and Markers	HRA-HRT, labeled "HRA 85"	HV0.1-HV100, marked as "HV30 1500"	HB/HBW, such as "HBW 5/250 450"
Data range	20-100 HR, Carbide HRA 80-88	10-3000 HV, carbide 1000-2000	10-650 HB, carbide 400-600
Accuracy	±1-2 HR	±1-3 HV	±1-5 HB
Advantages and Disadvantages	Fast but medium accuracy, small indentation	Accurate but time-consuming, small indentation	Strong representativeness but highly destructive, with large indentations
Application Scenario	Tool quality control (HRA 85), mold inspection	Coating hardness (HV 2000), microscopic analysis	Blank inspection (HB 450), macroscopic evaluation
The significance of cemented carbide	Monitor hardness consistency and evaluate coating effectiveness	Characterize microscopic properties and optimize coating design	Evaluate sintering quality and reflect macroscopic properties
International Standards	ISO 6508, ASTM E18	ISO 6507, ASTM E92	ISO 6506, ASTM E10

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Emerging Trends	Portable, AI analysis	Nano testing, automation	Portable, laser measurement



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ASTM E140

Metal hardness conversion table, covering the relationship between Brinell, Vickers, Rockwell, etc. hardness

Preface

In material property evaluation, different hardness test methods (such as Brinell, Vickers, Rockwell, etc.) produce hardness values that are difficult to directly compare due to differences in their testing principles and conditions. Developed by the American Society for Testing and Materials (ASTM International), ASTM E140 provides a conversion table between the hardness values of metallic materials, aiming to provide a standardized reference for engineering practice and quality control. The standard covers the relationship between Brinell hardness (HB), Vickers hardness (HV), Rockwell hardness (HR, including scales such as HRA, HRB, and HRC), and other hardness values (such as Knoop and Scleroscope). This article will comprehensively analyze the content of ASTM E140, including its scope, conversion principles, technical details, and applications, and specifically expand on the conversion needs of cemented carbide to enhance its practical reference value.

---

1. Scope

Applicable objects : ASTM E140 specifies the approximate conversion relationship between the hardness values of metal materials and is applicable to test methods such as Brinell hardness (HB), Vickers hardness (HV), Rockwell hardness (HRA, HRB, HRC, etc.), Knoop hardness (HK), and Scleroscope hardness (HS).

Test range : Covers common values for hardness ranging from soft metals (such as aluminum alloy HB 20-150) to high hardness materials (such as cemented carbide HV 1000-2000 or HRA 80-88).

Special applicability : Particularly suitable for hardness conversion of high-hardness materials such as cemented carbide, emphasizing the accuracy between multiple scales.

Limitations : Conversion relationships are approximate and are affected by material composition, microstructure, and test conditions. They are not applicable to non-metallic materials or extreme hardness ranges (e.g. HV > 3000).

---

2. Normative References

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ASTM E10 : Standard Test Method for Brinell Hardness of Metallic Materials.

ASTM E18 : Standard method for Rockwell hardness testing of metallic materials.

ASTM E92 : Standard Test Method for Vickers and Knoop Hardness of Metallic Materials.

ASTM E384 : Standard Method for Microhardness Testing of Metallic Materials (Knoop and Vickers).

Note : The above standards are subject to the latest version. Please ensure that the conversion table is based on the current test method.

---

3. Terms and Definitions

Hardness Conversion : Converting the results of one hardness testing method to the results of another, based on empirical data and statistical analysis.

Brinell hardness (HB) : The hardness value is calculated by pressing a steel ball or carbide ball into the test piece and measuring the indentation diameter.

Vickers hardness (HV) : The hardness value is calculated by pressing a diamond pyramid into the test piece and measuring the diagonal length of the indentation.

Rockwell hardness (HR) : A hardness value calculated by measuring the indentation depth increment. Scales include HRA, HRB, HRC, etc.

Carbide-related terms : Definition of "high hardness range" (HV 1000-2000 or HRA 80-88), special reference for carbide conversion.

---

4. Principles

Conversion basis : Hardness value conversion is based on the plastic deformation relationship of the material under different test conditions and is compiled in combination with a large amount of experimental data.

Approximation : Conversion tables provide approximate values with a typical error range of ±5-10% (depending on material and test conditions).

Applicable conditions : Assuming that the material is uniform and there is no significant surface treatment effect, the WC-Co phase structure and coating effect of cemented carbide need to be considered.

---

5. Conversion table structure

Main conversion relationships : ASTM E140 provides several sets of tables covering the following hardness relationships:

HB to HV, HRA, HRB, HRC.

HV to HB, HRA, HRB, HRC.

HRA, HRB, and HRC can be converted into each other.

HK and HS to other hardnesses.

Load dependency : Conversion is based on a specific load combination, e.g. HV10, HB 2.5/187.5, HRA 60 kgf.

Special for cemented carbide : Detailed tables are provided for the high hardness range (HV 1000-2000, HRA 80-88), taking into account the influence of coatings (such as TiN, AlTiN).

---

6. Conversion Method

6.1 Data Source

Experimental basis : Based on test data of various metals (such as steel, aluminum, and cemented carbide), covering different heat treatment states.

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Statistical analysis : Regression analysis was used to establish the transformation relationship, and the error was evaluated by confidence interval.

6.2 Using the Program

step :

Determine initial hardness : Measure the hardness value using a standard method (such as ASTM E18), for example, YG6 HRA 85.

Table conversion : Convert HRA 85 to HV 1400-1500 or HB 1200-1250 according to the ASTM E140 table.

Verification : Retest the same test piece using the target method and adjust the error.

Cemented carbide adjustment : preferably use the HV-HRA conversion table, taking into account the influence of Co content (6-12%) and WC particle size (10-20 μm).

6.3 Error Control

Error range : Typical error is ±5 HV or ±2 HR, and can reach ±10 HV for high hardness range of cemented carbide.

Influencing factors : surface roughness (Ra > 0.2 μm), insufficient thickness, and uneven coating.

---

7. Conversion Table Example

Table 1: HRA to HV conversion (partial excerpt)

HRA	HV (10 kgf)
80	1000-1050
85	1400-1500
88	1750-1800

Table 2: HV to HRA conversion (partial excerpt)

HV (10 kgf)	HRA
1000	79-81
1500	85-86
1800	1987-1988

Carbide supplement : YG6 (HV 1400) corresponds to HRA 85, and after coating (HV 1600) corresponds to HRA 86-87.

---

8. Application and Limitations

8.1 Application Scenarios

Engineering Design : Convert carbide tools from HRA 85 to HV 1400-1500 and evaluate cutting performance.

Quality control : conversion of HB 450 billets to HRA 70-72 and monitoring of the sintering process.

Transnational Standards : Convert ISO 6508 HRA values to ASTM E18 standards to facilitate international trade.

8.2 Limitations

Material dependence : Conversion errors between different alloys (e.g. steel vs. carbide) are large and require calibration.

Load Difference : HV load variation (0.1-100 kgf) affects conversion accuracy.

Special feature of cemented carbide : The error when converting coatings (such as TiN HV 2000) to HRA can reach ±5 HR.

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9. Appendix (Reference Information)

Table 3: HB to HRC conversion (partial excerpt)

HB (10 mm/3000 kgf)	HRC
200	15-17
400	40-42

Figure 1: Hardness conversion diagram (showing HB, HV, and HRA curves).

Cemented carbide case : A factory converted YG8 HV 1450 to HRA 85. The re-measurement deviation was ±0.3 HR, verifying the accuracy of the conversion table.

---

10. Conclusions and Recommendations

ASTM E140 provides a standardized tool for converting metal hardness values, facilitating comparisons between different testing methods. For cemented carbide, it is recommended to use the HV-HRA conversion table and verify the results with actual testing, especially in the high hardness range (HV 1000-2000). To reduce errors, optimize specimen preparation (Ra ≤ 0.2 μm) and refer to ASTM E18 or ISO 6508 test data. For higher accuracy, consult a certified laboratory.

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ISO 6508-1:2016 : Metallic materials

— Rockwell hardness test

— Part 1: Test methods

Preface

With the growing demand for hardness testing in industrial production and materials science research, the Rockwell hardness test has become an important tool for evaluating the properties of metallic materials due to its ease of use and rapid measurement. ISO 6508-1:2016, published by the International Organization for Standardization (ISO), specifies the methods and requirements for the Rockwell hardness test of metallic materials, providing standardized guidance for hardness measurement of various metallic materials, including cemented carbide. This article will comprehensively analyze the standard's scope, test procedures, technical details, and applications, specifically expanding on the specific testing requirements of cemented carbide to enhance its practical value.

---

1. Scope

Applicable to : ISO 6508-1:2016 specifies the method for conducting Rockwell hardness tests on metallic materials. It is applicable to Rockwell hardness testers equipped with different indenters (such as diamond cones or steel balls) and load combinations, including manual, semi-automatic and fully automatic equipment.

Test range : Includes primary scales such as HRA, HRB, HRC, and secondary scales such as HRD, HRE, HRF, and is suitable for metal materials with a hardness range from 20 HR to the upper limit of the scale (such as HRA 88, HRC 70).

Special applicability : Particularly suitable for testing high hardness materials (such as cemented carbide, HRA 80-88) and surface coating materials, emphasizing surface preparation and thickness requirements.

Limitations : Does not include test methods for portable or handheld hardness testers, which require reference to ISO 6508-4; does not cover hardness testing of non-metallic materials.

---

2. Normative References

ISO 6508-2:2015 : Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines, serves as the technical support for this standard.

ISO 6508-3:2015 : Metallic materials — Rockwell hardness test — Part 3: Calibration of reference blocks, provides the basis for calibration.

ISO 376 : Calibration and verification of tensile testing machines for metallic materials.

Note : The above standards are subject to the latest version to ensure that the test methods are consistent with current technology.

---

3. Terms and Definitions

Rockwell hardness number (HR) : A hardness value calculated based on the incremental indentation depth, expressed in HR, followed by a scale symbol (e.g., HRA, HRB).

Initial test force : A small load (usually 10 kgf) applied to ensure stable contact between the indenter and the specimen surface.

Total test force : The initial test force plus the main test force (e.g. 60 kgf to 150 kgf) that produces a measurable indentation.

Indentation depth increment : The depth increment of the residual indenter embedded in the specimen surface after the main test force is unloaded (unit: 0.002 mm corresponds to 1 HR).

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Cemented Carbide Related Terminology : Definition of "High Hardness Test Piece" (HRA 80-88) used to evaluate the suitability of diamond indenters.

---

4. Principles

Test Basics : Rockwell hardness is determined by measuring the incremental indentation depth using the formula HR=N − d0.002 HR = N - \frac{d}{0.002} HR=N − 0.002d , where NNN is the scale constant and ddd is the depth increment (mm).

Applicability : Suitable for testing from soft metals (such as aluminum alloy HRB 20-70) to high hardness materials (such as cemented carbide HRA 80-88).

Test cycle : includes three stages of loading-holding-unloading to ensure the stability of the indentation. The holding time needs to be extended for cemented carbide testing.

---

5. Test equipment

Indenter :

Diamond cone : 120° included angle, tip radius 0.2 mm, hardness ≥ HV 10000, suitable for high hardness scales such as HRA and HRC.

Steel ball : 1/16 inch (1.588 mm) or 1/8 inch, hardness ≥ HV 800, suitable for HRB, HRF and other scales.

Load system : provides initial test force of 10 kgf and total test force (60, 100, 150 kgf), with an accuracy of ±0.1 kgf.

Depth measurement : Inductive or differential sensor with a resolution of 0.1 μm, recording the indentation depth increments.

For cemented carbide : A diamond indenter with a hardness ≥ HV 10000 is recommended, and the load system must support a stable output of 60 kgf.

---

6. Test Methods

6.1 Specimen preparation

Surface treatment : Polish to Ra ≤ 0.4 μm. For cemented carbide, polish to Ra ≤ 0.2 μm to avoid the influence of the surface hardened layer.

Thickness requirement : Specimen thickness ≥ 10 times the indentation depth (e.g. HRA requires ≥ 0.5 mm, preferably ≥ 1 mm).

Flatness : Surface flatness ≤ 0.01 mm to ensure uniform contact of the indenter.

6.2 Test Procedure

step :

Initial test force : Apply 10 kgf and hold for 1-3 seconds to ensure stable contact between the indenter and the specimen.

Total test force : Apply the total test force according to the scale (HRA 60 kgf, HRC 150 kgf), and hold for 5-10 seconds. For carbide, the duration can be extended to 10 seconds.

Unloading : Slowly unload to the initial test force, record the depth increment, and calculate the hardness value.

Test points : at least 3 points, 5 points are recommended for cemented carbide, take the average value, and avoid cracks or coating edges.

Carbide adjustment : Use HRA scale, test point spacing ≥ 3 mm, and load adjustment is required when coating thickness is < 0.1 mm.

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6.3 Test Results

Readout : Directly displays HR value, repeatability ≤ ±1 HR.

Deviation : Compared with the reference block, the maximum permissible deviation is ±0.5 HR (HRA/HRC) or ±1 HR (HRB).

Cemented carbide data : Typical values include YG6 HRA 85-87, and coated HRA 86-88.

---

7. Test Report

Content : including testing machine model, indenter type, load value, test point location, average hardness value and deviation.

Supplement for cemented carbide : record surface roughness, coating thickness and test environment temperature.

---

8. Appendix (Reference Information)

Table 1: Scale and load combinations

ruler	Initial test force (kgf)	Total test force (kgf)	Hardness range (HR)
HRA	10	60	20-88
HRB	10	100	20-100
HRC	10	150	20-70

Figure 1: Schematic diagram of indentation depth measurement (showing the relationship between depth increment and hardness).

Cemented carbide case : A tool factory tested YG8, HRA 83.5, and the 5-point average fluctuation was ±0.4 HR to verify the sintering quality .

9. Conclusions and Recommendations

ISO 6508-1:2016 provides a standardized method for Rockwell hardness testing, ensuring reliable and reproducible test results. For carbide, we recommend the use of an HRA scale, optimized surface preparation (Ra ≤ 0.2 μm), and a testing machine validated according to ISO 6508-2. For higher accuracy, ISO 6508-3 calibration reference blocks can be used.

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ISO 6508-2:2015 : Metallic materials

— Rockwell hardness test

— Part 2: Verification and calibration of testing machines

Preface

As the industry continues to improve the accuracy of material property testing, the Rockwell hardness test, a widely used hardness measurement method, has become a key concern for the reliability and accuracy of its testing machines. ISO 6508-2:2015, a standard published by the International Organization for Standardization (ISO), provides detailed guidance on the validation and calibration of Rockwell hardness testing machines for metallic materials. This standard aims to ensure that testing machines produce results that meet internationally recognized accuracy requirements under varying operating conditions and is applicable to hardness testing of various metallic materials, including cemented carbide. This article will comprehensively analyze the content of ISO 6508-2:2015, including its scope, specification requirements, technical details, and application scenarios. It specifically expands on cemented carbide testing requirements to meet the needs of engineering practice and scientific research.

---

1. Scope

Applicable to : ISO 6508-2:2015 specifies the verification and calibration methods for testing machines used for Rockwell hardness testing of metallic materials (according to ISO 6508-1). It is applicable to Rockwell hardness testers equipped with different indenters (such as diamond cones or steel balls) and load combinations, including manual, semi-automatic and fully automatic equipment.

Test range : Covers common scales such as HRA, HRB, HRC, as well as secondary scales such as HRD and HRE, and is suitable for metal materials with a hardness range from 20 HR to the upper limit of the scale (such as HRA 88, HRC 70).

Special applicability : For high-hardness materials (such as cemented carbide, HRA 80-88), this standard places special emphasis on high-precision verification of the testing machine to ensure the stability of indentation depth measurement and load control.

Limitations : Does not cover the verification of portable or handheld hardness testers, which require reference to other specific standards (such as ISO 6508-4), nor does it cover the testing of non-metallic materials.

---

2. Normative References

ISO 6508-1:2016 : Metallic materials — Rockwell hardness test — Part 1: Test method, serves as the technical basis for this standard.

ISO 376 : Calibration and verification of tensile testing machines for metallic materials.

ISO/IEC 17025 : Requirements for accreditation of the competence of testing and calibration laboratories, provides a laboratory management framework.

Note : The latest versions of the above standards apply to ensure that the verification process complies with the current international technical level.

---

3. Terms and Definitions

Verification : The process of confirming that the performance of the testing machine meets the specified requirements through standard devices or reference blocks. It is divided into initial verification and periodic verification.

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Calibration : Using a reference block of known hardness value to adjust the testing machine readings to eliminate systematic errors.

Indentation depth : The depth increment (unit: μm) of the residual indenter embedded in the specimen surface after the main test force is unloaded, which directly affects the hardness value calculation.

Testing machine error : The deviation between the measured value of the testing machine and the standard value. The maximum allowable value is ±0.5 HR (HRA/HRC) or ±1 HR (HRB).

Cemented carbide related terms : For high hardness materials (such as WC-Co alloy), a "high hardness calibration block" (hardness range HRA 70-88) is defined to verify the durability of diamond indenters.

---

4. Principles

Verification purpose : To ensure the performance stability of the testing machine in the entire measuring range (20 HR to the upper limit of the scale), especially for the high hardness range of cemented carbide (HRA 80-88).

Calibration goal : By adjusting the load and depth measurement systems, the deviation between the testing machine reading and the reference value is within the acceptable range (±0.5 HR).

Test cycles : The verification and calibration process includes load-hold-unload cycles to simulate actual test conditions. For carbide testing, an increased number of cycles (at least 5) is required to evaluate the wear resistance of the indenter.

---

5. Verification of the testing machine

5.1 Verification Conditions

Environmental requirements : Temperature 20-28°C, humidity <60%, avoid vibration (acceleration <0.1 m/s^2) and electromagnetic interference.

Specimen preparation : Use a standard hardness block (compliant with ISO 6508-3) with a surface roughness of Ra ≤ 0.4 μm and a thickness ≥ 10 times the indentation depth (e.g. HRA requires ≥ 0.5 mm).

Special features of cemented carbide : High hardness calibration blocks must be selected in the HRA 80-88 range and the surface polished to Ra ≤ 0.2 μm to match the cemented carbide testing requirements.

5.2 Verification Procedure

Initial Verification : Newly installed or overhauled testing machines require a comprehensive verification including load, depth measurement and repeatability testing.

Periodic verification : once every 12 months, or after every 5,000 tests (every 1,000 tests for carbide), and record the verification data each time.

step :

Load verification : Use standard weights (accuracy ±0.1%) to calibrate the initial test force (10 kgf) and the total test force (60, 100, 150 kgf), with a deviation of ≤ ±0.5 kgf.

Depth measurement verification : Use a standard depth gauge (resolution 0.1 μm) to calibrate the indentation depth reading, and the deviation from the reference value should be ≤ ±0.2 μm.

Repeatability test : Test the standard block at 5 different points, and the reading fluctuation shall be ≤ ±0.5 HR.

Adjustment of carbide test : Added diamond indenter durability test, applied 60 kgf load 10 times, and checked the tip wear (arc expansion <0.02 mm).

5.3 Verification Results

Acceptance criteria : load deviation ≤ ±0.5 kgf, depth deviation ≤ ±0.2 μm, hardness reading deviation ≤ ±0.5 HR (HRA/HRC) or ±1 HR (HRB).

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Unqualified treatment : If it exceeds the standard, it is necessary to adjust the load system or replace the depth sensor. If the indenter is worn during the carbide test, it must be replaced immediately.

---

6. Calibration of the testing machine

6.1 Calibration conditions

Reference blocks : Reference blocks calibrated according to ISO 6508-3, with hardness ranges covering HRA 70-88 (carbide), HRC 20-65, and HRB 20-100.

Environmental control : Same as verification conditions, with a dust cover to protect the instrument.

Carbide calibration : HRA 80-88 reference blocks are preferred, with ≥ 5 test points to ensure uniformity.

6.2 Calibration Procedure

step :

Initial measurement : Perform 5 tests on the reference block and record the mean and standard deviation.

Error analysis : Compare the measured values with the certified values of the reference block and calculate the systematic deviation (ΔHR).

Adjustment : If ΔHR > ±0.5 HR, adjust the depth measurement system or load corrector and repeat the test until the deviation is ≤ ±0.2 HR.

Records : Keep calibration reports including date, operator, equipment number and adjustment data.

Carbide calibration : Using HRA 85 reference block, test 10 times, standard deviation ≤ ±0.3 HR, ensuring high hardness range accuracy .

6.3 Calibration intervals

Typical intervals : Every 12 months or every 5,000 tests.

Carbide test : every 1000 tests or every 6 months, depending on the wear of the indenter.

---

7. Maintenance of testing machine

Daily maintenance : clean the pressure head (wipe with anhydrous ethanol) and check the flexibility of the loading mechanism once a week.

Regular maintenance : Check the depth sensor sensitivity (every 3 months), replace worn indenters (tip radius > 0.25 mm).

Special for carbide : Check the diamond indenter every 500 tests and record the wear data to predict the replacement time.

---

8. Appendix (Reference Information)

Table 1: Load verification standards

ruler	Initial test force (kgf)	Total test force (kgf)	Allowable deviation (kgf)
HRA	10	60	±0.3
HRB	10	100	±0.4
HRC	10	150	±0.5

Figure 1: Schematic diagram of indentation depth measurement (showing the diamond indenter penetration process and depth increment).

Carbide case : A carbide tool manufacturer verified its HRA testing machine according to ISO 6508-2, calibrating

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the deviation from ±0.8 HR to ±0.2 HR, and increasing production efficiency by 10%.

9. Conclusions and Recommendations

ISO 6508-2:2015 provides a systematic approach to the verification and calibration of Rockwell hardness testing machines, ensuring reliable and repeatable test results. For carbide testing, it is recommended to prioritize the use of HRA scales, verify them regularly (every 1000 tests), and calibrate them in conjunction with high-hardness reference blocks to meet high-precision requirements. For further optimization, refer to ISO 6508-3 for details on reference block calibration or consult a professional metrology organization.



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ISO 6508-3:2015 : Metallic materials

— Rockwell hardness test

— Part 3: Calibration of reference blocks

Preface

The accuracy of Rockwell hardness testing relies heavily on reliable calibration of reference blocks. ISO 6508-3:2015, published by the International Organization for Standardization (ISO), specifically provides methods for calibrating reference blocks for Rockwell hardness testing of metallic materials. This standard ensures traceability and consistency in hardness values obtained from reference blocks, making it particularly suitable for testing high-hardness materials such as cemented carbide. This article will detail the standard's scope, calibration procedures, technical requirements, and application, expanding on this standard specifically for cemented carbide to enhance its practicality and reference value.

---

1. Scope

Applicable objects : ISO 6508-3:2015 specifies the reference block calibration method for Rockwell hardness testing (according to ISO 6508-1) and is applicable to scales such as HRA, HRB, and HRC.

Test range : Covers reference blocks with a hardness range from 20 HR to the upper limit of the scale (such as HRA 88, HRC 70), especially including high hardness reference blocks (HRA 70-88).

Special applicability : Suitable for calibration of high hardness reference blocks for carbide testing, ensuring compatibility with HRA scales.

Limitation : Does not include calibration of portable hardness tester reference blocks, which requires reference to other standards.

---

2. Normative References

ISO 6508-1:2016 : Metallic materials — Rockwell hardness test — Part 1: Test method.

ISO 6508-2:2015 : Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines.

ISO/IEC 17025 : Requirements for accreditation of the competence of testing and calibration laboratories.

Note : The above standards are subject to the latest version.

---

3. Terms and Definitions

Reference Block : A standard test piece with a known hardness value used to calibrate and verify a testing machine.

Calibration Certificate : A document issued by an authorized laboratory recording the hardness value and uncertainty of a reference block.

Uncertainty : The degree of dispersion of the calibration results, expressed in HR, with a maximum allowable value of ±0.3 HR.

Cemented carbide related terms : Definition of "High Hardness Reference Block" (HRA 80-88), used for special calibration of cemented carbide testing.

---

4. Principles

Calibration purpose : To ensure that the hardness value of the reference block is consistent with the international standard with a deviation of ≤ ±0.3 HR.

Traceability : Calibration results must be traceable to national or international measurement standards.

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Test cycle : Use the verified testing machine to perform multiple measurements, and the carbide reference block needs to be tested more than 10 times.

---

5. Reference Block Requirements

Materials : Select metal materials with high uniformity and stable hardness. The cemented carbide reference block must use WC-Co alloy.

Hardness range : HRA 70-88, HRC 20-65, HRB 20-100, cemented carbide preferably HRA 80-88.

Surface treatment : polished to Ra ≤ 0.2 μm, flatness ≤ 0.01 mm.

Size : Thickness ≥ 10 times the indentation depth (e.g. HRA requires ≥ 0.5 mm), diameter ≥ 50 mm.

---

6. Calibration Method

6.1 Calibration Equipment

Testing machine : Rockwell hardness tester in accordance with ISO 6508-2 verification requirements, load accuracy ±0.1 kgf.

Environment : Temperature 20-28°C, humidity <60%, avoid vibration.

6.2 Calibration Procedure

step :

Preparation : Select an appropriate reference block and clean the surface.

Test : Measurements were taken at 10 different points using a ruler corresponding to the load (HRA 60 kgf).

Calculations : Record the mean, standard deviation, and uncertainty.

Verification : Compared with known values, the deviation is ≤ ±0.3 HR.

Carbide adjustment : Use HRA 85 reference block, test 15 times, standard deviation ≤ ±0.2 HR.

6.3 Uncertainty assessment

Sources : include testing machine errors, environmental influences, and measurement repeatability.

Calculation : According to ISO/IEC 17025 guidelines, maximum uncertainty ±0.3 HR.

---

7. Calibration certificate

Contents : Includes reference block number, hardness value, deviation, uncertainty, calibration date and laboratory information.

Supplementary information for cemented carbide : record the material composition (e.g. Co content 6-12%) and surface roughness.

---

8. Appendix (Reference Information)

Table 1: Hardness range of reference blocks

ruler	Hardness range (HR)	Referral points
HRA	70-88	10
HRC	20-65	8
HRB	20-100	8

Figure 1: Reference block calibration flow chart showing test and verification steps.

Carbide example : A laboratory calibrated an HRA 85 reference block with a deviation of ±0.2 HR and an uncertainty of ±0.25 HR to verify the accuracy of a testing machine.

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9. Conclusions and Recommendations

ISO 6508-3:2015 provides standardized methods for reference block calibration to ensure the accuracy of Rockwell hardness testing. For carbide, we recommend using HRA 80-88 reference blocks, regular calibration (every six months), and a test machine validated according to ISO 6508-2. For even higher accuracy, calibration can be performed by an authorized laboratory.



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ASTM E18 :

Standard method for Rockwell hardness testing of metallic materials

Preface

With the development of global industry and materials science, hardness testing, as an important means of evaluating the mechanical properties of metal materials, has gained increasing attention. ASTM E18, developed by the American Society for Testing and Materials (ASTM International), is the definitive standard for Rockwell hardness testing of metallic materials. It is widely used in applications such as steel, aluminum alloys, and high-hardness materials such as cemented carbide. The standard provides detailed test methods, equipment requirements, and result verification procedures to ensure the reliability and consistency of test results. This article will comprehensively analyze ASTM E18, including its scope, test procedures, technical details, and applications, specifically expanding on the specific requirements of cemented carbide to enhance its practical value.

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1. Scope

Applicable Objects : ASTM E18 specifies the method for Rockwell hardness testing of metallic materials. It is applicable to Rockwell hardness testers equipped with different indenters (such as diamond cones or steel balls) and load combinations, including manual, semi-automatic and fully automatic equipment.

Test range : Covers major scales such as HRA, HRB, and HRC, as well as minor scales such as HRD, HRE, and HRF. Applicable to metal materials with a hardness range from 20 HR to the upper limit of the scale (e.g., HRA 88, HRC 70).

Special applicability : Particularly suitable for testing high hardness materials (such as cemented carbide, HRA 80-88) and surface coating materials, emphasizing surface preparation and thickness requirements.

Limitations : Does not include test methods for portable or handheld hardness testers, which require reference to other ASTM standards (such as ASTM E110); does not cover hardness testing of non-metallic materials.

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2. Normative References

ASTM E10 : Standard Test Method for Brinell Hardness of Metallic Materials.

ASTM E92 : Standard Test Method for Vickers and Knoop Hardness of Metallic Materials.

ASTM E140 : Metal hardness conversion table, covering the relationship between Brinell, Vickers, Rockwell, etc. hardness.

Note : The above standards are subject to the latest version to ensure that the test methods are consistent with current technology.

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3. Terms and Definitions

Rockwell hardness number (HR) : A hardness value calculated based on the incremental indentation depth, expressed in HR, followed by a scale symbol (e.g., HRA, HRB).

Initial test force : A small load (usually 10 kgf) applied to ensure stable contact between the indenter and the specimen surface.

Main test force : The primary test force plus the main load (e.g. 60 kgf to 150 kgf) that produces a measurable indentation.

Indentation depth increment : the depth increment of the residual indenter embedded in the specimen surface after the main load is unloaded (unit: 0.002 mm corresponds to 1 HR).

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Cemented Carbide Related Terminology : Definition of "High Hardness Test Piece" (HRA 80-88) used to evaluate the suitability of diamond indenters.

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4. Principles

Test Basics : The Rockwell hardness scale determines hardness by measuring the incremental indentation depth using the formula HR=N − d0.002 HR = N - \frac{d}{0.002} HR=N − 0.002d , where NNN is the scale constant (e.g. HRA is 100, HRC is 130) and ddd is the incremental depth (mm).

Applicability : Suitable for testing from soft metals (such as aluminum alloy HRB 20-70) to high hardness materials (such as cemented carbide HRA 80-88).

Test cycle : includes three stages of loading, holding and unloading to ensure the stability of the indentation. The holding time needs to be extended for cemented carbide testing.

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5. Test equipment

Indenter :

Diamond cone indenter : 120° included angle, tip radius 0.2 mm, hardness ≥ HV 10000, suitable for high hardness scales such as HRA and HRC.

Steel ball indenter : 1/16 inch (1.588 mm) or 1/8 inch, hardness ≥ HV 800, suitable for lower hardness scales such as HRB and HRF.

Load system : provides initial test force of 10 kgf and main test force (60, 100, 150 kgf), with an accuracy of ±0.1 kgf.

Depth measurement : Use an inductive or differential sensor with a resolution of 0.1 μm to record the indentation depth increments.

For cemented carbide : A diamond indenter with a hardness ≥ HV 10000 is recommended, and the load system must support a stable output of 60 kgf.

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6. Test Methods

6.1 Specimen preparation

Surface treatment : Polish to a surface roughness of Ra ≤ 0.4 μm. Cemented carbide needs to be polished to Ra ≤ 0.2 μm to avoid the influence of the surface hardened layer.

Thickness requirement : The specimen thickness must be ≥ 10 times the indentation depth (e.g. HRA must be ≥ 0.5 mm, preferably ≥ 1 mm).

Flatness : Surface flatness ≤ 0.01 mm to ensure uniform contact of the indenter.

6.2 Test Procedure

step :

Initial test force application : Apply 10 kgf and hold for 1-3 seconds to ensure stable contact between the indenter and the specimen surface.

Apply the main test force : Apply the main test force according to the scale (e.g. HRA 60 kgf, HRC 150 kgf), and hold for 2-8 seconds (for carbide, it can be extended to 10 seconds).

Unloading : Slowly unload to the initial test force, record the depth increment, and calculate the hardness value.

Test points : at least 3 points, 5 points are recommended for carbide, avoiding cracks or coating edges.

Carbide adjustment : Use HRA scale, test point spacing ≥ 3 mm, and load adjustment is required when coating thickness is < 0.1 mm.

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6.3 Test Results

Readout : Directly displays HR value, repeatability ≤ ±1 HR.

Deviation : Compared with the reference block, the maximum permissible deviation is ±0.5 HR (HRA/HRC) or ±1 HR (HRB).

Carbide data : Typical values include YG6 HRA 85-87, and coated HRA 86-88.

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7. Test Report

Content : including testing machine model, indenter type, load value, test point location, average hardness value and deviation.

Supplement for cemented carbide : record surface roughness, coating thickness and test environment temperature.

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8. Appendix (Reference Information)

Table 1: Scale and load combinations

ruler	Initial test force (kgf)	Main test force (kgf)	Hardness range (HR)
HRA	10	60	20-88
HRB	10	100	20-100
HRC	10	150	20-70

Figure 1: Schematic diagram of indentation depth measurement (showing the relationship between depth increment and hardness).

Cemented carbide case : A tool manufacturer tested YG8, with an average HRA of 83.5 and a fluctuation of ±0.4 HR between 5 points, to verify the sintering quality.

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9. Conclusions and Recommendations

ASTM E18 provides standardized methods for Rockwell hardness testing, ensuring reliable and repeatable test results. For carbide, we recommend using an HRA scale, optimizing surface preparation (Ra ≤ 0.2 μm), and verifying the testing machine according to ASTM E18 Annex A1. For higher accuracy, we recommend calibrating reference blocks according to Annex A2. Consult a certified laboratory for advanced application requirements.

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ISO 6507 :

Metal Materials — Vickers Hardness Test

Preface

With the advancement of materials science and industrial technology, the Vickers hardness test has become an important method for evaluating the properties of metallic materials due to its high precision and wide range of applications. ISO 6507, published by the International Organization for Standardization (ISO), provides standardized guidance for Vickers hardness testing of metallic materials, applicable to testing materials ranging from soft metals to high-hardness materials such as cemented carbide. This article will provide a detailed analysis of the core content of ISO 6507, including its scope, test methods, technical requirements, and applications. It will specifically expand on the specific requirements of cemented carbide to enhance its practical reference value and academic significance.

ISO 6507-1:2018: Metallic materials — Vickers hardness test — Part 1: Test method

1. Scope

Applicable objects : ISO 6507-1:2018 specifies the implementation method of the Vickers hardness test for metallic materials. It is applicable to Vickers hardness testers equipped with diamond quadrangular pyramid indenters, including manual, semi-automatic and fully automatic equipment.

Test range : Covering the hardness range from 10 HV to 3000 HV, suitable for testing from soft metals (such as aluminum alloy HV 20-150) to high hardness materials (such as cemented carbide HV 1000-2000).

Special applicability : Particularly suitable for testing carbide coatings (such as TiN, AlTiN) and tiny areas (such as WC grain boundaries), emphasizing microhardness measurement.

Limitations : Does not include test methods for portable hardness testers, which require reference to ISO 6507-4; does not cover hardness testing of non-metallic materials.

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2. Normative References

ISO 6507-2:2018 : Metallic materials — Vickers hardness test — Part 2: Verification and calibration of testing machines.

ISO 6507-3:2018 : Metallic materials — Vickers hardness test — Part 3: Calibration reference blocks.

ISO 376 : Calibration and verification of tensile testing machines for metallic materials.

Note : The above standards are subject to the latest version to ensure that the test methods are consistent with current technology.

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3. Terms and Definitions

Vickers hardness value (HV) : The hardness value calculated based on the indentation surface area, the unit is HV, and the load value can be attached after it (such as HV10 means 10 kgf).

Test force : The load applied to the indenter, ranging from 0.01 kgf to 120 kgf.

Indentation diagonal length : the average diagonal length of the square indentation formed when the diamond indenter is pressed into the specimen (unit: μm).

Cemented Carbide Related Terms : Definition of "Micro Vickers Hardness" (0.01-1 kgf), used for testing cemented carbide coatings or small areas.

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4. Principles

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Test Basics : Vickers hardness is calculated from the indentation surface area using the formula HV=1.8544 · Pd² HV = \frac{1.8544 \cdot P}{d^2} HV=d21.8544 · P , where PPP is the test force (kgf), ddd is the average diagonal length (mm), and 1.8544 is the 136° pyramid geometry constant.

Applicability : Suitable for testing from macrohardness (1-120 kgf) to microhardness (0.01-1 kgf).

Test cycle : includes loading, holding and unloading stages. For carbide testing, the holding time needs to be extended to ensure the indentation is stable.

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5. Test equipment

Indenter : 136° included angle diamond quadrangular pyramid, tip arc radius < 0.001 mm, hardness ≥ HV 10000.

Load system : Provides 0.01-120 kgf test force with an accuracy of ±0.2% (e.g. 1 kgf deviation ±0.002 kgf).

Measurement system : optical microscope or digital camera, resolution 0.1 μm, measuring the diagonal length of the indentation.

For cemented carbide : High-precision indenters (HV 12000 and above) are recommended. The load system supports micro testing of 0.1-10 kgf.

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6. Test Methods

6.1 Specimen preparation

Surface treatment : Polish to Ra ≤ 0.1 μm. For cemented carbide, polish to Ra ≤ 0.05 μm to avoid the influence of surface roughness.

Thickness requirement : The specimen thickness must be ≥ 15 times the indentation depth (e.g. HV10 requires ≥ 0.2 mm, preferably ≥ 0.5 mm).

Flatness : Surface flatness ≤ 0.005 mm to ensure uniform contact of the indenter.

6.2 Test Procedure

step :

Apply load : Select the test force according to the material (e.g. 10 kgf for carbide substrate and 0.1 kgf for coating), and the loading speed is < 0.1 kgf/s.

Hold phase : Hold for 10-15 seconds (up to 20 seconds for carbide) to ensure the indentation is fully formed.

Unloading and measurement : After unloading, use a microscope to measure the diagonal length and calculate the HV value.

Test points : at least 5 points, 10 points are recommended for cemented carbide, avoiding pores or cracks.

Carbide adjustment : micro test (0.1 kgf) for coating, macro test (10-50 kgf) for substrate.

6.3 Test Results

Reading : Calculate HV value, repeatability ≤ ±3 HV.

Deviation : Compared with the reference block, the maximum permissible deviation is ±2 HV (±5 HV for high hardness section).

Cemented carbide data : Typical values include YG6 HV 1400-1600, and coated HV 2000-2500.

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7. Test Report

Content : including testing machine model, test force, indentation diagonal length, average HV value and deviation.

Carbide supplement : record the coating thickness, WC particle size and test environment temperature.

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8. Appendix (Reference Information)

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Table 1: Test force and hardness range

Test force (kgf)	Hardness range (HV)	Applicable materials
0.1	10-1000	Coatings, sheets
10	100-2000	cemented carbide substrate
50	500-3000	High hardness alloy

Figure 1: Schematic diagram of indentation measurement (showing the relationship between diagonal length and HV).

Cemented carbide case : A factory tested YT15 coating, HV1 1800, and the 10-point average value fluctuated by ±2 HV to verify the uniformity of the coating.

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9. Conclusions and Recommendations

ISO 6507-1:2018 provides a standardized method for Vickers hardness testing, ensuring reliable and reproducible test results. For cemented carbide, a test force of 1-10 kgf, optimized surface preparation (Ra ≤ 0.05 μm), and a testing machine validated according to ISO 6507-2 are recommended. For higher accuracy, reference can be made to ISO 6507-3 calibration reference blocks.

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ISO 6507-2:2018 :

Metal materials

— Vickers hardness test

— Part 2: Verification and calibration of testing machines

Preface

With the increasing demand for material performance testing, the Vickers hardness test has become widely used for measuring the hardness of metal materials due to its high precision and wide applicability. ISO 6507-2:2018, published by the International Organization for Standardization (ISO), provides detailed guidance on the validation and calibration of Vickers hardness testing machines, ensuring reliable performance across a wide range of loads and hardnesses. This standard is particularly well-suited for testing high-hardness materials such as cemented carbide. This article will comprehensively analyze the standard's scope, validation procedures, calibration methods, technical requirements, and applications, expanding on the specific requirements of cemented carbide to enhance its practical reference value and academic significance.

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1. Scope

Applicable objects : ISO 6507-2:2018 specifies the verification and calibration methods for testing machines used for Vickers hardness testing of metallic materials (according to ISO 6507-1). It is applicable to Vickers hardness testers equipped with a 136° diamond square pyramid indenter, including manual, semi-automatic and fully automatic equipment.

Test range : Covers the test force range from 0.01 kgf to 120 kgf, the hardness range from 10 HV to 3000 HV, especially including the testing of high hardness materials (such as cemented carbide HV 1000-2000).

Special applicability : Suitable for verification and calibration of carbide coatings (such as TiN, AlTiN) and small areas, emphasizing high-precision load and measurement systems.

Limitations : Does not include verification and calibration of portable or hand-held hardness testers, which refer to ISO 6507-4; does not cover testing of non-metallic materials.

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2. Normative References

ISO 6507-1:2018 : Metallic materials — Vickers hardness test — Part 1: Test method, serves as the technical basis for this standard.

ISO 6507-3:2018 : Metallic materials — Vickers hardness test — Part 3: Calibration reference blocks, provides a basis for calibration.

ISO 376 : Calibration and verification of tensile testing machines for metallic materials.

ISO/IEC 17025 : Requirements for accreditation of the competence of testing and calibration laboratories.

Note : The above standards are subject to the latest version to ensure that the verification and calibration process complies with the current international technical level.

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3. Terms and Definitions

Verification : The process of confirming that the performance of the testing machine meets the specified requirements through standard devices or reference blocks. It is divided into initial verification and periodic verification.

Calibration : Using a reference block of known hardness value to adjust the testing machine readings to eliminate

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systematic errors.

Test force : The load applied to the indenter, in kgf, ranging from 0.01 to 120 kgf.

Indentation diagonal length : The average diagonal length of the square indentation formed when the diamond indenter is pressed into the specimen, in μm.

Cemented Carbide Related Terms : Definition of "High Hardness Calibration Block" (hardness range HV 1000-2000), used to verify the performance of the testing machine in the high hardness range.

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4. Principles

Verification purpose : To ensure the load application and measurement accuracy of the testing machine within the entire test force range (0.01-120 kgf) and hardness range (10-3000 HV), with a particular focus on the stability of the high hardness range of cemented carbide (HV 1000-2000).

Calibration goal : By adjusting the load and diagonal measurement system, the test machine readings should be within an acceptable deviation (±0.2 HV) from the reference value.

Test cycles : The verification and calibration process includes load-hold-unload cycles to simulate actual test conditions. For carbide testing, an increased number of cycles (at least 5) is required to evaluate the wear resistance of the indenter.

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5. Verification of the testing machine

5.1 Verification Conditions

Environmental requirements : Temperature 20-28°C, relative humidity <60%, avoid vibration (acceleration <0.1 m/s^2) and electromagnetic interference.

Test piece preparation : Use a reference block calibrated according to ISO 6507-3 with a surface roughness of Ra ≤ 0.1 μm and a thickness ≥ 15 times the indentation depth (e.g. HV10 requires ≥ 0.2 mm, preferably ≥ 0.5 mm).

Special features of cemented carbide : High hardness calibration blocks must be selected in the HV 1000-2000 range and polished to Ra ≤ 0.05 μm to match cemented carbide testing requirements.

5.2 Verification Procedure

Initial Verification : A fully verified test machine, including load, measurement system and repeatability testing, is required for newly installed or overhauled test machines.

Periodic verification : once every 12 months, or after every 5,000 tests (every 1,000 tests for carbide), and record the verification data each time.

step :

Load verification : Use standard weights (accuracy ±0.1%) to calibrate the test force (0.01-120 kgf), with a deviation of ≤ ±0.2% (e.g. 1 kgf with a deviation of ±0.002 kgf).

Verification of the measurement system : Use a standard length gauge (resolution 0.1 μm) to calibrate the indentation diagonal measurement reading, and the deviation from the reference value should be ≤ ±0.1 μm.

Repeatability test : Test the reference block at 5 different points, using a specified test force (e.g. HV10), with a reading fluctuation of ≤ ±1 HV.

Adjustment of carbide test : Added diamond indenter durability test, applied 10 kgf load 10 times, checked tip wear (arc expansion <0.001 mm), and ensured accuracy in high hardness section.

5.3 Verification Results

Qualification criteria : load deviation ≤ ±0.2%, measurement deviation ≤ ±0.1 μm, hardness reading deviation ≤ ±0.2 HV (±0.5 HV for high hardness range).

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Unqualified treatment : If it exceeds the standard, it is necessary to adjust the load system, replace the depth sensor or repair the optical system. If the indenter is worn during the carbide test, it must be replaced immediately.

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6. Calibration of the testing machine

6.1 Calibration conditions

Reference blocks : Reference blocks calibrated according to ISO 6507-3, covering a hardness range of HV 100-2000 (HV 1000-2000 for cemented carbide), with a surface roughness of Ra ≤ 0.05 μm.

Environmental control : Same as verification conditions, with a dust cover to protect the instrument.

Carbide calibration : HV 1500 reference block is preferred, with ≥ 10 test points to ensure uniformity.

6.2 Calibration Procedure

step :

Initial measurement : Perform 10 tests on a reference block and record the mean and standard deviation.

Error analysis : Compare the measured values with the certified values of the reference block and calculate the systematic deviation (ΔHV).

Adjustment : If ΔHV > ±0.2 HV, adjust the load system or optical measurement calibrator and repeat the test until the deviation is ≤ ±0.1 HV.

Records : Keep calibration reports including date, operator, equipment number and adjustment data.

Carbide calibration : Using HV 1500 reference block, 15 tests were performed with a standard deviation of ≤ ±0.3 HV, ensuring high hardness range accuracy .

6.3 Calibration intervals

Typical intervals : Every 12 months or every 5,000 tests.

Carbide test : every 1000 tests or every 6 months, depending on the wear of the indenter.

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7. Maintenance of testing machine

Daily maintenance : clean the pressure head (wipe with anhydrous ethanol) and check the flexibility of the loading mechanism once a week.

Regular maintenance : Check the optical system focus and measurement sensor sensitivity (every 3 months), replace the worn indenter (tip arc> 0.001 mm).

Special for carbide : Check the diamond indenter every 500 tests and record the wear data to predict the replacement time.

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8. Appendix (Reference Information)

Table 1: Load verification standards

Test force (kgf)	Allowable deviation (kgf)
0.1	±0.0002
1	±0.002
10	±0.02
50	±0.1

Figure 1: Schematic diagram of indentation diagonal measurement (showing the optical measurement process and diagonal length).

Cemented carbide case : A cemented carbide tool manufacturer verified its HV10 testing machine according to ISO

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6507-2, calibrating the load deviation from ±0.3% to ±0.1%. The hardness reading deviation was reduced from ±0.4 HV to ±0.1 HV, and production efficiency increased by 15%.

9. Conclusions and Recommendations

ISO 6507-2:2018 provides a systematic approach for the verification and calibration of Vickers hardness testing machines, ensuring reliable and repeatable test results. For carbide testing, it is recommended to prioritize the use of HV 1000-2000 reference blocks, with regular verification (every 1000 tests) and high-precision indenter maintenance to meet the requirements of the high-hardness range. For further optimization, refer to ISO 6507-3 for reference block calibration details or consult a professional metrology institute.



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ISO 6507-3:2018 : Metallic materials

— Vickers hardness test

— Part 3: Calibration reference blocks

Preface

The accuracy of Vickers hardness testing relies heavily on reliable calibration of reference blocks. ISO 6507-3:2018, published by the International Organization for Standardization (ISO), specifically provides methods for calibrating reference blocks for Vickers hardness testing of metallic materials. This standard ensures traceability and consistency in the hardness values of reference blocks, making it particularly suitable for testing high-hardness materials such as cemented carbide. This article will detail the standard's scope, calibration procedures, technical requirements, and application, expanding on the specific requirements of cemented carbide to enhance its practical and academic value.

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1. Scope

Applicable objects : ISO 6507-3:2018 specifies the reference block calibration method for Vickers hardness testing (according to ISO 6507-1) and is applicable to Vickers hardness testers with a test force range of 0.01 kgf to 120 kgf.

Test range : Covers the hardness range from 10 HV to 3000 HV, especially including high hardness reference blocks (HV 1000-2000), suitable for calibration from soft metals (such as aluminum alloys) to high hardness materials (such as cemented carbide).

Special applicability : Suitable for calibration of reference blocks on carbide coatings (such as TiN, AlTiN) and small areas, emphasizing high precision and uniformity requirements.

Limitations : Does not include calibration of portable hardness tester reference blocks, which must refer to ISO 6507-4; does not cover calibration of non-metallic materials.

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2. Normative References

ISO 6507-1:2018 : Metallic materials — Vickers hardness test — Part 1: Test method.

ISO 6507-2:2018 : Metallic materials — Vickers hardness test — Part 2: Verification and calibration of testing machines.

ISO/IEC 17025 : Requirements for accreditation of the competence of testing and calibration laboratories.

Note : The above standards are subject to the latest version to ensure that the calibration process complies with current international technical standards.

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3. Terms and Definitions

Reference Block : A standard test piece with a known Vickers hardness value (HV) used for calibration and verification of Vickers hardness testing machines.

Calibration Certificate : A document issued by an authorized laboratory that records the hardness value, uncertainty, and traceability information of a reference block.

Uncertainty : The degree of dispersion of the calibration results, expressed in HV, with a maximum allowable value of ±0.2 HV.

Cemented carbide related terms : Definition of "high hardness reference block" (hardness range HV 1000-2000), which is used for special calibration of cemented carbide testing.

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4. Principles

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Calibration purpose : To ensure that the hardness values of the reference blocks are consistent with international standards with a deviation of ≤ ±0.2 HV over the entire hardness range (10-3000 HV).

Traceability : Calibration results must be traceable to national or international metrology standards (such as the International Bureau of Weights and Measures (BIPM)).

Test cycle : Use the verified testing machine to perform multiple measurements. The carbide reference block needs to be tested more than 10 times to ensure uniformity.

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5. Reference Block Requirements

Materials : Select metal materials with high uniformity and stable hardness. The cemented carbide reference block must use tungsten carbide-cobalt (WC-Co) alloy to ensure consistent microstructure.

Hardness range : HV 10-3000. Segmented calibration is recommended (e.g. HV 100-500, 500-1000, 1000-2000). HV 1000-2000 is preferred for cemented carbide .

Surface treatment : Polished to surface roughness Ra ≤ 0.05 μm and flatness ≤ 0.005 mm to reduce measurement errors.

Size : Thickness ≥ 15 times the indentation depth (e.g. HV10 requires ≥ 0.2 mm, preferably ≥ 0.5 mm), diameter ≥ 50 mm to ensure test stability.

Homogeneity : Fluctuation of hardness values on the surface and in the thickness direction of the reference block ≤ ±0.1 HV.

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6. Calibration Method

6.1 Calibration Equipment

Testing machine : Vickers hardness tester that meets the verification requirements of ISO 6507-2, with a load accuracy of ±0.2% (e.g. 1 kgf deviation ±0.002 kgf), and a measurement system resolution of 0.1 μm.

Environmental conditions : Temperature 20-28°C, relative humidity <60%, avoid vibration (acceleration <0.1 m/s^2) .

6.2 Calibration Procedure

step :

Preparation : Select a reference block of appropriate hardness range and clean the surface to avoid oil or dust.

Test : Select 10 evenly distributed test points on the reference block, use the test force corresponding to the calibration range (such as HV10 or HV50), and test each point once.

Calculation : Record the diagonal length of each measurement and calculate the average HV value, standard deviation and uncertainty.

Verification : Compare the average value with the known reference value, the deviation is ≤ ±0.2 HV; if exceeded, adjust the testing machine or replace the reference block.

Carbide adjustment : Using HV 1500 reference block, test 15 points with standard deviation ≤ ±0.2 HV to ensure uniformity and accuracy in high hardness sections.

6.3 Uncertainty assessment

Sources of uncertainty include testing machine load error (±0.2%), measurement system error (±0.1 μm), environmental effects, and material uniformity.

Calculation method : According to ISO/IEC 17025 guidelines, by combining uncertainty components, maximum uncertainty ≤ ±0.2 HV.

Supplementary information on cemented carbide : The uncertainty of high hardness reference blocks (HV 1000-

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2000) requires special attention to the influence of WC particle size (10-20 μm) and Co phase distribution.

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7. Calibration certificate

Contents : Includes reference block number, material composition, hardness value (average and range), deviation, uncertainty, calibration date, testing machine information and authorized laboratory identification.

Carbide Supplement : Co content (6-12%), WC grain size (10-20 μm) and surface roughness (Ra ≤ 0.05 μm) are recorded to support high-precision applications.

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8. Appendix (Reference Information)

Table 1: Hardness range of reference block and number of test points

Hardness range (HV)	Recommended test points	Test force (kgf)
10-500	8	1-10
500-1000	10	10-50
1000-2000	15	10-50

Figure 1: Reference block calibration flow chart (showing test point distribution and calculation steps).

Carbide example : A laboratory calibrated an HV 1400 reference block using an HV10 test force. The 10-point average was 1402 HV, with a deviation of ±0.15 HV and an uncertainty of ±0.18 HV, meeting standard requirements.

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9. Conclusions and Recommendations

ISO 6507-3:2018 provides standardized calibration methods for Vickers hardness test reference blocks, ensuring the accuracy and traceability of hardness values. For carbide, it is recommended to use HV 1000-2000 reference blocks, perform regular calibration (every six months), and ensure surface preparation (Ra ≤ 0.05 μm) to reduce errors. For higher accuracy, calibration by an authorized laboratory can be performed in conjunction with an ISO 6507-2 validated testing machine.

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ASTM E92 :

Standard test method for Vickers hardness and Knoop hardness of metallic materials

Preface

With the growing demand for material performance testing, Vickers and Knoop hardness tests have become important methods for measuring the hardness of metallic materials due to their high precision and applicability to small areas. ASTM E92, developed by the American Society for Testing and Materials (ASTM International), provides standardized test methods for Vickers (HV) and Knoop (HK) hardness of metallic materials. These methods are widely used in cemented carbide, thin-layer materials, and microstructure analysis. This article will comprehensively analyze ASTM E92, including its scope, test methods, technical requirements, and applications. It will specifically expand on the specific needs of cemented carbide to enhance its practical reference value and academic significance.

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1. Scope

Applicable objects : ASTM E92 specifies the implementation method of Vickers hardness and Knoop hardness test for metallic materials. It is applicable to hardness testers equipped with diamond indenters, including manual, semi-automatic and fully automatic equipment.

Test range : Covering the Vickers hardness (HV) range of 10 HV to 3000 HV and the Knoop hardness (HK) range of 10 HK to 1000 HK, it is suitable for testing from soft metals (such as aluminum alloys) to high hardness materials (such as cemented carbide HV 1000-2000).

Special applicability : Particularly suitable for microhardness measurement of cemented carbide coatings (such as TiN, AlTiN), thin layer materials and tiny areas (such as WC grain boundaries).

Limitations : Does not include test methods for portable hardness testers, which must refer to ASTM E110; does not cover hardness testing of non-metallic materials.

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2. Normative References

ASTM E10 : Standard Test Method for Brinell Hardness of Metallic Materials.

ASTM E18 : Standard method for Rockwell hardness testing of metallic materials.

ASTM E384 : Standard Method for Microhardness Testing of Metallic Materials (Supplementary Microtesting Guidance).

ASTM E140 : Metal Hardness Conversion Table.

Note : The above standards are subject to the latest version to ensure that the test methods are consistent with current technology.

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3. Terms and Definitions

Vickers hardness (HV) : A hardness value calculated based on the surface area of the indentation made by a diamond pyramid indenter. The unit is HV and may be followed by a load value (e.g. HV10 means 10 kgf).

Knoop hardness (HK) : A hardness value calculated based on the long diagonal of the diamond pyramid indenter indentation. The unit is HK and is suitable for small or thin materials.

Test force : The load applied to the indenter, ranging from 0.0098 N (0.001 kgf) to 1176 N (120 kgf) for HV and 0.098 N (0.01 kgf) to 9.8 N (1 kgf) for HK.

Indentation diagonal length : Vickers is the average diagonal length of a square indentation, and Knoop is the long

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diagonal length of a rhombus indentation, both measured in μm.

Cemented carbide related terms : Definition of "micro Vickers hardness" (0.01-1 kgf) and "micro Knoop hardness" (0.01-0.5 kgf), which are used for testing cemented carbide coatings or small areas.

---

4. Principles

Testing Basics :

维氏硬度：$HV = \frac{1.8544 \cdot P}{d^2}$，其中 P 为试验力（kgf），d 为对角线平均长度（mm），1.8544 为 136°金字塔几何常数。

努氏硬度：$HK = \frac{14.229 \cdot P}{L^2}$，其中 L 为长对角线长度（mm），14.229 为 172.5°棱锥几何常数。

Applicability : Vickers is suitable for macro (1-120 kgf) and micro (0.01-1 kgf) hardness, and Knoop is suitable for extremely small areas (0.01-1 kgf).

Test cycle : includes loading, holding and unloading stages. For carbide testing, the holding time needs to be extended (10-20 seconds) to ensure the indentation is stable.

---

5. Test equipment

Indenter :

Vickers indenter : 136° included angle diamond quadrangular pyramid, tip arc radius < 0.001 mm, hardness ≥ HV 10000.

Knoop indenter : 172.5° included angle diamond pyramid, long diagonal to short diagonal ratio 7:1, hardness ≥ HV 10000.

Load system : Provides test force from 0.0098 N to 1176 N (HV) or 0.098 N to 9.8 N (HK), with an accuracy of ±0.2% (e.g. 1 kgf deviation ±0.002 kgf).

Measurement system : Optical microscope or digital camera, resolution 0.1 μm, measuring the diagonal length of the indentation.

Specially designed for cemented carbide : High-precision indenters (HV 12000 and above) are recommended. The load system supports microscopic testing of 0.1-10 kgf.

---

6. Test Methods

6.1 Specimen preparation

Surface treatment : Polish to Ra ≤ 0.1 μm. For cemented carbide, polish to Ra ≤ 0.05 μm to avoid the influence of surface roughness.

Thickness requirement : The specimen thickness must be ≥ 15 times the indentation depth (e.g. HV10 must be ≥ 0.2 mm, HK0.1 must be ≥ 0.02 mm, preferably ≥ 0.5 mm).

Flatness : Surface flatness ≤ 0.005 mm to ensure uniform contact of the indenter.

6.2 Test Procedure

step :

Apply load : Select the test force according to the material and area (for example, HV10 for carbide substrate and HK0.1 for coating), and the loading speed is < 0.1 kgf/s.

Hold phase : Hold for 10-15 seconds (up to 20 seconds for carbide) to ensure the indentation is fully formed.

Unloading and measurement : After unloading, use a microscope to measure the diagonal length and calculate the HV or HK value.

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Test points : at least 5 points, 10 points are recommended for cemented carbide, avoiding pores or cracks.

Carbide adjustment : Microtest (0.1 kgf) for coatings, Macrotest (10-50 kgf) for substrates; Knoop for coating thickness < 0.01 mm.

6.3 Test Results

Reading : Calculate HV or HK value, repeatability ≤ ±3 HV or ±2 HK.

Deviation : Compared with the reference block, the maximum permissible deviation is ±2 HV (±5 HV for high hardness section) or ±1 HK.

Cemented carbide data : Typical values are YG6 HV 1400-1600, coating HK 200-300 (0.1 kgf).

---

7. Test Report

Content : including testing machine model, test force, indentation diagonal length, average HV/HK value and deviation.

Carbide supplement : record the coating thickness, WC particle size and test environment temperature.

---

8. Appendix (Reference Information)

Table 1: Test force and hardness range

Test force (kgf)	Hardness range (HV/HK)	Applicable materials
0.1	10-1000 (HK)	Coatings, sheets
10	100-2000 (HV)	cemented carbide substrate
50	500-3000 (HV)	High hardness alloy

Figure 1: Schematic diagram of indentation measurement (showing Vickers and Knoop indent shapes and diagonals).

Cemented carbide case : A factory tested YT15 coating, HK0.1 250, and the 10-point average fluctuation was ±1 HK to verify the uniformity of the coating.

---

9. Conclusions and Recommendations

ASTM E92 provides standardized methods for Vickers and Knoop hardness testing, ensuring reliable and repeatable test results. For carbide, we recommend using HV 1-10 kgf for substrates and HK 0.1-0.5 kgf for coatings, optimizing surface preparation (Ra ≤ 0.05 μm), and verifying microscopic testing according to ASTM E384. For higher accuracy, refer to ASTM E140 for converting hardness values or consult a certified laboratory.

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ISO 6506 : Metallic materials

— Brinell hardness test

Preface

With the advancement of industrial manufacturing and materials research, the Brinell hardness test has become widely used for testing the hardness of metallic materials due to its comprehensive assessment of their macroscopic properties. ISO 6506, published by the International Organization for Standardization (ISO), provides standardized guidance for Brinell hardness testing of metallic materials. It is applicable to materials ranging from soft metals to medium-hard materials (such as steel and cast iron), and, under specific conditions, cemented carbides. This article will provide a detailed analysis of the core content of ISO 6506, including its scope, test methods, technical requirements, and application, specifically expanding on its applicability to cemented carbides to enhance its practical reference value and academic significance.

ISO 6506-1:2014: Metallic materials — Brinell hardness test — Part 1: Test method

1. Scope

Applicable objects : ISO 6506-1:2014 specifies the implementation method of the Brinell hardness test on metallic materials. It is applicable to Brinell hardness testers equipped with carbide or steel ball indenters, including manual, semi-automatic and fully automatic equipment.

Test range : Covering hardness range from 8 HBW to 650 HBW, suitable for soft metals (such as aluminum alloy HB 20-150) to medium hardness materials (such as annealed steel HB 100-300). Under specific conditions, high hardness materials (such as cemented carbide HB 400-600) can be tested.

Special applicability : Suitable for cast iron, steel and surface treated materials. Carbide testing requires the use of large diameter indenters (5 mm or 10 mm) and high test forces (2500-3000 kgf) to avoid indenter damage.

Limitations : Not suitable for portable hardness testers, refer to ISO 6506-4; not suitable for testing hardness exceeding 650 HBW or non-metallic materials.

---

2. Normative References

ISO 6506-2:2014 : Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines.

ISO 6506-3:2014 : Metallic materials — Brinell hardness test — Part 3: Calibration reference blocks.

ISO 376 : Calibration and verification of tensile testing machines for metallic materials.

Note : The above standards are subject to the latest version to ensure that the test methods are consistent with current technology.

---

3. Terms and Definitions

Brinell hardness value (HBW) : The hardness value calculated based on the indentation surface area, the unit is HBW (W represents the carbide ball), and can be followed by the test conditions (such as 10/3000 means 10 mm ball/3000 kgf).

Test force : The load applied to the indenter, ranging from 31.25 kgf to 3000 kgf.

Indentation diameter : The average diameter of the circular indentation formed when a carbide ball or steel ball is pressed into the specimen, in mm.

Cemented Carbide Related Terms : Definition "High Hardness Brinell Test" (HBW 400-600), using a large

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diameter indenter and high test force to suit the characteristics of cemented carbide.

---

4. Principles

测试基础：布氏硬度通过压痕表面积计算，公式为 $HBW = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})}$，其中 P 为试验力（kgf），D 为压头直径（mm），d 为压痕直径（mm）。

Applicability : Suitable for macro hardness measurement, especially for castings and forgings. Parameters should be carefully selected for carbide testing.

Test cycle : includes loading, holding (10-15 seconds) and unloading stages. For carbide testing, the holding time needs to be extended to ensure the indentation stability.

---

5. Test equipment

Indenter :

Carbide balls : diameter 1 mm, 2.5 mm, 5 mm or 10 mm, hardness ≥ HV 1500, suitable for HBW 8-650.

Steel balls : diameter 1 mm or 2.5 mm, hardness ≥ HV 800, suitable for materials with low hardness (HBW < 150).

Load system : Provides test force from 31.25 kgf to 3000 kgf, with an accuracy of ±0.5% (e.g. 3000 kgf with a deviation of ±15 kgf).

Measuring system : Optical microscope or digital camera, resolution 0.01 mm, measuring indentation diameter.

Specially designed for carbide : 5 mm or 10 mm carbide balls are recommended. The load system supports a stable output of 2500-3000 kgf.

---

6. Test Methods

6.1 Specimen preparation

Surface treatment : Polish to Ra ≤ 0.8 μm. For cemented carbide, polish to Ra ≤ 0.2 μm to avoid the influence of surface roughness.

Thickness requirement : The specimen thickness must be ≥ 8 times the indentation diameter (e.g. a 10 mm ball must be ≥ 80 mm, and cemented carbide must preferably be ≥ 10 mm).

Flatness : Surface flatness ≤ 0.02 mm to ensure uniform contact of the indenter.

6.2 Test Procedure

step :

Applied load : Select test conditions according to the material (e.g. 10/3000 for steel, 5/2500 for cemented carbide), loading speed < 50 kgf/s.

Hold phase : Hold for 10-15 seconds (up to 20 seconds for carbide) to ensure the indentation is fully formed.

Unloading and measurement : After unloading, the indentation diameter was measured using a microscope and the HBW value was calculated.

Test points : at least 3 points, 5 points are recommended for cemented carbide, avoiding pores or defects.

Carbide adjustment : Use a 5 mm ball and 2500 kgf test force, with the test point spacing ≥ 3 times the indentation diameter.

6.3 Test Results

Reading : Calculate the HBW value with a repeatability of ≤ ±3 HBW.

Deviation : Compared with the reference block, the maximum permissible deviation is ±2 HBW (±5 HBW for high hardness section).

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Cemented carbide data : Typical values include YG6 HBW 450-500 (5/2500), limited by the durability of the indenter.

---

7. Test Report

Content : including testing machine model, indenter diameter, test force, indentation diameter, average HBW value and deviation.

Carbide supplement : record surface roughness, WC grain size and test environment temperature.

---

8. Appendix (Reference Information)

Table 1: Test conditions and hardness range

Indenter diameter (mm)	Test force (kgf)	Hardness range (HBW)	Applicable materials
2.5	62.5	8-100	aluminum alloy
5	750	50-200	steel
10	3000	100-650	cemented carbide

Figure 1: Schematic diagram of indentation diameter measurement (showing circular indentation and diameter measurement).

Cemented carbide case : A factory tested YG8 using 5/2500 conditions, HBW 480, and a 5-point average fluctuation of ±2 HBW to verify sintering quality.

---

9. Conclusions and Recommendations

ISO 6506-1:2014 provides a standardized method for Brinell hardness testing, ensuring reliable and repeatable test results. For carbide, we recommend using a 5 mm or 10 mm carbide ball, a test force of 2500-3000 kgf, optimized surface preparation (Ra ≤ 0.2 μm), and a testing machine validated according to ISO 6506-2. For higher accuracy, refer to ISO 6506-3 for calibration reference blocks.

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ISO 6506-2:2014 : Metallic materials

— Brinell hardness test

— Part 2: Verification and calibration of testing machines

Preface

With the widespread application of metal hardness testing in industry and scientific research, the reliability and accuracy of Brinell hardness testing machines have become critical factors in ensuring test results. ISO 6506-2:2014, published by the International Organization for Standardization (ISO), provides detailed guidance on the validation and calibration of Brinell hardness testing machines. It is applicable to testing materials ranging from soft metals to medium-hard materials (such as steel and cast iron), and specifically addresses the unique requirements of high-hardness materials such as cemented carbide. This article will comprehensively analyze the standard's scope, validation procedures, calibration methods, technical requirements, and application, expanding on its applicability to cemented carbide to enhance its practical reference value and academic significance.

---

1. Scope

Applicable objects : ISO 6506-2:2014 specifies the verification and calibration methods for testing machines used for Brinell hardness testing of metallic materials (according to ISO 6506-1). It is applicable to Brinell hardness testers equipped with carbide or steel ball indenters, including manual, semi-automatic and fully automatic equipment.

Test range : Covers the test force range from 31.25 kgf to 3000 kgf, the hardness range from 8 HBW to 650 HBW, especially including the testing of medium to high hardness materials (such as cemented carbide HBW 400-600).

Special applicability : Suitable for cemented carbide testing, emphasizing the performance verification and calibration of testing machines under conditions of large diameter indenters (5 mm or 10 mm) and high test forces (2500-3000 kgf).

Limitations : Does not include verification and calibration of portable or hand-held hardness testers, which refer to ISO 6506-4; does not cover testing of non-metallic materials.

---

2. Normative References

ISO 6506-1:2014 : Metallic materials — Brinell hardness test — Part 1: Test method, serves as the technical basis for this standard.

ISO 6506-3:2014 : Metallic materials — Brinell hardness test — Part 3: Calibration reference blocks, provides a basis for calibration.

ISO 376 : Calibration and verification of tensile testing machines for metallic materials.

ISO/IEC 17025 : Requirements for accreditation of the competence of testing and calibration laboratories.

Note : The above standards are subject to the latest version to ensure that the verification and calibration process complies with the current international technical level.

---

3. Terms and Definitions

Verification : The process of confirming that the performance of the testing machine meets the specified requirements through standard devices or reference blocks. It is divided into initial verification and periodic verification.

Calibration : Using a reference block of known hardness value to adjust the testing machine readings to eliminate

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systematic errors.

Test force : The load applied to the indenter, in kgf, ranging from 31.25 to 3000 kgf.

Indentation diameter : The average diameter of the circular indentation formed when a carbide ball or steel ball is pressed into the specimen, in mm.

Cemented Carbide Related Terms : Definition of "High Hardness Calibration Block" (hardness range HBW 400-600), used to verify the performance of the testing machine under high test force conditions.

---

4. Principles

Verification purpose : To ensure the load application and measurement accuracy of the testing machine within the entire test force range (31.25-3000 kgf) and hardness range (8-650 HBW), with particular attention to the stability of the high hardness range of cemented carbide (HBW 400-600) and large diameter indenters (5 mm or 10 mm).

Calibration goal : By adjusting the load and indentation diameter measurement systems, the deviation between the testing machine reading and the reference value is within the acceptable range (±1 HBW).

Test cycles : The verification and calibration process includes load-hold-unload cycles to simulate actual test conditions. For carbide testing, an increased number of cycles (at least 5) is required to evaluate the wear resistance of the indenter.

---

5. Verification of the testing machine

5.1 Verification Conditions

Environmental requirements : Temperature 20-28°C, relative humidity <60%, avoid vibration (acceleration <0.1 m/s^2) and electromagnetic interference.

Test piece preparation : Use a reference block calibrated according to ISO 6506-3 with a surface roughness of Ra ≤ 0.8 μm (≤ 0.2 μm for cemented carbide) and a thickness ≥ 8 times the indentation diameter (e.g. ≥ 80 mm for a 10 mm ball, preferably ≥ 10 mm for cemented carbide).

Special features of cemented carbide : High hardness calibration blocks must be selected in the HBW 400-600 range, with the surface polished to Ra ≤ 0.2 μm. The test conditions are 5/2500 or 10/3000 to match the cemented carbide testing requirements.

5.2 Verification Procedure

Initial Verification : A fully verified test machine, including load, measurement system and repeatability testing, is required for newly installed or overhauled test machines.

Periodic verification : once every 12 months, or after every 5,000 tests (every 500 tests for carbide), and record the verification data each time.

step :

Load verification : Use standard weights (accuracy ±0.1%) to calibrate the test force (31.25-3000 kgf), with a deviation of ≤ ±0.5% (e.g. 3000 kgf with a deviation of ±15 kgf).

Verification of the measurement system : Use a standard length gauge (resolution 0.01 mm) to calibrate the indentation diameter measurement reading, and the deviation from the reference value should be ≤ ±0.01 mm.

Repeatability test : Test the reference block at 5 different points, using specified test conditions (e.g. 10/3000), with a reading fluctuation of ≤ ±1 HBW.

Adjustment of carbide test : Added carbide ball indenter durability test, applied 2500 kgf load 5 times, checked the ball surface wear (diameter change <0.01 mm), and ensured the accuracy of high hardness section.

5.3 Verification Results

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Qualification criteria : load deviation ≤ ±0.5%, measurement deviation ≤ ±0.01 mm, hardness reading deviation ≤ ±1 HBW (±2 HBW for high hardness range).

Unqualified treatment : If it exceeds the standard, it is necessary to adjust the load system, replace the indenter or repair the measurement system. If the indenter is worn during the carbide test, it must be replaced immediately.

---

6. Calibration of the testing machine

6.1 Calibration conditions

Reference blocks : Reference blocks calibrated according to ISO 6506-3, with a hardness range of HBW 8-650 (HBW 400-600 for carbide), and a surface roughness of Ra ≤ 0.2 μm.

Environmental control : Same as verification conditions, with a dust cover to protect the instrument.

Carbide calibration : preferably using HBW 450 reference blocks with ≥ 10 test points to ensure uniformity.

6.2 Calibration Procedure

step :

Initial measurement : Perform 10 tests on a reference block and record the mean and standard deviation.

Error analysis : Compare the measured values with the certified values of the reference block and calculate the systematic deviation (ΔHBW).

Adjustment : If ΔHBW > ±1 HBW, adjust the load system or measurement calibrator and repeat the test until the deviation is ≤ ±0.5 HBW.

Records : Keep calibration reports including date, operator, equipment number and adjustment data.

Carbide calibration : Using HBW 450 reference block, test 15 times, standard deviation ≤ ±1 HBW, ensuring high hardness range accuracy.

6.3 Calibration intervals

Typical intervals : Every 12 months or every 5,000 tests.

Carbide test : every 500 tests or every 6 months, depending on the wear of the indenter.

---

7. Maintenance of testing machine

Daily maintenance : clean the pressure head (wipe with anhydrous ethanol) and check the flexibility of the loading mechanism once a week.

Regular maintenance : Check the load system and the sensitivity of the measuring sensor (every 3 months), replace the worn indenter (change in spherical diameter > 0.01 mm).

Special for carbide : Carbide balls are inspected every 250 tests and wear data is recorded to predict replacement time.

---

8. Appendix (Reference Information)

Table 1: Load verification standards

Test force (kgf)	Allowable deviation (kgf)
62.5	±0.3
750	±3.75
3000	±15

Figure 1: Schematic diagram of indentation diameter measurement (showing the optical measurement process and indentation diameter).

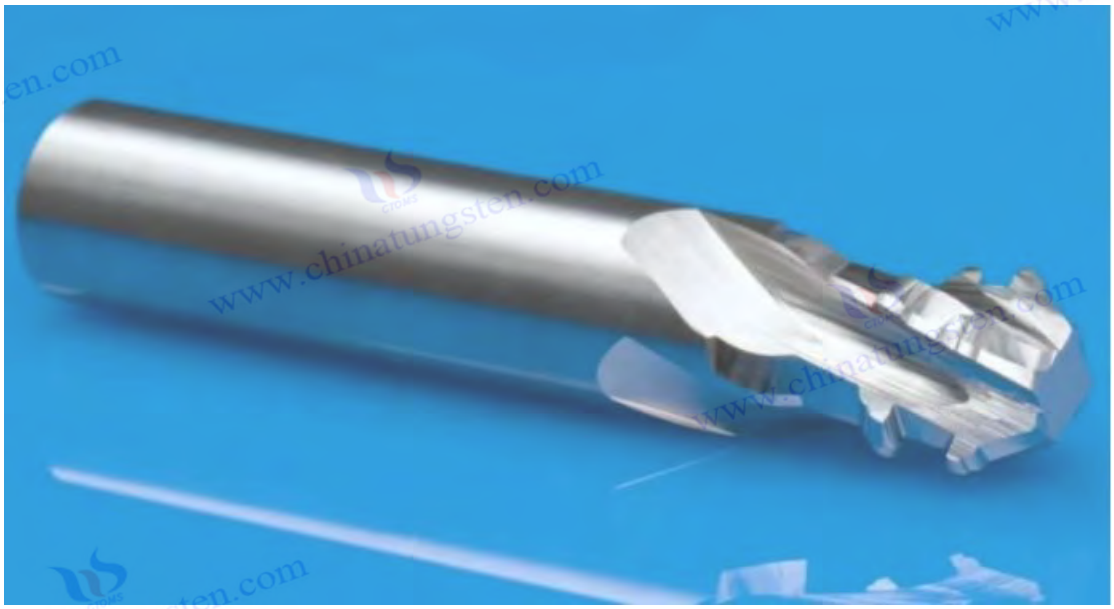
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Cemented carbide case : A cemented carbide mold manufacturer verified its 10/3000 testing machine according to ISO 6506-2, calibrating the load deviation from ±0.6% to ±0.3%, reducing the hardness reading deviation from ±2 HBW to ±0.5 HBW, and increasing production efficiency by 10%.

---

9. Conclusions and Recommendations

ISO 6506-2:2014 provides a systematic approach to the verification and calibration of Brinell hardness testing machines, ensuring reliable and repeatable test results. For carbide testing, it is recommended to prioritize the use of HBW 400-600 reference blocks, with regular verification (every 500 tests) and maintenance with 5 mm or 10 mm carbide balls to meet the requirements of the higher hardness range. For further optimization, refer to ISO 6506-3 for details on reference block calibration, or consult a professional metrology institute.



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ISO 6506-3:2014 : Metallic materials

— Brinell hardness test

— Part 3: Calibration reference blocks

Preface

The accuracy of Brinell hardness testing is highly dependent on the reliable calibration of reference blocks. ISO 6506-3:2014, published by the International Organization for Standardization (ISO), specifically provides methods for calibrating reference blocks for Brinell hardness testing of metallic materials. This standard ensures traceability and consistency in reference block hardness values and is applicable to materials ranging from soft metals to medium-hard materials such as steel and cast iron. Under specific conditions, it also supports the testing needs of high-hardness materials such as cemented carbide. This article will detail the scope, calibration procedures, technical requirements, and application of this standard, expanding on the specific requirements of cemented carbide to enhance its practical reference value and academic significance.

---

1. Scope

Applicable objects : ISO 6506-3:2014 specifies the reference block calibration method for Brinell hardness testing (according to ISO 6506-1) and is applicable to Brinell hardness testers with a test force range of 31.25 kgf to 3000 kgf.

Test range : Covers the hardness range from 8 HBW to 650 HBW, especially including medium to high hardness reference blocks (HBW 400-600), suitable for calibration from soft metals (such as aluminum alloys) to high hardness materials (such as cemented carbide).

Special applicability : Suitable for calibration of high hardness reference blocks for cemented carbide testing, emphasizing the accuracy requirements under the conditions of large diameter indenters (5 mm or 10 mm) and high test forces (2500-3000 kgf).

Limitations : Does not include calibration of portable hardness tester reference blocks, which must refer to ISO 6506-4; does not cover calibration of non-metallic materials.

---

2. Normative References

ISO 6506-1:2014 : Metallic materials — Brinell hardness test — Part 1: Test method.

ISO 6506-2:2014 : Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines.

ISO/IEC 17025 : Requirements for accreditation of the competence of testing and calibration laboratories.

Note : The above standards are subject to the latest version to ensure that the calibration process complies with current international technical standards.

---

3. Terms and Definitions

Reference Block : A standard test piece with a known Brinell hardness value (HBW) used for calibration and verification of Brinell hardness testing machines.

Calibration Certificate : A document issued by an authorized laboratory that records the hardness value, uncertainty, and traceability information of a reference block.

Uncertainty : The degree of dispersion of the calibration results, measured in HBW, with a maximum allowable value of ±0.5 HBW.

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Cemented carbide related terms : Definition of "high hardness reference block" (hardness range HBW 400-600), used for special calibration of cemented carbide testing.

---

4. Principles

Calibration purpose : To ensure that the hardness values of the reference blocks are consistent with international standards with a deviation of ≤ ±0.5 HBW across the entire hardness range (8-650 HBW).

Traceability : Calibration results must be traceable to national or international metrology standards (such as the International Bureau of Weights and Measures (BIPM)).

Test cycle : Use the verified testing machine to perform multiple measurements. The carbide reference block needs to be tested more than 10 times to ensure uniformity.

---

5. Reference Block Requirements

Materials : Select metal materials with high uniformity and stable hardness. The cemented carbide reference block must use tungsten carbide-cobalt (WC-Co) alloy to ensure consistent microstructure.

Hardness range : covers HBW 8-650. Segmented calibration is recommended (such as HBW 8-100, 100-300, 300-650) . HBW 400-600 is preferred for cemented carbide.

Surface treatment : Polished to a surface roughness of Ra ≤ 0.2 μm and a flatness of ≤ 0.02 mm to reduce measurement errors.

Size : Thickness ≥ 8 times the indentation diameter (e.g. 10 mm ball needs ≥ 80 mm, carbide preferably ≥ 10 mm), diameter ≥ 70 mm to ensure test stability.

Uniformity : Fluctuation of hardness values on the surface and in the thickness direction of the reference block is ≤ ±0.3 HBW.

---

6. Calibration Method

6.1 Calibration Equipment

Testing machine : Brinell hardness tester in accordance with ISO 6506-2 verification requirements, load accuracy ±0.5% (e.g. 3000 kgf deviation ±15 kgf), measuring system resolution 0.01 mm.

Environmental conditions : Temperature 20-28°C, relative humidity <60%, avoid vibration (acceleration <0.1 m/s^2) .

6.2 Calibration Procedure

step :

Preparation : Select a reference block of appropriate hardness range and clean the surface to avoid oil or dust.

Test : Select 10 evenly distributed test points on the reference block, use the test conditions corresponding to the calibration range (such as 10/3000 or 5/2500), and test each point once.

Calculation : Record the indentation diameter for each measurement and calculate the average HBW value, standard deviation and uncertainty.

Verification : Compare the average value with the known reference value, the deviation is ≤ ±0.5 HBW; if it exceeds, adjust the testing machine or replace the reference block.

Carbide adjustment : Using HBW 450 reference block, test 15 points with standard deviation ≤ ±0.4 HBW to ensure uniformity and accuracy of high hardness section.

6.3 Uncertainty assessment

Sources of uncertainty include testing machine load error (±0.5%), measurement system error (±0.01 mm),

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environmental effects, and material uniformity.

Calculation method : According to ISO/IEC 17025 guidelines, by combining uncertainty components, the maximum uncertainty is ≤ ±0.5 HBW.

Supplementary information on cemented carbide : The uncertainty of high hardness reference blocks (HBW 400-600) requires special attention to the influence of WC particle size (10-20 μm) and Co phase distribution.

---

7. Calibration certificate

Contents : Includes reference block number, material composition, hardness value (average and range), deviation, uncertainty, calibration date, testing machine information and authorized laboratory identification.

Carbide Supplement : Co content (6-12%), WC grain size (10-20 μm) and surface roughness (Ra ≤ 0.2 μm) are recorded to support high-precision applications.

---

8. Appendix (Reference Information)

Table 1: Reference block hardness range and test point number

Hardness range (HBW)	Recommended test points	Test conditions (mm/kgf)
8-100	8	2.5/62.5
100-300	10	5/750
300-650	15	10/3000

Figure 1: Reference block calibration flow chart (showing test point distribution and calculation steps).

Carbide example : A laboratory calibrated a HBW 450 reference block using 5/2500 test conditions. The 10-point average was 452 HBW, with a deviation of ±0.3 HBW and an uncertainty of ±0.4 HBW, meeting standard requirements.

---

9. Conclusions and Recommendations

ISO 6506-3:2014 provides standardized calibration methods for Brinell hardness test reference blocks, ensuring the accuracy and traceability of hardness values. For carbide, we recommend using HBW 400-600 reference blocks, regular calibration (every six months), and ensuring surface preparation (Ra ≤ 0.2 μm) to minimize errors. For higher accuracy, calibration by an authorized laboratory can be performed in conjunction with an ISO 6506-2 validated testing machine.

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GB/T 15020 :

Terminology for hardness testing of metallic materials

Preface

With the widespread application of metal material hardness testing in industrial production and scientific research, a unified terminology system is crucial for standardizing test methods, promoting technical exchange, and implementing standards. GB/T 15020, issued by the Standardization Administration of China, defines the terms and definitions related to metal material hardness testing. This article will provide a detailed analysis of GB/T 15020, including its scope, term classification, technical definitions, and application. It will specifically expand on the terminology used in cemented carbide testing to enhance its practical reference value and academic significance.

---

1. Scope

Applicable objects: GB/T 15020 specifies the terms and definitions in the field of hardness testing of metallic materials, and is applicable to test methods such as Brinell hardness (HB), Rockwell hardness (HR), Vickers hardness (HV), and Knoop hardness (HK).

Test scope: Covers hardness test equipment, indenters, loads, indentation measurement, calculation methods and result presentation, and is applicable to the unified terminology from soft metals (such as aluminum alloys) to high-hardness materials (such as cemented carbide HV 1000-2000).

Special applicability: Particularly suitable for the definition of terms related to cemented carbide coatings (such as TiN), thin layer materials and microscopic areas, with an emphasis on high-precision testing.

Limitation: Does not include terminology for hardness testing of non-metallic materials, which requires reference to other standards.

---

2. Normative References

GB/T 231.1: Brinell hardness test for metallic materials - Part 1: Test method.

GB/T 4340.1: Vickers hardness test for metallic materials - Part 1: Test method.

GB/T 230.1: Rockwell hardness test for metallic materials - Part 1: Test method.

GB/T 4341: Knoop hardness test for metallic materials.

Note: The above standards are subject to the latest version to ensure consistency between term definitions and test methods.

---

3. Terms and Definitions

GB/T 15020 divides hardness testing terms into the following main categories and provides detailed definitions. The following are some key terms and their explanations, especially expanded for cemented carbide testing:

3.1 Basic Terminology

3.1.1 Hardness:

The ability of a material to resist indentation or scratching by an external force, usually quantified by the characteristics of the indentation or scratch.

Cemented carbide expansion: High hardness materials (such as YG6 HV 1400-1600) need to be evaluated in combination with the microstructure (such as WC-Co phase).

3.1.2 Hardness Value

The numerical representation of the hardness test result, such as HBW, HRA, HV, reflects the material's ability to resist deformation.

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Cemented carbide extension: The coating hardness (e.g. TiN HV 2000) must be marked with a separate test force (e.g. HV0.1).

3.2 Test equipment related terms

3.2.1 Indenter:

A hard tool used to apply test force, such as a steel ball, diamond cone, or square pyramid.

Carbide expansion: It is recommended to use a diamond indenter with a hardness ≥ HV 12000 for testing in the HV 1000-2000 range.

3.2.2 Test Force:

The load applied to the indenter, in N or kgf, with a range varying depending on the method (e.g. Brinell 31.25-3000 kgf).

Carbide expansion: Micro testing (such as HV0.1) uses 0.1-1 kgf, macro testing (such as HBW 5/2500) uses 2500 kgf.

3.2.3 Hardness Tester:

An instrument used for hardness testing, including load application and indentation measurement systems.

Carbide expansion: High-precision load control (±0.2%) and micron-level measurement capabilities are required.

3.3 Terminology related to indentation measurement

3.3.1 Indentation:

The mark formed by the indenter pressing into the surface of the specimen. The shape varies depending on the method (e.g., Brinell circle, Vickers square).

Cemented carbide expansion: Cracks should be avoided when indenting high hardness materials, and the coating indentation diameter should be less than the coating thickness.

3.3.2 Indentation Diameter:

The average diameter of the indentation in Brinell hardness, in mm.

Carbide expansion: 5 mm ball/2500 kgf The indentation diameter is about 2-3 mm.

3.3.3 Diagonal Length of Indentation:

The average diagonal length of the indentation in Vickers or Knoop hardness measurement, in μm.

Carbide expansion: HV10 diagonal length is about 50-100 μm.

3.4 Terms related to test conditions

3.4.1 Preliminary Test Force:

The smaller load (e.g., 10 kgf) used to bring the indenter into contact with the test piece in Rockwell hardness testing.

Carbide expansion: The initial test force of the HRA scale must be stable to ±0.1 kgf.

3.4.2 Total Test Force:

The initial test force plus the main test force, such as HRA 60 kgf.

Carbide Expansion: HRA The total test force needs to be precisely controlled to penetrate the coating.

3.4.3 Dwell Time:

The time the test force is maintained after it is applied, in seconds.

Carbide expansion: 15-20 seconds is recommended to ensure stable indentation in high hardness materials.

3.5 Terms related to result representation

3.5.1 Repeatability refers

to the degree of dispersion of test results under the same conditions, expressed in hardness values.

Carbide expansion: HV test repeatability ≤ ±3 HV.

3.5.2 Uncertainty

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The uncertainty range of hardness value measurement reflects the accuracy of the measurement system.

Carbide expansion: HV 1000-2000 Uncertainty ≤ ±0.2 HV.

3.6 Terminology specific to cemented carbide

3.6.1 Microhardness:

The local hardness measured using a low test force (0.01-1 kgf) and is applicable to coatings or small areas.

Example: YG6 coating HK0.1 200-300.

3.6.2 High-Hardness Material:

Materials with a hardness value higher than HV 1000 or HRA 80, such as cemented carbide.

Example: YT15 HV 1600.

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4. Terminology Application

Classification basis: Terms are categorized by test method (Brinell, Rockwell, Vickers, Knoop), equipment, measurement, and results to facilitate cross-standard use.

Cemented carbide scenario: For example, in GB/T 231.1 (Brinell), cemented carbide uses the 5/2500 condition, and the term "indentation diameter" needs to be defined in conjunction with the large-diameter indenter.

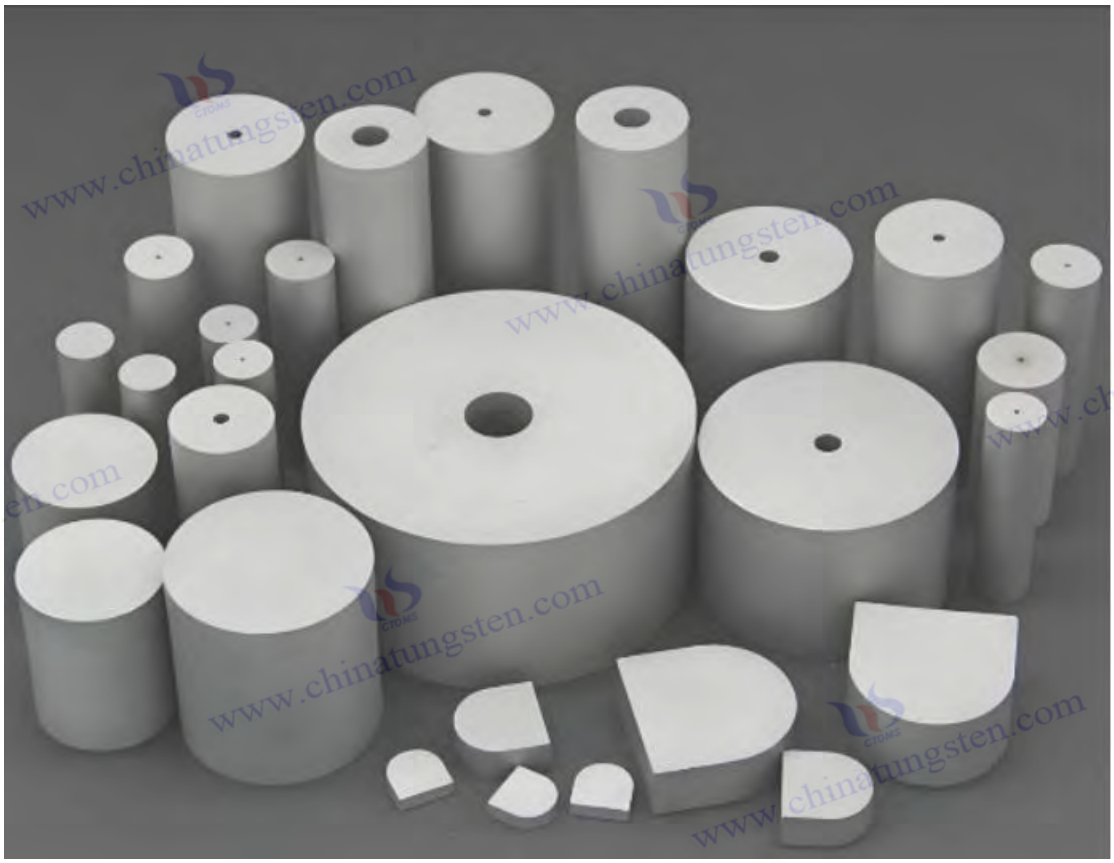
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5. Appendix (Reference Information)

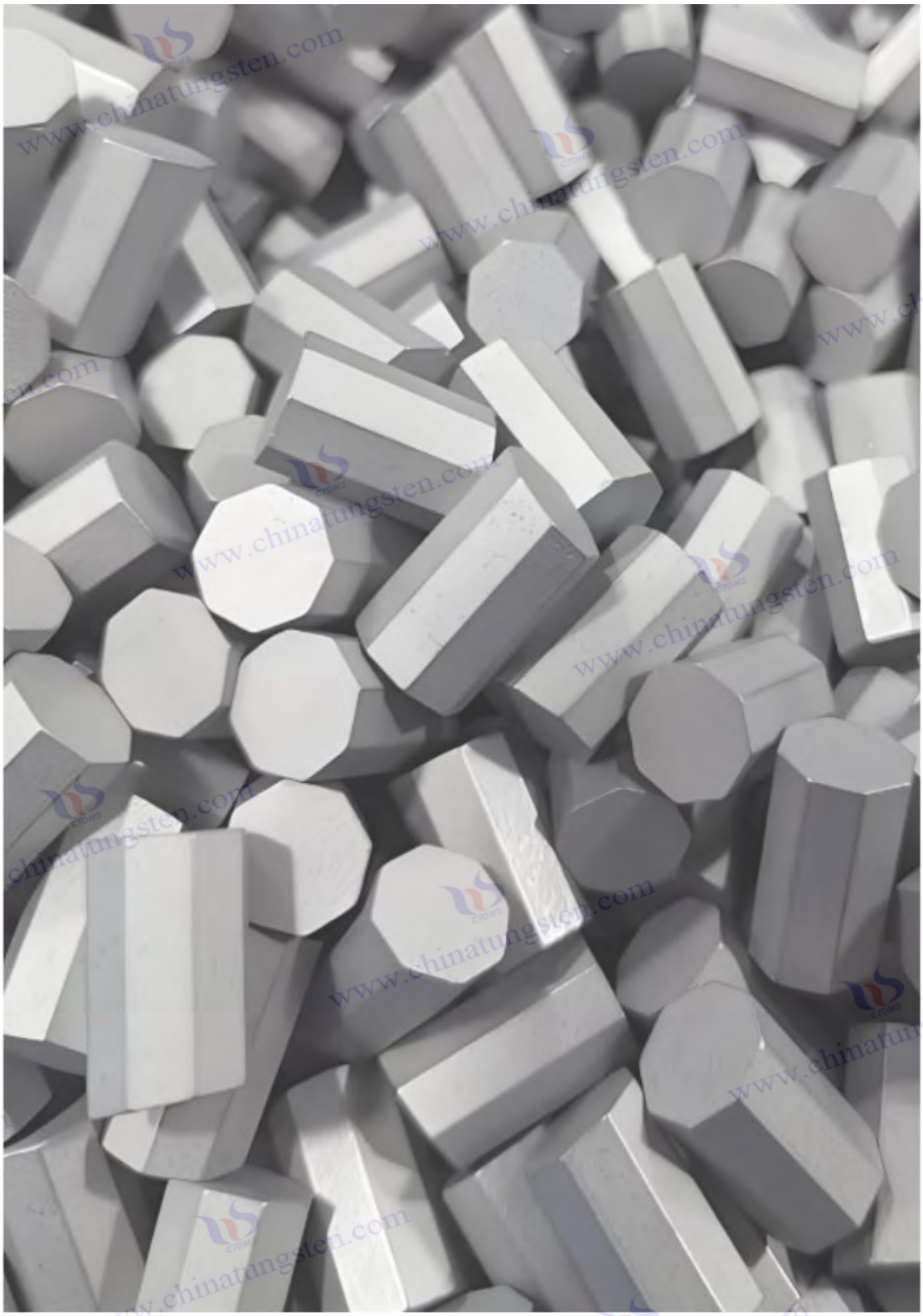
Table 1: Common terms and methods

the term	Brinell (HBW)	Rockwell (HR)	Vickers (HV)	Knox (HK)
Indentation shape	round	round	Square	diamond
Test force range (kgf)	31.25-3000	10-150	0.01-120	0.01-1
Measurement parameters	diameter	depth	diagonal	Long diagonal

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Cemented carbide related standards

1.1 Summary of ISO, ASTM and GB cemented carbide standards

ISO cemented carbide standards

ISO 513:2012 Classification and application of cemented carbide tool materials

ISO 3369:2006 Determination of density of cemented carbide

ISO 3327:2009 Hardness test of cemented carbide

ISO 28079:2009 Wear and life test of cemented carbide tools

ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework

ASTM cemented carbide standards

ASTM B40696(2015) Transverse Fracture Strength Test of Cemented Carbide

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ASTM B61113 Abrasive Wear Test of Cemented Carbide

ASTM E40707(2015) Microstructure Analysis of Cemented Carbide

ASTM G6516 Dry Sand/Rubber Wheel Wear Test of Cemented Carbide

GB cemented carbide standard

GB/T 18376:2014 Classification and Properties of Cemented Carbide Tool Materials;

GB/T 34506:2017 Hardness and Microstructure Testing of Cemented Carbide;

GB/T 34639:2017 Chemical Composition Analysis of Cemented Carbide;

GB/T 38499: 2020 Cemented Carbide Recycling Technical Specifications; Recycling Rate 94%±2%.

1.2 Performance test methods and specifications of cemented carbide (hardness, toughness, density, etc.)

What are the Chinese standards for cemented carbide ?

1. Cemented carbide classification and grade standards

GB/T 18376.1-2015: Cemented carbide grades Part 1: Cemented carbide grades for cutting tools

GB/T 18376.2-2015: Cemented carbide grades Part 2: Cemented carbide grades for geological and mining tools

GB/T 18376.3-2015: Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts

GB/T 20705-2006: Classification and application of cemented carbide grades

JB/T 12716-2016: Cemented Carbide Grade Designation

2. Cemented Carbide Performance and Test Method Standards

GB/T 18377-2001: Test method for Vickers hardness of cemented carbide

GB/T 18378-2001: Test method for flexural strength of cemented carbide

GB/T 18379-2001: Test method for compressive strength of cemented carbide

GB/T 18380-2001: Test method for fracture toughness of cemented carbide

GB/T 3488.1-2016: Evaluation of cemented carbide microstructure Part 1: Grain size

GB/T 3488.2-2016: Evaluation of cemented carbide microstructure Part 2: Defects and abnormal structures

GB/T 5243-2008: Chemical analysis methods for cemented carbide

GB/T 38522-2020: Test method for corrosion performance of cemented carbide

3. Cemented carbide product standards

GB/T 1832-2017: Indexable inserts for cutting tools — Marking

GB/T 20707-2006: Geometric dimensions and tolerances of cemented carbide inserts

GB/T 20708-2006: Surface quality inspection of cemented carbide inserts

JB/T 4127-2016: Carbide Cold Heading Dies

JB/T 4128-2016: Carbide Wire Drawing Dies

JB/T 12609-2016: Cemented Carbide Geological Mining Tools

YS/T 1044-2015: Carbide Nozzles

4. Cemented carbide production and processing standards

GB/T 20706-2006: Specification for cemented carbide powder metallurgy process

GB/T 3489-2016: Inspection method for sintering defects of cemented carbide

JB/T 12608-2016: Technical requirements for cemented carbide electrospark machining

JB/T 12607-2016: Technical Requirements for Cemented Carbide Grinding

5. Other relevant standards

GB/T 16780-2021: Energy consumption indicators for the cement industry

YS/T 1045-2015: Cemented Carbide Agricultural Wear Parts

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JB/T 12899-2016: Cemented Carbide Surface Modification Technology

6. Main cemented carbide grades and applications (reference standards)

Tungsten-cobalt series (YG series) :

Brand: YG3, YG6, YG8, YG15, YG20

Tungsten-titanium-cobalt (YT series) :

Brand: YT5, YT15, YT30

General type (YW series) :

Brand: YW1, YW2, YA6

Summary table of relevant standards for cemented carbide in China

GB/T 20705-2006 Classification and application of alloy grades

JB/T 12716-2016 Cemented Carbide Grade Indication Method

GB/T 18376.3-2015 Cemented Carbide Grades Part 3: Cemented carbide grades for wear-resistant parts

GB/T 18376.2-2015 Cemented Carbide Grades Part 2: Cemented carbide grades for geological and mining tools

GB/T 18376.1-2015 Cemented Carbide Grades Part 1: Cemented carbide grades for cutting tools

GB/T 20707-2006 Geometrical dimensions and tolerances of cemented carbide inserts

JB/T 12609-2016 Cemented Carbide Geological Mining Tools

YS/T 1045-2015 Cemented Carbide Agricultural Wear-Resistant Parts

International Organization for Standardization (ISO) cemented carbide standards

ISO 513:2012 Classification and application of cemented carbide tool materials

Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation of the main groups and groups of application

Classification and application of hard cutting materials - Designation of main groups and application groups

ISO 1832:2017 Indexable inserts for cutting tools — Marking

ISO 1832:2017 Indexable inserts for cutting tools — Designation

ISO 513:2011 Classification and application of hard cutting materials for metal removal with defined cutting edges — Designation

ISO 513:2011 Classification and application of hard cutting materials - Designation of defined cutting edges for metal removal

ISO 3364:2017 Indexable hardmetal (carbide) inserts with rounded corners, with cylindrical fixing hole — Dimensions

ISO 3364:2017 Indexable carbide inserts with corner radii and cylindrical fixing holes — Dimensions

ISO 3365:2016Indexable hardmetal (carbide) inserts with wiper edges, without fixing hole — Dimensions

ISO 3365:2016 Indexable carbide inserts with wiper edge and no fixing hole - Dimensions

ISO 5608:1995 Turning and copying tool holders and cartridges for indexable inserts

ISO 5608:1995 Turning and profiling toolholders and indexable insert chucks - marking

ISO 883:2013 Indexable hardmetal (carbide) inserts with rounded corners, with partly cylindrical fixing hole — Dimensions

ISO 883:2013 Indexable carbide inserts with rounded corners and partially cylindrical fixing holes - dimensions

ISO 6987:2012Indexable hardmetal (carbide) inserts with rounded corners, with partly cylindrical fixing hole — Dimensions

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ISO 6987:2012 Indexable carbide inserts with rounded corners and partially cylindrical fixing holes - dimensions

ISO 16462:2014 Cubic boron nitride inserts, tipped or solid — Dimensions, types

ISO 16462:2014 Cubic boron nitride inserts, pointed or solid — sizes, types

ISO 16463:2014 Polycrystalline diamond inserts, tipped — Dimensions, types

ISO 16463:2014 Polycrystalline diamond blades, tipped - sizes, types

ISO 3002-1:1982 Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers Fundamentals of cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terminology, reference systems, tool and machining angles, chipbreakers

ISO 3002-1:1982 Fundamentals of cutting and grinding - Part 1:

Geometry of the active part of the cutting tool - general terminology, reference frames, tool and machining angles, chipbreakers

ISO/TS 13399-80:2017 Cutting tool data representation and exchange — Part 80: Creation and exchange of 3D models — Overview and principles

(Cutting tool data representation and exchange — Part 80: Creation and exchange of 3D models — Overview and principles)

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3D Model Creation and Exchange — Overview and Principles

ISO 13399-1:2006 Cutting tool data representation and exchange — Part 1: Overview, fundamental principles and general information model

Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model

ISO 13399-1:2006 Cutting tool data representation and exchange — Part 1: Overview, basic principles and common information model

ISO 13399-2:2005Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items

Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items

ISO 13399-2:2005 Cutting tool data representation and exchange — Part 2: Reference dictionary for cutting items

ISO 13399-3:2014 Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items

Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items

ISO 13399-3:2014 Cutting tool data representation and exchange — Part 3: Reference dictionary for tool items

ISO 1832:2017 Indexable inserts for cutting tools — Designation

Indexable inserts for cutting tools - identification.

ISO 1832:2017 Indexable inserts for cutting tools - marking

ISO 3369:2006 Density determination of cemented carbide

ISO 3327:2009 ardmetals—Determination of transverse rupture strength

Cemented carbide — Determination of transverse rupture strength

ISO 28079:2009 Wear and life testing of cemented carbide cutting tools

Hardmetals — Palmqvist toughness test

American Society for Testing and Materials (ASTM) standards

ASTM B40696(2015) Test Method for Transverse Rupture Strength of Cemented Carbide

ASTM B40696 (2015) Test Method for Transverse Fracture Strength of Tungsten Cemented Carbide

ASTM B61113 Standard Test Method for Determining the High Stress Abrasion Resistance of Hard Materials

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ASTM B61113 Test Method for Abrasive Wear of Cemented Carbide

ASTM E40707(2015) Standard Practice for Microetching Metals and Alloys

ASTM E40707(2015) Standard Practice for Microetching of Metals and Alloys

ASTM G6516 Test Method for Measuring Abrasive Wear Using a Dry Sand/Rubber Wheel Device

Test method for measuring abrasive wear using a dry sand/rubber wheel apparatus

China National Standard (GB) Cemented Carbide Standard

GB/T 18376-2014 Classification and properties of cemented carbide tool materials

Classification and Properties of Cemented Carbide Cutting Tool Materials

GB/T 345062017 Hardness and microstructure test of cemented carbide

Test Methods for Hardness and Microstructure of Cemented Carbides

GB/T 230.1:2009 Rockwell hardness test for metallic materials—Part 1: Test method (A, B, C, D, E, F, G, H, K, N, T scales)

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GB/T 18378-2001 Methods for observing the microstructure of cemented carbide

GB/T 3488:2015 Cemented carbide microstructure evaluation method

GB/T 183752001 Test method for density of cemented carbide

GB/T 346392017 Chemical composition analysis of cemented carbide

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Physical and chemical properties of WC, Co, and Ni

Common cemented carbide grades and properties

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Typical properties of cemented carbide tool materials

Chinese cemented carbide grades and performance table

International main cemented carbide grades and performance table

Sandvik carbide grades and properties comparison table

Kennametal carbide grades and performance comparison table

Mitsubishi Carbide Grade and Performance Comparison Table

Iscar cemented carbide grades and performance comparison table

Seco Tools Carbide Grade and Performance Comparison Table

Walter Tools Carbide Grade and Performance Comparison Table

Ceratizit Carbide Grade and Performance Comparison Table

Kyocera Carbide Grade and Performance Comparison Table

Tungaloy carbide grades and properties comparison table

Sumitomo Electric Carbide Grade and Performance Comparison Table

Cemented Carbide and Superhard Materials Terminology in Chinese, English, Japanese, Korean and German (including tool, process and product terms)

1. Material composition and classification

2. Physical and mechanical properties

3. Production tools and process names

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4. Terminology of cemented carbide and superhard material products

Cemented Carbide Product Classification Table

1. Cemented carbide for cutting tools

1.1 Bar

Cemented carbide for cutting tools

1.2 Board

1.3 Pipe

1.4 Special-shaped parts

1.5 Cemented carbide mixture powder

1.6 Carbide particles

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1.8 Coating substrate

Cemented Carbide Product Classification Table

Cemented carbide for geological and mining tools

Mining and drilling tools

Carbide pipes

Carbide for cutting tools

Ball/round products

GB/T 5124.4-2008 Chemical analysis methods for cemented carbide - Part 4: Determination of titanium, niobium and tantalum by inductively coupled plasma atomic emission spectrometry

GB/T 5124.3-2008 Chemical analysis methods for cemented carbide - Part 3: Gravimetric determination of free carbon

GB/T 5124.2-2008 Chemical analysis methods for cemented carbide - Part 2: Gravimetric determination of total carbon content

GB/T 5124.1-2008 Chemical analysis methods for cemented carbide - Part 1: Determination of cobalt, iron and nickel by inductively coupled plasma atomic emission spectrometry

YS/T 1045-2015 - Cemented Carbide Agricultural Wear Parts

JB/T 4127-2016 - Carbide cold heading dies

ISO 513:2012 - Classification and use of hard cutting materials — Designation of cutting materials for metal removal with a defined cutting edge

GB/T 18376.1-2001 - Cemented carbide grades Part 1: Cemented carbide grades for cutting tools

GB/T 18376.1-2015- Cemented carbide grades Part 1: General purpose cemented carbide grades

GB/T 20708-2006 - Surface quality inspection of cemented carbide inserts

ISO 1832:2004 - Indexable inserts for cutting tools — Marking

GB/T 18376.2-2015 - Cemented carbide grades Part 2: Cemented carbide grades for cutting

GB/T 18376.3-2015 - Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts

GB/T 18376.3-2015 - Cemented carbide grades Part 3: Cemented carbide grades for wear-resistant parts

GB/T 1832-2017 - Marking of cutting tool inserts

YS/T 1044-2015 - Carbide Nozzles

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Indexable inserts for cutting tools — Designation
ISO 86881:1989 Tool life testing in milling— Part 1: Face milling
ISO 86881:1989 - Tool life testing in milling — Part 1: Face milling
ISO 86882:1989 Tool life testing in milling — Part 2: End milling
Tool Life Testing in Milling — Part 2: End Milling
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ISO 513:2011 Classification and use of hard cutting materials — Designation of cutting edges for metal removal
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— General conversion formula
ISO 513:2011 - Classification and use of hard cutting materials for metal cutting — Designation of principal classes and application classes
ISO 5609 - Internal turning tool holders with indexable inserts and cylindrical shanks
ISO 1832 - Cutting tools — Indexable inserts — Dimensions and designation
ISO 2768 - General tolerances — Linear and angular dimensions
ISO 5608:1995 - Turning and profiling toolholders and indexable insert holders — Marking
ASTM B243- Standard Terminology of Powder Metallurgy
ASTM B243 - Standard Terminology for Powder Metallurgy
ASTM E7- Standard Terminology Relating to Metallography
ASTM E7 - Standard Terminology Relating to Metallography
ASTM B243- Standard Terminology of Powder Metallurgy
ASTM B243 - Standard Terminology for Powder Metallurgy
ASTM E177- Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods
ASTM E177 - Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods
ASTM G40- Standard Terminology Relating to Wear and Erosion
ASTM G40 - Standard Terminology Relating to Wear and Erosion
ASTM E3- Standard Guide for Preparation of Metallographic Specimens
ASTM E3 - Standard Guide for Preparation of Metallographic Specimens of Metals and Alloys
ASTM E112- Standard Test Methods for Determining Average Grain Size
ASTM E7 - Standard Terminology Relating to Metallography
ASTM E112- Standard Test Methods for Determining Average Grain Size
ASTM E112 - Standard Test Method for Determining Average Grain Size
ASTM E340- Standard Practice for Macroetching Metals and Alloys
ASTM E340 - Standard Practice for Macroetching of Metals and Alloys
GB/T 13239 Preparation and dimensions of tensile test specimens for metallic materials
GB/T 16825.1 Materials testing machines - Verification of static testing machines - Part 1: Tension, compression

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and bending tests

GB/T 228.1-2010 Tensile testing of metallic materials Part 1: Room temperature test method

GB/T 7997-2012 Test method for Vickers hardness of cemented carbide

GB/T 18377-2001 Test method for flexural strength of cemented carbide

GB/T 15020 Terminology for Hardness Testing of Metallic Materials

JG 112 Metal Rockwell Hardness Tester (A, B, C, D, E, F, G, H, K, N, T scales)

GB/T 230.2-2012 Rockwell hardness test for metallic materials

Part 2: Verification and calibration of testing machines (A, B, C, D, E, F, G, H, K, N, T scales)

GB/T 230.3-2012 Rockwell hardness test for metallic materials

Part 3: Calibration of standard hardness blocks (A, B, C, D, E, F, G, H, K, N, T scales)

GB/T 230.12009 Rockwell hardness test for metallic materials

Part 1: Test methods (A, B, C, D, E, F, G, H, K, N, T scales)

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GB/T 3488:2015 Cemented carbide microstructure evaluation method

GB/T 18375-2001 Test method for density of cemented carbide

Rockwell, Vickers, and Brinell Hardness Testing: Theory, Methods, and a Guide to Cemented Carbide Applications

STM E140 metal hardness conversion table, covering the relationship between Brinell, Vickers, Rockwell and other hardness

ISO 6508-1:2016: Metallic materials — Rockwell hardness test — Part 1: Test method

ISO 6508-2:2015: Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines

ISO 6508-3:2015: Metallic materials — Rockwell hardness test — Part 3: Calibration of reference blocks

ASTM E18 : Standard Method for Rockwell Hardness Testing of Metallic Materials

ISO 6507: Metallic materials — Vickers hardness test

ISO 6507-2:2018: Metallic materials — Vickers hardness test — Part 2: Verification and calibration of testing machines

ISO 6507-3:2018: Metallic materials — Vickers hardness test — Part 3: Calibration reference blocks

ASTM E92: Standard Test Method for Vickers Hardness and Knoop Hardness of Metallic Materials

ISO 6506: Metallic materials — Brinell hardness test

ISO 6506-2:2014: Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines

ISO 6506-3:2014: Metallic materials — Brinell hardness test — Part 3: Calibration reference blocks

GB/T 15020: Terminology for hardness testing of metallic materials

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CTIA GROUP LTD

30 Years of Cemented Carbide Customization Experts

Core Advantages

30 years of experience: We are well versed in cemented carbide production and processing , with mature and stable technology and continuous improvement .

Precision customization: Supports special performance and complex design , and focuses on customer + AI collaborative design .

Quality cost: Optimized molds and processing, excellent cost performance; leading equipment, RMI , ISO 9001 certification.

Serving Customers

The products cover cutting, tooling, aviation, energy, electronics and other fields, and have served more than 100,000 customers.

Service Commitment

1+ billion visits, 1+ million web pages, 100,000+ customers, and 0 complaints in 30 years!

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