

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

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 12 Cemented Carbide Wear-Resistant Parts and Surface Engineering

12.0 Overview of Cemented Carbide Wear-Resistant Parts and Surface Engineering

Carbide wear-resistant parts play an important role in modern industry due to their excellent mechanical properties and durability. Their high hardness (HV 1600-2500±30), excellent wear resistance (wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$) and excellent impact resistance (impact energy $>50 \text{ J} \pm 5 \text{ J}$) make them the preferred materials for applications such as molds, seals, nozzles, mining drills and surface coatings. The performance parameters of these parts show significant advantages in practical applications, such as mold life of $>10^6$ times $\pm 10^5$ times, seal leakage rate as low as $<0.01 \text{ mL/min} \pm 0.001 \text{ mL/min}$, nozzle flow deviation controlled at $<1\% \pm 0.1\%$, mining drill life of more than 100 hours ± 10 hours, and surface coating thickness range of $50\text{-}500 \mu\text{m} \pm 1 \mu\text{m}$. Through geometric optimization (such as stress concentration coefficient $K_t < 1.3 \pm 0.05$), thermal spraying technology (such as WC-Co, bonding strength $>70 \text{ MPa} \pm 1 \text{ MPa}$) and surface strengthening technology (such as laser cladding, hardness HV 2000-3000±50), the performance of cemented carbide wear-resistant parts has been significantly improved, and the wear resistance can be reduced by $30\% \pm 5\%$, effectively extending the service life and improving work efficiency.

12.0.1 Concept of Cemented Carbide Wear-Resistant Parts

Cemented carbide wear-resistant parts refer to high-performance wear-resistant parts made by powder metallurgy process with hard phases such as tungsten carbide (WC), titanium carbide (TiC) or niobium carbide (NbC) as the matrix, supplemented by metal binding phases such as cobalt (Co) and nickel (Ni). These parts have ultra-high wear resistance because their grain size is usually in the range of 0.2-2 microns, and are particularly suitable for industrial applications under high loads, frequent friction or extreme environments. The wear resistance of cemented carbide comes from the balance between its high hardness and appropriate toughness. The hardness value is usually between Vickers hardness (HV) 1600-2500, which is far higher than traditional steel (HV 200-600), and by adding trace elements or composite materials (such as WC-Co system), its impact resistance can reach more than 50 J, which is enough to cope with mechanical shock and thermal stress. The design goal of wear-resistant parts is not only to extend the service life (for example, the mold can withstand millions of stamping cycles), but also to ensure stability under complex working conditions. For example, seals need to maintain a small leakage rate and nozzles need to ensure precise flow. These characteristics make them indispensable in the manufacturing, mining and energy industries.

12.0.2 Definition and significance of surface engineering

Surface engineering is a technology that modifies or coats the surface of materials by physical, chemical or mechanical methods, aiming to improve the wear resistance, corrosion resistance, high temperature resistance or biocompatibility of parts. In cemented carbide wear-resistant parts, surface

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engineering significantly enhances the surface performance through processes such as thermal spraying, laser cladding, and ion implantation. For example, thermal spraying technology can deposit WC-Co coating on the substrate, with a bonding strength of more than 70 MPa and a thickness controllable within the range of 50-500 microns, significantly improving wear resistance; laser cladding forms a metallurgical bonding reinforcement layer through local melting and rapid solidification, with a hardness of up to HV 2000-3000, and a wear resistance rate reduced by about 30%, effectively extending the life of the parts. The core of surface engineering is to optimize the surface microstructure, reduce stress concentration ($K_t < 1.3$), improve fatigue resistance, and maintain the overall mechanical properties of the base material. This technology is particularly important in cemented carbide applications, because the surface is the area where the part is in direct contact with the external environment, and its performance directly affects the reliability and service life of the entire component.

12.0.3 Application Background and Development of Cemented Carbide Wear- Resistant Parts and Surface Engineering Technology

The combination of cemented carbide wear-resistant parts and surface engineering technology benefits from the demand of modern industry for efficient and durable equipment. With the development of intelligent manufacturing, green energy and extreme environment mining, the application scenarios of cemented carbide continue to expand. For example, in mold manufacturing, cemented carbide parts meet the needs of high-precision stamping and complex forming through geometric optimization and surface strengthening; in mining drilling, the increase in the life of wear-resistant drill bits directly reduces the replacement frequency and operating costs. Advances in surface engineering technologies, such as nano-coatings and multi-layer composite coatings, have further promoted the application of cemented carbide in high-tech fields, such as aerospace components and medical devices. In addition, combined with digital twin technology and real-time monitoring, surface engineering can achieve dynamic performance optimization and adapt to diverse working conditions.

multiple aspects such as wear-resistant parts, thermal spraying applications, mining and drilling, and surface strengthening technology . By deeply exploring material properties, processing technology, and application scenarios, it aims to provide theoretical support and practical guidance for related industries, especially in performance optimization and innovative applications under high load and high wear environments.

12.1 Cemented Carbide Wear-Resistant Parts

Cemented carbide wear-resistant parts achieve high wear resistance (wear rate $< 0.05 \text{ mm}^3 / \text{N} \cdot \text{m}$ $\pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$) and long service life ($> 10^6$ times $\pm 10^5$ times) through optimized geometric design (radius of curvature $> 0.5 \text{ mm} \pm 0.01 \text{ mm}$), material ratio (WC $> 90\% \pm 1\%$, Co $6\% - 12\% \pm 1\%$) and precision processing (sintering temperature $1450^\circ\text{C} \pm 10^\circ\text{C}$) . These parts perform well in industrial environments with high loads and frequent friction. Their performance is due to the

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balance between the high hardness (HV 1600-2200±30) and appropriate toughness (fracture toughness K_{IC} 10-20 MPa·m^{1/2} ± 0.5) of cemented carbide materials. Carbide wear-resistant parts are widely used in various fields, including carbide dies (for stamping and forming), carbide seals (for preventing fluid leakage) and carbide nozzles (for precise injection). Their design needs to take into account both wear resistance and impact resistance to meet the needs of diverse working conditions.

12.1.1 Concept of cemented carbide wear-resistant parts

Cemented carbide wear-resistant parts are composite materials sintered by powder metallurgy process with tungsten carbide (WC) as the main hard phase and cobalt (Co) as the binding phase. The WC content is usually more than 90% ± 1%, providing high hardness as a hard skeleton, while the Co content is between 6%-12% ± 1%, which acts as a binding phase to enhance toughness and impact resistance. The best balance between hardness and toughness can be achieved by adjusting the ratio. The sintering process is carried out at a high temperature of 1450°C ± 10°C, using vacuum or argon to protect the environment, ensuring that the grain size is controlled within the range of 0.5-2 microns, thereby obtaining excellent wear resistance (wear rate <0.05 mm³ / N · m). This low wear rate allows it to maintain dimensional stability in long-term use. For example, the mold can withstand more than one million stampings, while the seals and nozzles need to maintain a small leakage rate (<0.01 mL/min) and flow deviation (<1%). The geometrically optimized curvature radius (>0.5 mm) design effectively reduces stress concentration and prolongs the life of parts, while its impact resistance (impact energy >50 J) ensures reliability under dynamic loading. In addition, cemented carbide wear-resistant parts can be further improved in high temperature performance and oxidation resistance by adding trace elements (such as tantalum carbide TaC or niobium carbide NbC) to adapt to more demanding industrial environments.

12.1.2 Characteristics of cemented carbide wear-resistant parts

The characteristics of cemented carbide wear-resistant parts are reflected in their unique microstructure and physical properties. High hardness (HV 1600-2200±30) makes it resistant to surface wear and is particularly suitable for machining high-hardness materials (such as hardened steel HRC 50-60 or titanium alloy HRC 30-35), while fracture toughness K_{IC} 10-20 MPa·m^{1/2} ± 0.5 ensures the structural integrity of the parts under shock or vibration conditions. In addition, cemented carbide also has excellent corrosion resistance (durability >1000 hours in acidic or alkaline environments) and high temperature stability (operating temperature can reach 800°C±50°C), which makes it outstanding in the chemical, energy and metallurgical fields. Thermal conductivity (about 80-120 W / m · K) also helps to dissipate heat and reduce thermal damage during cutting or friction. The surface roughness (Ra 0.1-0.5 microns) after precision polishing further improves the contact performance and service life of the parts. These properties together constitute the competitive advantage of cemented carbide wear-resistant parts under high-intensity working conditions.

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12.1.3 Performance balance of cemented carbide wear-resistant parts

The performance optimization of cemented carbide wear-resistant parts is inseparable from the coordination of hardness and toughness. The hardness range HV 1600-2200±30 provides excellent resistance to surface wear, and is particularly suitable for the processing of high-hardness workpieces (such as hardened steel HRC 50-60); at the same time, the fracture toughness K_{IC} 10-20 MPa·m^{1/2} ± 0.5 ensures that the parts are not easy to crack when encountering mechanical shock or thermal stress. This balanced characteristic makes cemented carbide wear-resistant parts perform well in applications such as mold forming, sealing and leak prevention, and injection control. For example, the mold needs to withstand high-frequency impact (hundreds of times per minute), the seal needs to resist corrosive media (such as sulfuric acid or salt water), and the nozzle needs to precisely control fluid dynamics (flow deviation <1%). These requirements are achieved through fine regulation of materials and processes. In addition, through heat treatment (such as low-temperature tempering 500°C±20°C) or surface coating (such as TiN or CrN), the hardness can be further enhanced (increase of 10%-20%) or the friction coefficient can be reduced (<0.3), thereby optimizing the performance in specific application scenarios.

12.1.4 Application of Cemented Carbide Wear-Resistant Parts

have shown extensive and diverse application value in the industrial field due to their high hardness (HV 1600-2500), excellent wear resistance (wear rate <0.05 mm³ / N · m) and impact resistance (impact energy >50 J). The following systematically organizes and optimizes their applications according to application fields and functional logic, covering traditional manufacturing, emerging high-tech industries and usage scenarios in special environments.

(1) Metal processing and forming

Carbide mold

Widely used in metal stamping, plastic injection molding and powder metallurgy molds, it has high wear resistance and dimensional stability, with a typical life of more than 10⁶ times. Especially in the automotive manufacturing industry (such as engine blocks and transmission parts) and electronic component production (such as mobile phone housings and circuit board connectors), its high hardness (HV 1600-2200) ensures accuracy and durability under long-term high-frequency use, especially in smart manufacturing to support the precision molding of complex geometries.

Carbide cutting tools

It is used for high-speed cutting (such as turning, milling and drilling) in metal processing and wood processing. Due to its high hardness (HV 1800-2500) and resistance to high-temperature oxidation (heat resistance up to 900°C), it performs well in aerospace (such as titanium alloy parts) and automobile manufacturing (such as engine crankshafts). The cutting speed can reach 200-300 m/min and the service life can reach 200-300 hours.

Carbide extrusion die

For aluminum profiles and plastic extrusion, with a temperature resistance of up to 600°C, a

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hardness of HV 1700-2100, and a dimensional accuracy of ± 0.01 mm, it is widely used in the construction industry (such as aluminum alloy doors and windows) and packaging material production to ensure efficient molding and surface quality.

(2) Fluid control and sealing

Carbide seals

Used in pumps, valves and compressors to prevent fluid or gas leakage, with a leakage rate of < 0.01 mL/min. Its excellent corrosion resistance and low friction properties make it outstanding in the petrochemical industry (such as refining equipment and pipeline systems) and water treatment industry (such as sewage treatment pumps and filtration systems), especially when dealing with acidic or alkaline media, it extends the equipment maintenance cycle.

Carbide valve core and seat

Used for high-pressure valves in oil and gas and chemical equipment, with a pressure resistance of > 50 MPa, excellent corrosion resistance (resistance to H_2S and CO_2 corrosion > 2000 hours), and a leakage rate of < 0.005 mL/min, ensuring reliable sealing performance in extreme environments.

Carbide Nozzle

Applied to sandblasting, spraying and 3D printing, with flow deviation of $< 1\%$, it performs well in aerospace (such as jet engine components), additive manufacturing (such as high-precision metal 3D printing), semiconductor manufacturing (such as chemical vapor deposition equipment) and energy industries (such as gas turbine nozzles). Its high wear resistance and precise fluid control capabilities significantly improve production efficiency and finished product quality.

(3) Mining and abrasive processing

Carbide Mining Drill Bits

It exhibits ultra-long service life (> 100 hours) under extreme conditions such as deep mining. Its high hardness and impact resistance support efficient drilling. It is widely used in the coal, metal mining and oil drilling industries, reducing replacement frequency and operating costs.

Carbide grinding balls and grinding media

Used for mineral processing, ceramic production and coating grinding, with a ball diameter range of 5-50 mm, hardness HV 1600-2000, and wear rate $< 0.01\%$ /hour, it significantly improves grinding efficiency and product uniformity, especially in the preparation of lithium battery materials and high-end ceramic production.

(4) Transmission and mechanical parts

Carbide Rollers

In the hot and cold rolling process of the steel industry, the wear-resistant layer thickness reaches 5-10 mm and the hardness HV 1500-2000, ensuring the surface quality of the rolled steel ($R_a < 0.8$ micron) and the service life > 5000 tons of steel rolled. Its stability under high load (pressure > 200

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MPa) and high temperature (600-1000°C) conditions makes it indispensable in heavy metallurgical equipment.

Carbide gears and transmission parts

Used in heavy machinery, wind power equipment and ship propulsion systems, the tooth surface hardness is HV 1800-2200, the fatigue strength is >1000 MPa, it reduces wear and noise, performs well under high torque (>500 Nm) conditions, and has a service life of up to 10 years.

Carbide bearing bushings

It provides low wear and high load support in heavy machinery and wind power generation equipment, has excellent wear resistance and anti-fatigue performance, and is widely used in high speed (>3000 RPM) and high load (>10 kN) environments.

(5) Wire and precision manufacturing

Carbide Wire Drawing Dies

Applied to metal wire and cable manufacturing, with a hole diameter tolerance of ± 0.001 mm and a surface roughness of $R_a < 0.1$ micron, it is suitable for drawing copper wire, steel wire and optical fiber preforms, with a service life of $>10^4$ drawing cycles, especially in the electronics and communications industries (such as 5G infrastructure).

(6) Medical and special industries

Cemented Carbide Medical Device Components

Such as orthopedic surgical saw blades and dental drills, with a diameter of 0.5-6 mm, a hardness of HV 1800-2200, biocompatibility in accordance with ISO 10993 standards, and a lifespan of >50 surgeries. In 2025, with the development of medical robot technology, its application in minimally invasive surgery and implant processing will increase.

(7) Emerging fields and future potential

With the advancement of industrial technology, carbide wear-resistant parts have shown broad prospects in electric vehicle battery production equipment (improving electrode material processing accuracy), robot joint components (enhancing motion durability) and space exploration equipment processing (such as high-temperature resistant spacecraft components). In addition, its high wear resistance and stability have also become key support in the manufacture of quantum computing equipment and renewable energy equipment (such as hydrogen production equipment). In the future, combined with artificial intelligence optimization design and sustainable manufacturing technology, its application boundaries will be further expanded.

These applications benefit from the excellent performance of cemented carbide, and its performance in diverse industrial scenarios has promoted a comprehensive upgrade from traditional manufacturing to cutting-edge technology.

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12.1.5 Technological development and challenges of cemented carbide wear-resistant parts

With the diversification of industrial needs, the manufacturing technology of cemented carbide wear-resistant parts continues to improve. The development of nano-grained cemented carbide and composite phases (such as WC- TiC -Co) has further improved wear resistance and service life. Grain refinement to 100-300 nanometers can increase hardness by 15%-25% and extend service life by 20%-30%.

In addition, composite coatings (such as WC-Co-Cr) and gradient material design (such as gradual change in surface hardness) have also become research hotspots. However, the challenge lies in the high-cost sintering process (cost of about \$200-500 per kilogram) and the processing accuracy requirements of complex geometries (tolerance ± 0.005 mm). In the future, the combination of additive manufacturing (such as 3D printing, which can realize complex internal structures) and intelligent monitoring technology (such as sensors that feedback wear status in real time) is expected to achieve more efficient and customized production of wear-resistant parts. At the same time, the development of environmentally friendly sintering processes (such as low-carbon emission sintering furnaces) will also promote the sustainable development of the industry.

This section discusses in detail the structural design, performance characteristics and engineering applications of cemented carbide wear-resistant parts from three aspects: cemented carbide molds, seals and nozzles, and geometry and stress distribution optimization.

1 2. 2 .1 Cemented Carbide Wear-resistant Parts - Cemented Carbide Molds

(1) Basic principles and technical overview

of wear resistance of cemented carbide molds Cemented carbide molds are mainly used in high-load forming processes such as stamping, wire drawing, and cold extrusion. They need to have high hardness (HV 1800-2200 $\pm$ 30) and low friction coefficient ($<0.3\pm 0.05$) to ensure dimensional accuracy and surface finish under high-frequency use. These molds play a key role in metal processing (such as steel plate stamping) and non-metal forming (such as plastic injection), and their performance directly affects product consistency and production efficiency. The material is mainly based on the WC-Co system, with a WC content of $>90\%\pm 1\%$ as a hard skeleton and a Co content of $6\%-12\%\pm 1\%$ as a binding phase to adjust toughness. The grain size is precisely controlled at $0.5-2\ \mu\text{m}\pm 0.01\ \mu\text{m}$, and high density and micro-uniformity are achieved through spark plasma sintering (SPS) process ($1400^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $50\ \text{MPa}\pm 1\ \text{MPa}$). The rapid heating and pressure of SPS technology effectively reduce grain growth and pore defects, and improve the material's fatigue resistance.

(2) Application

of cemented carbide molds Cemented carbide molds have shown wide application value in many fields:

Automotive Manufacturing

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Used for stamping engine blocks, transmission gears and body panels, the die life is $>10^6$ times $\pm 10^5$ times, supporting high-precision (tolerance ± 0.01 mm) and high-efficiency production to meet the demand for an annual production of one million vehicles.

Electronic component manufacturing

Used to produce mobile phone casings, circuit board connectors and chip lead frames, the mold hardness (HV 1800-2200) ensures long-term stability of micron-level precision and is suitable for mass production of 5G devices and smart wearable devices.

Home appliance industry

Used for stamping refrigerator compressor housings and washing machine drum parts. Its wear resistance (wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m}$) supports high-frequency stamping (>500 times/minute), improving production efficiency by $20\% \pm 3\%$.

Aerospace

Used for cold extrusion of titanium alloys and aluminum alloys, such as aircraft wing skins and engine blades. The mold fatigue resistance (lifespan $> 8 \times 10^5$ times) meets the requirements of high-strength material processing.

Medical Devices

Used for stamping orthopedic implants (such as hip prostheses) and surgical instrument housings. The surface roughness $Ra < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ ensures biocompatibility and processing accuracy, in line with ISO 13485 standards.

(3) Wear resistance mechanism and performance analysis

of cemented carbide molds The excellent performance of the molds is derived from their microstructure and material design. WC as a hard phase provides high hardness (HV 1800 ± 30), and its hexagonal crystal structure gives excellent wear resistance; Co as a metal bonding phase ($6\% - 12\% \pm 1\%$) absorbs energy through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{IC} \geq 14 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, enhancing the ability to resist crack growth. Fine grains ($0.5 - 1 \mu\text{m} \pm 0.01 \mu\text{m}$) significantly improve strength and wear resistance through the Hall-Petch equation (Hall-Petch equation, $\sigma_y = \sigma_0 + k d^{-1/2}$), and the wear rate is controlled at $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$. Surface polishing ($Ra < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$) reduces friction and adhesion by reducing surface roughness, and the density measured based on the Archimedeian principle ($14.8 - 15.2 \text{ g/cm}^3 \pm 0.1 \text{ g/cm}^3$) reflects its high density. SEM analysis shows that the YG8 die wears evenly (depth $<0.05 \text{ mm} \pm 0.01 \text{ mm}$) without microcracks, and X-ray diffraction (XRD) confirms that the lattice matching degree of WC and Co phases is high. Performance tests show that the YG8 die has a stamping life of 10^6 times $\pm 10^5$ times, which is better than YG6 (8×10^5 times $\pm 10^5$ times), thanks to better grain refinement and surface treatment.

(4) Analysis of factors affecting the wear resistance of cemented carbide molds

Co content

$6\% - 12\% \pm 1\%$ optimizes toughness, and $<6\% \pm 1\%$ leads to a $10\% \pm 2\%$ increase in crack rate due to insufficient bonding phase.

Grain size

$0.5 - 1 \mu\text{m} \pm 0.01 \mu\text{m}$ provides the best wear resistance, and $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases the wear rate

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by $10\% \pm 2\%$ due to the reduction of grain boundaries.

Surface roughness

$Ra < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces the friction coefficient by $10\% \pm 2\%$, and $> 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$ increases the wear by $15\% \pm 3\%$, which is consistent with the Stribeck curve theory.

For example, the wear rate of the YG6 mold (grain $2 \mu\text{m} \pm 0.01 \mu\text{m}$) rises to $0.06 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, highlighting the influence of grain size.

(5) The optimization strategy

for the wear resistance of cemented carbide molds is to achieve a wear rate of $< 0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$ and a life of $> 10^6 \text{ times} \pm 10^5 \text{ times}$. It is recommended to:

Material Optimization

Co 6%-12% $\pm 1\%$, grain size $0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$, TaC ($< 1\%$) is added to improve high temperature stability.

Process Optimization

The porosity after SPS ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$) and hot isostatic pressing (HIP, 150 MPa) is $< 0.1\% \pm 0.01\%$.

Surface optimization

Diamond polishing to $Ra < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$, TiN coating (thickness $2 \mu\text{m}$) to reduce friction.

Test Specifications

ASTM G65 (wear), ASTM E92 (hardness).

After verification and optimization, the wear rate of YG8 mold (grain $0.5 \mu\text{m} \pm 0.01 \mu\text{m}$, $Ra 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$) is $0.04 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, and the service life is $10^6 \text{ times} \pm 10^5 \text{ times}$, which meets the automotive industry standards.

1 2. 2. 2 Hard alloy wear-resistant parts - Hard alloy seals

(1) Basic principles and technical overview of cemented carbide seals

Cemented carbide seals are widely used in mechanical seals (such as pumps and valves), requiring excellent corrosion resistance (corrosion rate $< 0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$) and low leakage rate ($< 0.01 \text{ mL/min}$) to cope with corrosive fluids (such as H_2SO_4 and NaCl solutions) in petrochemical and water treatment. The material is based on WC-Co (Co 6%-12% $\pm 1\%$), with Cr_3C_2 (2%-5% $\pm 0.5\%$) added to form a Cr_2O_3 protective layer with a grain size of $0.5\text{-}2 \mu\text{m} \pm 0.01 \mu\text{m}$. High density and corrosion resistance are achieved through SPS sintering ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$). The self-healing properties of the Cr_2O_3 layer are based on Pascal's law, which enhances the stability of the seal under high pressure environments.

(2) Application

of cemented carbide seals Cemented carbide seals perform well under a variety of harsh working conditions:

Petrochemical

Used for high-pressure pump seals in oil refining equipment and pipeline systems, with a pressure

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resistance of >50 MPa and a corrosion rate of <0.01 mm/year. It is suitable for media containing hydrogen sulfide (H_2S) and can extend the equipment maintenance cycle to >5000 hours.

Water treatment industry

Used in sewage treatment pumps and seawater desalination plants, the seals are resistant to chloride ion corrosion (resistant to NaCl solution >2000 hours), with a leakage rate of <0.01 mL/min, supporting the operation of efficient water circulation systems.

Energy Industry

Applied to cooling water pumps and gas turbine lubrication systems in nuclear power plants, it has a temperature resistance of $300^{\circ}C \pm 10^{\circ}C$, corrosion resistance that meets IAEA safety standards, and a leakage rate as low as 0.005 mL/min ± 0.001 mL/min.

Pharmaceutical Industry

Used in autoclaves and chemical reactors, seals are resistant to acidic cleaning agents (pH 2-12), ensuring a sterile production environment and meeting GMP certification requirements.

Ship Engineering

Used in seawater pumps and propulsion systems, it is resistant to salt spray corrosion (>3000 hours) and supports the long-term operation of deep-sea equipment (such as ROV) in high-pressure (>30 MPa) environments.

(3) Wear resistance mechanism and performance analysis of cemented carbide seals

WC ($>90\% \pm 1\%$) provides basic hardness (HV 1700 ± 30), Co ($6\% - 12\% \pm 1\%$) enhances toughness (K_{IC} $14 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$), and Cr_3C_2 ($2\% - 5\% \pm 0.5\%$) generates a Cr_2O_3 layer with a thickness of $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ through high-temperature oxidation, which significantly improves corrosion resistance. Its passivation mechanism follows the Nernst equation. SEM analysis shows that there is no pitting on the surface of the seal (deviation $<0.1\% \pm 0.02\%$), and energy dispersive spectroscopy (EDS) confirms that Cr_2O_3 is evenly distributed. Performance tests show that the optimized formula seal has a lifespan extended by $20\% \pm 3\%$ in 5% H_2SO_4 solution, and the leakage rate is stabilized at 0.008 mL/min ± 0.001 mL/min.

(4) Analysis of factors affecting the wear resistance of cemented carbide seals

Co content

$6\% - 12\% \pm 1\%$ balances hardness and toughness, $<6\% \pm 1\%$ increases the crack rate by $10\% \pm 2\%$ due to insufficient bonding phase.

Cr_3C_2 content

$2\% - 5\% \pm 0.5\%$ improves corrosion resistance by $20\% \pm 3\%$, $>10\% \pm 0.5\%$ reduces hardness by $10\% \pm 2\%$ due to excess phase precipitation.

Grain size

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0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$ reduces wear, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $10\% \pm 2\%$. For example, the corrosion rate of seals with low Cr_3C_2 content ($< 2\% \pm 0.5\%$) increases to $0.015 \text{ mm/year} \pm 0.001 \text{ mm/year}$.

(5) Optimization strategy for wear resistance of cemented carbide seals

To achieve a corrosion rate of $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$ and a leakage rate of $<0.01 \text{ mL/min}$, it is recommended that:

Material Optimization

Co 6%-12% $\pm 1\%$, Cr_3C_2 2%-5% $\pm 0.5\%$, grain size 0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$.

Process Optimization

SPS ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$), porosity $<0.1\% \pm 0.01\%$ after HIP.

Surface optimization

Electrolytic polishing to $\text{Ra} < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$.

1 2. 2 . 3 Hard alloy wear-resistant parts - Hard alloy nozzle

(1) Basic principles of cemented carbide wear-resistant parts - cemented carbide nozzles

injection, requiring erosion resistance (erosion rate $<0.05 \text{ mm}^3 / \text{g} \pm 0.01 \text{ mm}^3 / \text{g}$) and precise aperture ($0.5\text{-}2 \text{ mm} \pm 0.01 \text{ mm}$) to ensure uniform injection of fluid or particles. The material is mainly WC-Co (Co 6%-12% $\pm 1\%$), with a grain size of $0.5\text{-}2 \mu\text{m} \pm 0.01 \mu\text{m}$, and is prepared by SPS sintering ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$) to optimize erosion resistance. The aperture design is based on the Bernoulli principle to ensure fluid dynamic stability and is widely used in aerospace and additive manufacturing.

(2) Application

of carbide wear-resistant nozzles

Carbide nozzles perform well in a variety of high-precision jetting scenarios:

Aerospace

Used for jet engine fuel nozzle and surface sandblasting, with aperture accuracy of $\pm 0.01 \text{ mm}$ and erosion rate of $<0.05 \text{ mm}^3 / \text{g}$, ensuring uniform fuel atomization (particle diameter $<50 \mu\text{m}$), improving combustion efficiency by $10\% \pm 2\%$.

Additive Manufacturing

Used for high-precision metal 3D printing nozzles (such as SLM equipment), with a flow deviation of $<1\%$, supporting the printing of titanium alloys and nickel-based alloys, and a finished product accuracy of $\pm 0.02 \text{ mm}$, meeting the requirements of spacecraft components.

Semiconductor Manufacturing

Gas nozzles for chemical vapor deposition (CVD) equipment, erosion and corrosion resistance (HF gas resistance > 1000 hours) support high uniformity in wafer production (film thickness deviation $< 1\%$).

Energy Industry

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Used for spraying on gas turbine nozzles and wind turbine blades. Its high temperature resistance ($>800^{\circ}\text{C}$) and erosion resistance extend the equipment life to >3000 hours, in compliance with IEC 61400 standards.

Car spraying

Used for car body paint spraying and electroplating pre-treatment, the nozzle flow stability (deviation $<1\%$) ensures uniform coating thickness ($\pm 5\text{ }\mu\text{m}$), improving product aesthetics and durability.

Agricultural machinery

Used for pesticide spraying and fertilizer injection, the erosion resistance (erosion rate $<0.05\text{ mm}^3/\text{g}$) supports high-flow injection ($>5\text{ L/min}$), and the coverage area is increased by $15\%\pm 3\%$, improving agricultural production efficiency.

(3) Wear resistance mechanism and performance analysis of cemented carbide nozzles

WC ($>90\%\pm 1\%$) provides high hardness ($\text{HV } 1800\pm 30$), Co ($6\%-12\%\pm 1\%$) enhances toughness ($K_{\text{IC}} 14\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$), and optimized aperture ($0.5\text{-}2\text{ mm}\pm 0.01\text{ mm}$) reduces erosion concentration through fluid mechanics simulation. SEM shows that the YG8 nozzle is uniformly eroded (depth $<0.05\text{ mm}\pm 0.01\text{ mm}$) without peeling, and XRD confirms the high crystallinity of the WC phase. Performance testing shows that the erosion rate of the nozzle with optimized aperture is reduced to $0.04\text{ mm}^3/\text{g}\pm 0.01\text{ mm}^3/\text{g}$, and the flow stability is better than that of the non-optimized nozzle (deviation $<1\%$), which meets the high precision requirements of the spraying industry.

(4) Analysis of factors affecting the wear resistance of cemented carbide nozzles

Co content

$6\%-12\%\pm 1\%$ enhances toughness, $<6\%\pm 1\%$ increases crack rate by $10\%\pm 2\%$.

Grain size

$0.5\text{-}1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ reduces erosion, $>2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ increases erosion by $15\%\pm 3\%$.

Aperture

for $0.5\text{-}2\text{ mm}\pm 0.01\text{ mm}$, and increases by $15\%\pm 3\%$ for $>5\text{ mm}\pm 0.01\text{ mm}$ due to the turbulence effect. For example, the erosion rate of a nozzle with an aperture of $5\text{ mm}\pm 0.01\text{ mm}$ rises to $0.07\text{ mm}^3/\text{g}\pm 0.01\text{ mm}^3/\text{g}$.

(5) The optimization strategy

for cemented carbide nozzles is to achieve an erosion rate of $<0.05\text{ mm}^3/\text{g}\pm 0.01\text{ mm}^3/\text{g}$ and a flow rate deviation of $<1\%$. The following are recommended:

Material Optimization

Co $6\%-12\%\pm 1\%$, grain size $0.5\text{-}1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$, VC ($<1\%$) is added to improve erosion resistance.

Process Optimization

SPS ($1400^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $50\text{ MPa}\pm 1\text{ MPa}$), porosity $<0.1\%\pm 0.01\%$ after HIP.

Surface optimization

Aperture: $0.5\text{-}2\text{ mm}\pm 0.01\text{ mm}$, polished to $\text{Ra}<0.1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$.

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After optimization, the erosion rate of the YG8 nozzle is $0.04 \text{ mm}^3 / \text{g} \pm 0.01 \text{ mm}^3 / \text{g}$, and the flow deviation is $<1\%$.

1 2. 2 . 4 Hard alloy wear-resistant parts - Hard alloy wear-resistant valve core and valve seat

(1) Hard alloy wear-resistant parts - basic principle technology of hard alloy valve core and valve seat

Carbide valve cores and valve seats are mainly used in high-pressure valves (such as throttle valves and stop valves in oil and gas and chemical equipment), which require high corrosion resistance (corrosion rate $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$), erosion resistance (erosion rate $<0.05 \text{ mm}^3 / \text{g} \pm 0.01 \text{ mm}^3 / \text{g}$) and low leakage rate ($<0.005 \text{ mL/min} \pm 0.001 \text{ mL/min}$) to ensure sealing performance and flow control accuracy in extreme environments. The material is based on the WC-Co system (Co 6%-12% $\pm 1\%$), with Cr_3C_2 (2%-5% $\pm 0.5\%$) added to form a Cr_2O_3 protective layer. The grain size is controlled at $0.5\text{-}2 \mu\text{m} \pm 0.01 \mu\text{m}$ and is prepared by spark plasma sintering (SPS) process ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$) to achieve high density and excellent wear and corrosion resistance. The geometric design of the valve core and valve seat (such as spherical or conical contact surface) is based on fluid mechanics optimization to ensure that a stable sealing effect can be maintained under high pressure difference ($>50 \text{ MPa}$).

(2) Mechanism and performance analysis of hard alloy wear-resistant valve core and valve seat

WC ($>90\% \pm 1\%$) provides high hardness ($\text{HV } 1750 \pm 30$), Co (6%-12% $\pm 1\%$) enhances toughness ($K_{Ic} 14 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$), Cr_3C_2 (2 %-5% $\pm 0.5\%$) generates a Cr_2O_3 protective layer with a thickness of $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ through high temperature oxidation, which significantly improves corrosion resistance. Its passivation mechanism follows the Nernst equation. Fine grains ($0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$) improve strength and reduce erosion rate ($<0.05 \text{ mm}^3 / \text{g} \pm 0.01 \text{ mm}^3 / \text{g}$) through the Hall-Petch equation (Hall-Petch equation, $\sigma_y = \sigma_0 + k d^{(-1/2)}$). The contact surface of the valve core and valve seat is polished ($R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$) to reduce friction and wear. SEM analysis shows that the erosion depth of the YG8 valve core is $<0.05 \text{ mm} \pm 0.01 \text{ mm}$, and there is no pitting on the surface (deviation $<0.1\% \pm 0.02\%$). Energy dispersive spectroscopy (EDS) confirms that Cr_2O_3 is evenly distributed, and XRD analysis shows high crystallinity of the WC phase. Performance tests show that the erosion rate of the optimized valve core and valve seat in sand-containing fluids (flow rate $>10 \text{ m/s}$) is only $0.04 \text{ mm}^3 / \text{g} \pm 0.01 \text{ mm}^3 / \text{g}$, and the leakage rate is stable at $0.004 \text{ mL/min} \pm 0.001 \text{ mL/min}$.

(3) Analysis of factors affecting the performance of carbide wear-resistant valve core and valve seat

Co content: 6%-12% $\pm 1\%$ balances hardness and toughness, $<6\% \pm 1\%$ increases the crack rate by $10\% \pm 2\%$ due to insufficient bonding phase.

Cr_3C_2 content: 2%-5% $\pm 0.5\%$ improves corrosion resistance by $20\% \pm 3\%$, $>10\% \pm 0.5\%$ reduces

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hardness by 10%±2% due to excess phase precipitation.

Grain size: 0.5-1 μm ±0.01 μm reduces erosion and wear, >2 μm ±0.01 μm increases erosion by 15%±3%.

Surface roughness: Ra<0.1 μm ±0.01 μm reduces leakage rate by 10%±2%, >0.5 μm ±0.01 μm increases leakage by 15%±3% due to decreased sealing of contact surface.

For example, the corrosion rate of valve core without Cr₃C₂ addition increases to 0.02 mm/year±0.001 mm/year, and the erosion rate increases to 0.07 mm³ / g ± 0.01 mm³ / g.

(4) Application

of hard alloy wear-resistant valve core and valve seat

Carbide valve cores and valve seats are widely used in a variety of harsh working conditions:

Oil and Gas

Used for deep well drilling valves and high-pressure gas pipelines, with a pressure resistance of >50 MPa, resistance to H₂S and CO₂ corrosion (>2000 hours), and a leakage rate of <0.005 mL/min, supporting the reliable operation of deep-sea oil and gas extraction equipment (such as FPSO).

Chemical Equipment

The valve system is used in reactors with acidic media (such as sulfuric acid and hydrochloric acid). Its corrosion resistance (corrosion rate < 0.01 mm/year) ensures long-term leakage-free operation and complies with ASME B16.34 standards.

Power Industry

Used for boiler feed valves in thermal power plants and high-pressure valves in nuclear power plants. The temperature resistance reaches 400°C±10°C and the erosion resistance (erosion rate <0.05 mm³ / g) supports the precise control of high-temperature and high-pressure steam flow.

Aerospace

Used in rocket engine fuel valves, the valve core erosion resistance (erosion rate <0.04 mm³ / g) ensures the stability of liquid fuel (such as liquid oxygen and liquid hydrogen) injection and meets NASA safety standards.

Pharmaceutical Industry

Used for high-pressure syringe pump valves, corrosion resistance and low leakage rate (<0.005 mL/min) ensure no contamination in drug production and meet FDA certification requirements.

1 2. 2 . 5 Hard alloy wear-resistant parts - Hard alloy wear-resistant mining drill bits

(1) Basic technical principle

of cemented carbide wear-resistant mining drill bits Cemented carbide mining drill bits are mainly used for deep mine mining (such as coal, metal mines and oil drilling), requiring high hardness (HV 1800-2200±30), excellent wear resistance (wear rate <0.05 mm³ / N · m ± 0.01 mm³ / N · m) and impact resistance (impact energy>50 J±5 J) to cope with high-hardness rock formations and complex geological conditions. The material is mainly WC-Co system (Co 6%-12%±1%), with WC content>90%±1% to provide a hard skeleton, and the grain size is controlled at 0.5-2 μm ±0.01 μm . It is prepared by spark plasma sintering (SPS) process (1400°C±10°C, 50 MPa±1 MPa) to ensure high density and fatigue resistance. The drill bit design combines cutting mechanics and heat

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conduction optimization. The cutter head angle (usually $120^{\circ}\pm 5^{\circ}$) and spiral groove structure enhance drilling efficiency and slag removal capabilities, making it suitable for high-intensity operations in ultra-deep wells (>5000 m).

(2) Mechanism and performance analysis

of cemented carbide wear-resistant mining drill bits WC ($>90\%\pm 1\%$) provides high hardness (HV 1800-2200 ± 30), and its hexagonal crystal structure gives excellent wear and erosion resistance; Co ($6\%-12\%\pm 1\%$) as a binding phase absorbs impact energy through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{IC} 14 \text{ MPa}\cdot\text{m}^{1/2} \pm 0.5$, enhancing the ability to resist crack growth. Fine grains ($0.5\text{-}1 \mu\text{m}\pm 0.01 \mu\text{m}$) improve strength and wear resistance through the Hall-Petch equation (Hall-Petch equation, $\sigma_y = \sigma_0 + k_d(-1/2)$), and the wear rate is controlled at $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$. The drill bit surface heat treatment (hardening layer thickness $<0.5 \text{ mm} \pm 0.1 \text{ mm}$) improves high temperature resistance ($>600^{\circ}\text{C} \pm 10^{\circ}\text{C}$). SEM analysis shows that the wear depth of the YG8 drill bit is $<0.05 \text{ mm} \pm 0.01 \text{ mm}$, and there is no obvious cracking of the blade. X-ray diffraction (XRD) confirms the high crystallinity of the WC phase. Performance tests show that the optimized drill bit has a drilling life of more than 100 hours ± 10 hours in granite (hardness 7 Mohs), a drilling speed of $10\text{-}15 \text{ m/h} \pm 1 \text{ m/h}$, and an impact resistance that supports an instantaneous load of $5000 \text{ J} \pm 500 \text{ J}$.

(3) Analysis of factors affecting the performance of cemented carbide wear-resistant mining drill bits

Co content

$6\%-12\%\pm 1\%$ optimizes toughness and impact resistance, $<6\%\pm 1\%$ increases the crack rate by $10\%\pm 2\%$ due to insufficient bonding phase.

Grain size

$0.5\text{-}1 \mu\text{m}\pm 0.01 \mu\text{m}$ reduces wear and edge chipping, $>2 \mu\text{m}\pm 0.01 \mu\text{m}$ increases wear by $15\%\pm 3\%$ due to the reduction of grain boundaries.

Surface hardening layer

Thickness $<0.5 \text{ mm}\pm 0.1 \text{ mm}$ improves wear resistance, while thickness $>1 \text{ mm}\pm 0.1 \text{ mm}$ reduces toughness by $10\%\pm 2\%$, leading to an increased risk of chipping.

Blade Angle

$120^{\circ}\pm 5^{\circ}$ optimizes cutting efficiency, $>130^{\circ}\pm 5^{\circ}$ reduces drilling speed by $10\%\pm 2\%$ due to the increased contact area.

For example, the wear rate of a drill with a grain size of $2 \mu\text{m}\pm 0.01 \mu\text{m}$ increases to $0.07 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, and the life is shortened to $80 \text{ hours}\pm 10 \text{ hours}$.

(4) Main applications of cemented carbide wear-resistant mining drill bits

Carbide mining drill bits excel in a variety of mining scenarios:

Coal Mining

Used for deep coal mine drilling, the wear resistance supports continuous drilling > 100 hours, the

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drilling speed is 10-15 m/h, and the replacement frequency is reduced by 20%±3%. It is suitable for hard coal seams in North China.

Metal mining

Used for deep drilling in copper and iron ores, impact resistance (>50 J) for granite and basalt, life span >120 hours, supporting large open-pit mines in Chile and Australia.

Oil Drilling

Applied to offshore drilling platforms, its corrosion resistance (seawater resistance > 2000 hours) ensures efficient drilling of deep-sea oil and gas wells (> 3000 m), meeting API Spec 7-1 standards.

Geological Exploration

Used for core drilling in hard rocks (such as quartzite). The drill bit accuracy (aperture deviation <0.1 mm) supports precise sample collection and is widely used in geological research.

Tunnel Engineering

Used in subway and high-speed rail tunnel construction, its impact resistance and wear resistance support hard rock excavation (>8 Mohs), and the drilling length per shift is increased by 15%±2%.

1 2. 2 . 6 Cemented Carbide Wear-Resistant Parts - Cemented Carbide Grinding Balls and Grinding Media

(1) Basic technical principles

of cemented carbide grinding balls and grinding media

Carbide grinding balls and grinding media are mainly used in ultrafine powder processing equipment such as ball mills, vibration mills and stirred mills, requiring high hardness (HV 1800-2200±30), excellent wear resistance (wear rate <0.04 mm³ / N · m ± 0.01 mm³ / N · m) and fatigue resistance (cycle life >10⁶ times ± 10⁵ times) to adapt to high-energy grinding environments and long-term operation. The material is mainly WC-Co system (Co 6%-12%±1%), with WC content >90%±1% as a hard skeleton, and the grain size is controlled at 0.5-2 μm±0.01 μm. It is prepared by spark plasma sintering (SPS) process (1400°C±10°C, 50 MPa±1 MPa) to ensure high density and uniform microstructure. The shape of the grinding balls (usually spherical or cylindrical, with a diameter of 5-20 mm ± 0.1 mm) and the surface design of the grinding media are optimized based on friction mechanics to enhance grinding efficiency and material dispersion, and are suitable for mineral processing, ceramic production and nanomaterial preparation.

(2) Mechanism and performance analysis

of cemented carbide grinding balls and grinding media

WC (>90%±1%) provides high hardness (HV 1800-2200±30), and its hexagonal crystal structure gives excellent wear and erosion resistance; Co (6%-12%±1%) as a binding phase absorbs impact and fatigue stress through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{IC} \geq 14 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, enhancing the ability to resist crack growth. Fine grains (0.5-1 μm±0.01 μm) improve strength and wear resistance through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$), and the wear rate is controlled at <0.04 mm³ / N · m ± 0.01 mm³ / N · m. Surface polishing (Ra < 0.1 μm±0.01 μm) reduces adhesion and abrasive wear, and the density measured based on the Archimedeian principle (14.8-15.2 g/cm³ ± 0.1 g/cm³) reflects its high

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compactness. SEM analysis shows that the YG8 grinding ball wears evenly (depth $<0.05 \text{ mm} \pm 0.01 \text{ mm}$) without obvious peeling, and X-ray diffraction (XRD) confirms the high lattice matching of WC and Co phases. Performance tests show that the optimized grinding ball has a life of more than 10^6 times $\pm 10^5$ times when grinding quartz sand (hardness 7 Mohs), and the grinding efficiency is improved by $15\% \pm 2\%$, and the particle size can reach submicron level ($<1 \mu\text{m} \pm 0.1 \mu\text{m}$).

(3) Analysis of factors affecting the performance of cemented carbide grinding balls and grinding media

Co content

$6\% - 12\% \pm 1\%$ optimizes toughness and fatigue resistance, $<6\% \pm 1\%$ increases the crack rate by $10\% \pm 2\%$ due to insufficient bonding phase.

Grain size

$0.5 - 1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces wear and spalling, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $15\% \pm 3\%$ due to the reduction of grain boundaries.

Surface roughness

$R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces abrasive wear by $10\% \pm 2\%$, and $>0.5 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $20\% \pm 3\%$ due to increased surface adhesion.

Diameter consistency

$5 - 20 \text{ mm} \pm 0.1 \text{ mm}$ ensures grinding uniformity, and deviation $>0.5 \text{ mm} \pm 0.1 \text{ mm}$ reduces efficiency by $10\% \pm 2\%$ due to uneven material dispersion. For example, the wear rate of grinding balls with a grain size of $2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases to $0.06 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, and the life span is shortened to $8 \times 10^5 \text{ times} \pm 10^5 \text{ times}$.

(4) Application of cemented carbide grinding balls and grinding media

Carbide grinding balls and grinding media excel in a variety of high-precision grinding applications:

Mineral Processing

Used for ultra-fine grinding of copper and gold ores. The wear resistance supports continuous operation of >1000 hours and the grinding efficiency is improved by $20\% \pm 3\%$.

Ceramic production

Applied to alumina and zirconia ceramic powder grinding, particle uniformity ($<1 \mu\text{m}$) supports the manufacturing of high-quality ceramic tiles and electronic substrates in accordance with ISO 9001 standards.

Nanomaterial preparation

Used for ball milling of carbon nanotubes and metal oxide nanopowders. Its fatigue resistance ($>10^6$ times) ensures long-term high-energy grinding. It is widely used in battery material research and development.

Paints and pigments

Used for ultrafine dispersion of titanium dioxide and organic pigments. The corrosion resistance of the grinding media (acid and alkali resistance > 2000 hours) supports the production of chemical coatings and improves the gloss of the product by $10\% \pm 2\%$.

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Pharmaceutical Industry

Used for micronization of active pharmaceutical ingredients, the low pollution of grinding media (no heavy metal precipitation) complies with GMP requirements and supports efficient drug preparation.

1 2. 2 . 7 Hard alloy wear-resistant parts - Hard alloy rollers

(1) Basic principles and technical overview of cemented carbide wear-resistant rolls

Cemented carbide rolls are mainly used for metal rolling (such as cold and hot rolling of steel, aluminum and copper plates), requiring high hardness (HV 1800-2200±30), excellent wear resistance (wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$) and thermal fatigue resistance (cycle life $>10^6$ times $\pm 10^5$ times) to cope with the harsh conditions of high temperature ($>800^\circ\text{C} \pm 10^\circ\text{C}$), high pressure ($>200 \text{ MPa}$) and continuous operation. The material is mainly based on the WC-Co system (Co 6%-12%±1%), with a WC content of $>90\% \pm 1\%$ as a hard skeleton, and the grain size is controlled at $0.5\text{-}2 \mu\text{m} \pm 0.01 \mu\text{m}$. It is prepared by spark plasma sintering (SPS) process ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$) to ensure high density and thermal stability. The roller surface design adopts precision machining ($R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$) and geometric optimization (such as roller surface diameter $500\text{-}1000 \text{ mm} \pm 1 \text{ mm}$), based on the principles of contact mechanics and heat conduction, to enhance rolling accuracy and surface quality, and is suitable for high-precision rolling in the steel, automotive and aviation industries.

(2) Mechanism and performance analysis of cemented carbide wear-resistant rolls

WC ($>90\% \pm 1\%$) provides high hardness (HV 1800-2200±30), and its hexagonal crystal structure gives excellent wear resistance and thermal shock resistance; Co (6%-12%±1%) as a binding phase absorbs thermal and mechanical stresses through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{IC} \geq 14 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, enhancing the crack growth resistance. Fine grains ($0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$) improve strength and wear resistance through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$), and the wear rate is controlled at $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$. Surface heat treatment (hardening layer thickness $<0.5 \text{ mm} \pm 0.1 \text{ mm}$) improves high temperature resistance. SEM analysis shows that the YG8 roller wears evenly (depth $<0.05 \text{ mm} \pm 0.01 \text{ mm}$) without thermal cracks. X-ray diffraction (XRD) confirms the high thermal stability of the WC phase. Performance tests show that the optimized roller has a life of more than 10^6 times $\pm 10^5$ times when rolling stainless steel plates (thickness $1 \text{ mm} \pm 0.01 \text{ mm}$), the surface roughness remains $R_a < 0.2 \mu\text{m} \pm 0.02 \mu\text{m}$, and the rolling accuracy reaches $\pm 0.01 \text{ mm}$.

(3) Analysis of factors affecting carbide wear-resistant rolls

Co content

6%-12%±1% optimizes toughness and thermal fatigue resistance, $<6\% \pm 1\%$ increases the crack rate by $10\% \pm 2\%$ due to insufficient bonding phase.

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Grain size

0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$ reduces wear and thermal cracking, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $15\% \pm 3\%$ due to the reduction of grain boundaries.

Surface roughness

$R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces adhesive wear by $10\% \pm 2\%$, and $>0.5 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $20\% \pm 3\%$ due to the reduction of surface quality.

Roller diameter

500-1000 $\text{mm} \pm 1 \text{ mm}$ ensures rolling uniformity, and deviation $>5 \text{ mm} \pm 1 \text{ mm}$ reduces accuracy by $10\% \pm 2\%$ due to uneven contact pressure. For example, the wear rate of a roll with a grain size of $2 \mu\text{m} \pm 0.01 \mu\text{m}$ rises to $0.07 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, and the life is shortened to $8 \times 10^5 \text{ times} \pm 10^5 \text{ times}$.

(4) Application

of cemented carbide wear-resistant rollers

Carbide rolls excel in a variety of metal processing applications:

Steel Industry

Used for hot-rolled and cold-rolled steel plate production, high temperature resistance ($>800^\circ\text{C}$) supports continuous rolling >1000 hours, accuracy $\pm 0.01 \text{ mm}$, meeting the needs of construction steel and automotive plates.

Aluminum Processing

Applied to aluminum foil and aviation aluminum alloy rolling, wear resistance ensures surface finish ($R_a < 0.2 \mu\text{m}$), life $>10^6$ times, widely used in packaging and aircraft manufacturing.

Copper and alloys

Used for precision rolling of copper strips and brass plates. Its thermal fatigue resistance supports high-frequency rolling (>500 times/hour), improving production efficiency by $15\% \pm 2\%$, in line with electronics industry standards.

Energy Equipment

Used for rolling steel plates for nuclear power plant pipelines and wind turbine towers. Its corrosion resistance (acid resistance >2000 hours) meets the requirements of high-pressure environments and its service life is extended by $20\% \pm 3\%$.

Railway Manufacturing

Used for initial rolling of high-speed railway wheels and rails. The impact resistance ($>50 \text{ J}$) supports heavy-duty rolling. The accuracy is $\pm 0.02 \text{ mm}$, in accordance with EN 13674.

1 2. 2 . 8 Hard alloy wear-resistant parts - Hard alloy gears and transmission parts

(1) Basic principles

of cemented carbide wear-resistant parts - cemented carbide gears and transmission components Cemented carbide gears and transmission components are mainly used in high-load mechanical transmission systems (such as heavy machinery, aircraft engines and industrial reducers), requiring high hardness (HV 1800-2200 $\pm$ 30), excellent wear resistance (wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$) and fatigue resistance (cycle life $>10^6 \text{ times} \pm 10^5 \text{ times}$) to cope with complex

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working conditions of high speed ($>5000 \text{ rpm} \pm 500 \text{ rpm}$), high torque ($>1000 \text{ N} \cdot \text{m} \pm 100 \text{ N} \cdot \text{m}$) and long-term operation. The material is mainly based on the WC-Co system (Co 6%-12% $\pm$ 1%), with WC content $>90\% \pm 1\%$ as a hard skeleton, and the grain size is controlled at $0.5\text{-}2 \mu\text{m} \pm 0.01 \mu\text{m}$. It is prepared by spark plasma sintering (SPS) process ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$) to ensure high density and impact resistance. The gear design adopts precision molding (module $1\text{-}5 \text{ mm} \pm 0.1 \text{ mm}$) and surface treatment ($R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), and optimizes transmission efficiency and noise control based on gear meshing theory, which is suitable for high-precision and heavy-load transmission equipment.

(2) Mechanism and performance analysis of carbide gears and transmission components

WC ($>90\% \pm 1\%$) provides high hardness (HV 1800-2200 $\pm$ 30), and its hexagonal crystal structure gives excellent wear and impact resistance; Co (6%-12% $\pm$ 1%) as a binding phase absorbs fatigue stress through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{IC} 14 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, enhancing the ability to resist crack growth. Fine grains ($0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$) improve strength and wear resistance through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$), and the wear rate is controlled at $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$. The surface lubrication coating (thickness $<0.5 \mu\text{m} \pm 0.1 \mu\text{m}$) reduces the friction coefficient ($<0.3 \pm 0.05$), SEM analysis shows that the YG8 gear tooth surface wear is uniform (depth $<0.05 \text{ mm} \pm 0.01 \text{ mm}$), there is no root crack, and X-ray diffraction (XRD) confirms the high stability of the WC phase. Performance tests show that the optimized gear has a service life of more than 10^6 times $\pm$ 10^5 times at 5000 rpm, a transmission efficiency of $98\% \pm 1\%$, and a noise level of less than $70 \text{ dB} \pm 2 \text{ dB}$.

(3) Analysis of factors affecting carbide gears and transmission components

Co content

6%-12% $\pm$ 1% optimizes toughness and fatigue resistance, $<6\% \pm 1\%$ increases the crack rate by $10\% \pm 2\%$ due to insufficient bonding phase.

Grain size

$0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces wear and fatigue cracks, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $15\% \pm 3\%$ due to the reduction of grain boundaries.

Surface roughness

$R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces friction and noise by $10\% \pm 2\%$, and $>0.5 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $20\% \pm 3\%$ due to tooth surface adhesion.

Modulus accuracy

$1\text{-}5 \text{ mm} \pm 0.1 \text{ mm}$ ensures smooth transmission, and deviation $>0.5 \text{ mm} \pm 0.1 \text{ mm}$ reduces efficiency by $10\% \pm 2\%$ due to poor meshing. For example, the wear rate of a gear with a grain size of $2 \mu\text{m} \pm 0.01 \mu\text{m}$ rises to $0.07 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, and the life span is shortened to 8×10^5 times $\pm 10^5$ times.

(4) Application of carbide gears and transmission parts

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Carbide gears and transmission components excel in a variety of high-performance transmission fields:

Aviation Industry

Used in turbine engine and landing gear transmission systems, it is resistant to high temperatures ($>600^{\circ}\text{C}\pm 10^{\circ}\text{C}$) and supports high-speed transmission, has a service life of $>10^6$ times, and meets FAA certification standards.

Heavy Machinery

Applied to mining crusher and cement mill transmission, it has high impact resistance ($>50\text{ J}$) and supports high torque ($>1000\text{ N}\cdot\text{m}$), and the efficiency is improved by $15\%\pm 2\%$.

Automotive

Used in electric vehicle reducers and gearboxes, the wear resistance ensures long-term operation (>5000 hours), the noise is less than 70 dB , and meets EPA emission requirements.

Energy Equipment

For wind turbine gearboxes, fatigue resistance ($>10^6$ times) supports intermittent high-load operation, and life is extended by $20\%\pm 3\%$, in compliance with IEC 61400 standards.

Robotics

Used for industrial robot joint transmission, the accuracy (modulus deviation $<0.1\text{ mm}$) supports high dynamic response and is widely used in automobile assembly lines.

1 2. 2 . 9 Hard alloy wear-resistant parts - Hard alloy bearing bushings

(1) Basic principles and technologies

of cemented carbide wear-resistant parts - cemented carbide wear-resistant bearing bushings

Carbide bearing bushings are mainly used in high-load rotating equipment (such as pumps, compressors and turbines), requiring high hardness ($\text{HV } 1800\text{-}2200\pm 30$), excellent wear resistance (wear rate $<0.04\text{ mm}^3 / \text{N}\cdot\text{m} \pm 0.01\text{ mm}^3 / \text{N}\cdot\text{m}$) and corrosion resistance (corrosion rate $<0.01\text{ mm/year}\pm 0.001\text{ mm/year}$) to adapt to long-term operation at high speed ($>3000\text{ rpm}\pm 300\text{ rpm}$), high pressure ($>50\text{ MPa}$) and corrosive media. The material is mainly based on WC-Co system (Co $6\%\text{-}12\%\pm 1\%$), with WC content $>90\%\pm 1\%$ as a hard skeleton, and the grain size is controlled at $0.5\text{-}2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$. It is prepared by spark plasma sintering (SPS) process ($1400^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $50\text{ MPa}\pm 1\text{ MPa}$) to ensure high density and fatigue resistance. The inner surface of the bushing is precision ground (inner diameter $50\text{-}200\text{ mm}\pm 0.1\text{ mm}$, $\text{Ra}<0.1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and lubrication and wear resistance are optimized based on the principles of fluid mechanics and tribology. It is suitable for bearing support in the petrochemical, energy and shipbuilding industries.

(2) Mechanism and performance analysis

of cemented carbide wear-resistant bearing bushings

WC ($>90\%\pm 1\%$) provides high hardness ($\text{HV } 1800\text{-}2200\pm 30$), and its hexagonal crystal structure gives excellent wear and erosion resistance; Co ($6\%\text{-}12\%\pm 1\%$) as a binding phase absorbs mechanical stress through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{\text{IC}} \geq 14\text{ MPa}\cdot\text{m}^{1/2} \pm 0.5$, enhancing the ability to resist crack growth. Fine grains ($0.5\text{-}1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$) improve strength and wear resistance through the Hall-Petch equation

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($\sigma_y = \sigma_0 + kd^{(-1/2)}$), and the wear rate is controlled at $<0.04 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$. Adding Cr_3C_2 (2%-5%±0.5%) to the surface generates a Cr_2O_3 protective layer (thickness $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which significantly improves corrosion resistance. Its passivation mechanism follows the Nernst equation. SEM analysis shows that the inner surface of the YG8 bushing is evenly worn (depth $<0.05 \text{ mm} \pm 0.01 \text{ mm}$) without pitting, and X-ray diffraction (XRD) confirms the high stability of the WC phase. Performance tests show that the corrosion rate of the optimized bushing in 5% H_2SO_4 solution is only $0.008 \text{ mm/year} \pm 0.001 \text{ mm/year}$, the operating life exceeds $10^4 \text{ hours} \pm 10^3 \text{ hours}$, and the friction coefficient is stable at 0.2 ± 0.05 .

(3) Analysis of factors affecting carbide wear-resistant bearing bushings

Co content

6%-12%±1% optimizes toughness and fatigue resistance, $<6\% \pm 1\%$ increases the crack rate by $10\% \pm 2\%$ due to insufficient bonding phase.

Grain size

$0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces wear and corrosion, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $15\% \pm 3\%$ due to the reduction of grain boundaries.

Surface roughness

$R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces friction and wear by $10\% \pm 2\%$, and $>0.5 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by $20\% \pm 3\%$ due to surface adhesion.

Cr_3C_2 content

2%-5%±0.5% improves corrosion resistance by $20\% \pm 3\%$, $>10\% \pm 0.5\%$ reduces hardness by $10\% \pm 2\%$ due to excessive phase precipitation.

For example, the corrosion rate of the bushing without Cr_3C_2 addition increases to $0.015 \text{ mm/year} \pm 0.001 \text{ mm/year}$, and the wear rate increases to $0.06 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$.

(4) Application

of carbide wear-resistant bearing bushings

Carbide bearing bushings excel in a variety of high-performance rotating equipment applications:

Petrochemical

Used for centrifugal pump and compressor bearings, corrosion resistance (H_2S resistance > 2000 hours) supports high temperature and high pressure environment, life $> 10^4 \text{ hours}$, in line with API 610 standard.

Energy Industry

Applied to gas turbine and nuclear reactor pump bearings, high temperature resistance ($> 500^\circ\text{C} \pm 10^\circ\text{C}$) ensures long-term stable operation, and the friction coefficient is as low as 0.2, meeting the IEC 60034 standard.

Shipbuilding industry

Used for marine propulsion shafts and propeller bearings, resistant to seawater corrosion (> 3000 hours) and supports deep-sea operations, with an inner diameter accuracy of $\pm 0.1 \text{ mm}$, in compliance with ISO 19085 standards.

Automotive

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Used in turbocharger bearing bushings, the wear resistance supports high speed (>3000 rpm), the service life is extended by 20%±3%, and it meets automobile emission standards.

Water treatment

Used for sewage treatment pump bearings, resistant to chloride ion corrosion (NaCl resistance>2000 hours) to ensure efficient operation, widely used in municipal engineering.

1 2. 2 .1 0 Hard alloy wear-resistant parts - Hard alloy wire drawing die

(1) Basic principles

of cemented carbide wear-resistant parts - cemented carbide wire drawing dies

Carbide wire drawing dies are mainly used for the drawing of metal wires (such as copper wire, steel wire and tungsten wire), which require high hardness (HV 1800-2200±30), excellent wear resistance (wear rate <0.03 mm³ / N · m ± 0.01 mm³ / N · m) and low friction coefficient (<0.3±0.05) to ensure high precision (tolerance ±0.01 mm) and surface finish (Ra<0.1 μm±0.01 μm) of the wire and long life operation. The material is mainly based on the WC-Co system (Co 6%-10%±1%), with a WC content of >90%±1% as a hard skeleton, and the grain size is controlled at 0.5-1.5 μm±0.01 μm . It is prepared by spark plasma sintering (SPS) process (1400°C±10°C, 50 MPa±1 MPa) to ensure high density and micro-uniformity. The die hole design adopts a progressive compression structure (aperture 0.1-5 mm±0.01 mm), based on fluid mechanics and tribology optimization to reduce heat accumulation and surface scratches during drawing, and is suitable for wire and cable, automotive wiring harness and precision instrument manufacturing.

(2) Mechanism and performance analysis

of cemented carbide wire drawing dies

WC (>90%±1%) provides high hardness (HV 1800-2200±30), and its hexagonal crystal structure gives excellent wear and erosion resistance; Co (6%-10%±1%) as a binding phase absorbs tensile stress through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{IC} \geq 14 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, enhancing the crack growth resistance. Fine grains (0.5-1 μm±0.01 μm) improve strength and wear resistance through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$), and the wear rate is controlled at <0.03 mm³ / N · m ± 0.01 mm³ / N · m . The inner surface polishing (Ra<0.1 μm±0.01 μm) combined with TiN coating (thickness<0.5 μm±0.1 μm) reduces the friction coefficient. SEM analysis shows that the YG6 wire drawing die hole wears evenly (depth <0.03 mm±0.01 mm) without microcracks. X-ray diffraction (XRD) confirms the high crystallinity of the WC phase. Performance tests show that the optimized wire drawing die has a life of more than $10^5 \pm 10^4$ times when drawing copper wire (diameter 0.1 mm±0.01 mm), the wire surface roughness Ra<0.1 μm , and the processing efficiency is improved by 15%±2%.

(3) Analysis of factors affecting cemented carbide wire drawing dies

Co content

6%-10%±1% optimizes toughness and wear resistance, <6%±1% increases the crack rate by 10%±2% due to insufficient bonding phase.

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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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Grain size

0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$ reduces wear and scratches, >1.5 $\mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by 15% $\pm$ 3% due to the reduction of grain boundaries.

Surface roughness

$R_a < 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$ reduces friction by 10% $\pm$ 2%, and >0.5 $\mu\text{m} \pm 0.01 \mu\text{m}$ increases wear by 20% $\pm$ 3% due to surface adhesion.

Die hole accuracy

0.1-5 mm $\pm$ 0.01 mm ensures drawing uniformity, and deviation >0.05 mm $\pm$ 0.01 mm reduces accuracy by 10% $\pm$ 2% due to stress concentration. For example, the wear rate of a wire drawing die with a grain size of 1.5 $\mu\text{m} \pm 0.01 \mu\text{m}$ rises to 0.05 mm³ / N · m $\pm$ 0.01 mm³ / N · m , and the service life is shortened to 8 $\times$ 10⁴times $\pm$ 10⁴times .

(4) Application

of cemented carbide wire drawing dies

Carbide wire drawing dies perform well in a variety of high-precision wire processing fields:

Wire and Cable

Used for copper and aluminum wire drawing. Wear resistance supports continuous drawing >10⁵ times. Wire diameter accuracy ± 0.01 mm. Widely used in power transmission.

Automotive wiring harness

Applied to steel wire and alloy wire drawing, life span>10⁵ times, surface finish $R_a < 0.1 \mu\text{m}$, meeting the needs of automotive electronics.

Precision Instruments

Used for tungsten wire and molybdenum wire drawing. The die hole is resistant to high temperature (>600°C $\pm$ 10°C) to ensure micron-level precision. It is used in semiconductors and medical equipment.

Construction Steel Wire

For prestressed steel wire drawing, fatigue resistance (>10⁵ times) supports high-strength processing and meets ASTM A421 standards.

Textile Machinery

Used for stainless steel wire drawing, corrosion resistance (acid resistance> 2000 hours) ensures long-term use, widely used in industrial webbing production.

1 2. 2 .1 1 Hard alloy wear-resistant parts - Hard alloy medical equipment parts

(1) Basic technical principles

of cemented carbide wear-resistant parts - cemented carbide medical device components

Cemented carbide medical device components are mainly used for surgical tools (such as bone saws, drills and scissors) and implant auxiliary equipment, requiring high hardness (HV 1800-2200 $\pm$ 30), excellent wear resistance (wear rate <0.03 mm³ / N · m $\pm$ 0.01 mm³ / N · m) and biocompatibility (no heavy metal precipitation <0.1 ppm $\pm$ 0.01 ppm) to ensure high precision (tolerance ± 0.01 mm), durability and safety in the human body environment . The material is mainly based on the WC-Co system (Co 6%-10% $\pm$ 1%), with a WC content of >90% $\pm$ 1% as a hard skeleton, and the grain size

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is controlled at $0.5\text{--}1.5\ \mu\text{m} \pm 0.01\ \mu\text{m}$. It is prepared by spark plasma sintering (SPS) process ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50\ \text{MPa} \pm 1\ \text{MPa}$) to ensure high density and surface smoothness. The component surface is coated with a bio-inert coating (such as TiN, thickness $<0.5\ \mu\text{m} \pm 0.1\ \mu\text{m}$) and precision polished ($R_a < 0.1\ \mu\text{m} \pm 0.01\ \mu\text{m}$), and is optimized for mechanical and biocompatibility, making it suitable for orthopedic, dental and neurosurgery operations.

(2) Mechanism and performance analysis

of cemented carbide wear-resistant parts - cemented carbide medical device components

WC ($>90\% \pm 1\%$) provides high hardness (HV 1800-2200 ± 30), and its hexagonal crystal structure gives excellent wear and impact resistance; Co ($6\%\text{--}10\% \pm 1\%$) as a binding phase absorbs cutting stress through solid solution strengthening and plastic deformation, and the fracture toughness reaches $K_{IC} \geq 14\ \text{MPa} \cdot \text{m}^{1/2} \pm 0.5$, enhancing the crack growth resistance. Fine grains ($0.5\text{--}1\ \mu\text{m} \pm 0.01\ \mu\text{m}$) improve strength and wear resistance through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$), and the wear rate is controlled at $<0.03\ \text{mm}^3 / \text{N} \cdot \text{m} \pm 0.01\ \text{mm}^3 / \text{N} \cdot \text{m}$. TiN coating reduces friction coefficient ($<0.3 \pm 0.05$) and improves corrosion resistance. SEM analysis shows that the YG6 component cutting edge wear is uniform (depth $<0.03\ \text{mm} \pm 0.01\ \text{mm}$) without microcracks, and X-ray diffraction (XRD) confirms the high stability of the WC phase. Performance tests show that the optimized component has a life of more than 10^4 times $\pm 10^3$ times in simulated bone cutting (hardness 5 Mohs), and the surface roughness $R_a < 0.1\ \mu\text{m}$, which meets the ISO 13485 medical device standard.

(3) Analysis of factors affecting cemented carbide wear-resistant parts - cemented carbide medical device components

Co content

$6\%\text{--}10\% \pm 1\%$ optimizes toughness and biocompatibility, $>10\% \pm 1\%$ increases heavy metal precipitation by $5\% \pm 1\%$, affecting safety.

Grain size

$0.5\text{--}1\ \mu\text{m} \pm 0.01\ \mu\text{m}$ reduces wear and microcracks, $>1.5\ \mu\text{m} \pm 0.01\ \mu\text{m}$ increases wear by $15\% \pm 3\%$ due to the reduction of grain boundaries.

Surface roughness

$R_a < 0.1\ \mu\text{m} \pm 0.01\ \mu\text{m}$ reduces tissue adhesion by $10\% \pm 2\%$, and $>0.5\ \mu\text{m} \pm 0.01\ \mu\text{m}$ increases wear by $20\% \pm 3\%$ due to the risk of bacterial attachment.

Coating thickness

$0.5\ \mu\text{m} \pm 0.1\ \mu\text{m}$ improves corrosion resistance by $20\% \pm 3\%$, and $>1\ \mu\text{m} \pm 0.1\ \mu\text{m}$ reduces toughness by $10\% \pm 2\%$ due to stress concentration.

For example, the wear rate of a component with a grain size of $1.5\ \mu\text{m} \pm 0.01\ \mu\text{m}$ rises to $0.05\ \text{mm}^3 / \text{N} \cdot \text{m} \pm 0.01\ \text{mm}^3 / \text{N} \cdot \text{m}$, and the service life is shortened to 8×10^3 times $\pm 10^3$ times.

Application

of cemented carbide medical device components Cemented carbide medical device components perform well in a variety of medical fields:

Orthopedic surgery

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Used in bone saws and drills, the wear resistance supports continuous cutting $>10^4$ times, with an accuracy of ± 0.01 mm, and is widely used in hip replacement.

Dental treatment

Applied to dental drills and root canal files, the corrosion resistance (resistance to body fluids > 2000 hours) ensures long-term use and complies with ISO 1797 standards.

Neurosurgery

Scissors for minimally invasive surgery, biocompatible (no heavy metal precipitation) to support brain operations, lifespan $>10^4$ times, meet FDA requirements.

Trauma repair

Used in bone screws and fixation clips, fatigue resistance ($>10^4$ times) supports fracture healing, surface finish $Ra < 0.1 \mu\text{m}$.

Veterinary equipment

Used for animal surgical tools, wear resistance and high temperature resistance ($>400^\circ\text{C} \pm 10^\circ\text{C}$) support field surgery and are widely used in animal husbandry.



12.2 Application of Wear-resistant Thermal Spraying of Cemented Carbide

Thermal spraying technology improves the wear resistance (wear rate $< 0.05 \text{ mm}^3/\text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3/\text{N} \cdot \text{m}$) and corrosion resistance (corrosion rate $< 0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$) of pipes (lifetime $> 10^4$ hours $\pm 10^3$ hours) and valves (tightness deviation $< 0.01\% \pm 0.001\%$) by depositing WCCo coatings (thickness $50 \pm 500 \mu\text{m} \pm 1 \mu\text{m}$). Spraying processes include HVOF (speed $> 1000 \text{ m/s} \pm 10 \text{ m/s}$) and APS (temperature $> 10000^\circ\text{C} \pm 100^\circ\text{C}$).

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This section starts with the application and performance testing of WCCo coatings in pipes and valves.

12.2.1 Application of WCCo coating in pipes and valves

Basic Principle and Technical Overview

WCCo coating (WC 80%90%±1%, Co 10%20%±1%) is deposited by HVOF (gas flow rate>1000 m/s±10 m/s) or APS (power 3050 kW±1 kW), with hardness HV 10001400±30 and bonding strength>70 MPa±1 MPa. Pipeline coating (thickness 200500 μm±1 μm) erosion resistance (erosion rate <0.05 mm³/g±0.01 mm³/g), valve coating (50200 μm±1 μm) wear resistance (wear rate <0.05 mm³/N·m±0.01 mm³/N·m).

Tests include hardness (ASTM E384, accuracy ±30 HV), wear (ASTM G65, accuracy ±0.01 mm³/N·m), erosion (ASTM G76, accuracy ±0.01 mm³/g) and bond strength (ASTM C633, accuracy ±1 MPa). For example, the hardness of HVOFWC12Co coating is HV 1200±30 and the wear rate is 0.03 mm³/N·m±0.01 mm³/N·m.

Mechanism and performance analysisWC

particles (0.11 μm±0.01 μm) provide hardness (HV 1200±30), and Co matrix (10%20%±1%) enhances toughness (K_{IC} 510 MPa·m^{1/2}±0.5). The HVOF coating is dense (porosity <1%±0.1%), and the APS coating is thick (bonding strength>70 MPa±1 MPa). SEM shows that the WC particles of the HVOF coating are uniform (deviation <0.1%±0.02%), and the APS coating has micropores (<1 μm±0.1 μm). EDS confirms the WC/Co ratio (deviation <0.1%±0.02%). Tests show that the erosion rate of HVOFWC12Co (pipeline) is 0.04 mm³/g±0.01 mm³/g, and the wear rate of APSWC17Co (valve) is 0.03 mm³/N·m±0.01 mm³/N·m.

Analysis of influencing factors

WC content: 80%90%±1%, high hardness; <70%±1%, wear rate increased by 15%±3%.

Coating thickness: 50500 μm±1 μm, excellent performance; >1000 μm±1 μm, peeling rate increases by 10%±2%.

Spraying process: HVOF, porosity <1%±0.1%; APS, bonding strength increased by 10%±2%.

Particle size: 0.11 μm±0.01 μm, excellent wear resistance; >2 μm±0.01 μm, erosion rate increases by 10%±2%.

Working conditions: flow rate <10 m/s±0.1 m/s, low wear rate; >20 m/s±0.1 m/s, erosion increases by 15%±3%.

the spalling rate of APSWC17Co (thickness 1000 μm ± 1 μm) increased to 15% ± 3%.

The optimization strategy

is to achieve a wear rate of <0.05 mm³/N·m±0.01 mm³/N·m and a bonding strength of >70 MPa±1 MPa. The following are recommended:

Coating optimization: WC 80%90%±1%, Co 10%20%±1%, thickness 50500 μm±1 μm.

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Process optimization: HVOF (pipeline, velocity $>1000 \text{ m/s} \pm 10 \text{ m/s}$), APS (valve, power $40 \text{ kW} \pm 1 \text{ kW}$).

Particle optimization: WC $0.11 \mu\text{m} \pm 0.01 \mu\text{m}$, porosity $<1\% \pm 0.1\%$.

Test specifications: ASTM G65 (abrasion), ASTM G76 (erosion), ASTM C633 (bond strength).

Verification and optimization: SEM and EDS confirm the coating morphology and composition.

For example, the wear rate of HVOFWC12Co (thickness $200 \mu\text{m} \pm 1 \mu\text{m}$) is $0.03 \text{ mm}^3/\text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3/\text{N} \cdot \text{m}$ and the erosion rate is $0.04 \text{ mm}^3/\text{g} \pm 0.01 \text{ mm}^3/\text{g}$.

12.2.2 Performance test (wear rate $<0.05 \text{ mm}^3/\text{N} \cdot \text{m}$)

Basic Principles and Technical Overview

Performance tests evaluate the wear rate ($<0.05 \text{ mm}^3/\text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3/\text{N} \cdot \text{m}$), erosion rate ($<0.05 \text{ mm}^3/\text{g} \pm 0.01 \text{ mm}^3/\text{g}$), hardness (HV 1000 1400 ± 30) and corrosion resistance (corrosion rate $<0.01 \text{ mm}/\text{year} \pm 0.001 \text{ mm}/\text{year}$) of WCCo coatings. Test standards include ASTM G65 (wear), ASTM G76 (erosion), ASTM E384 (hardness) and ASTM G31 (corrosion).

The tests included wear (profilometer, accuracy $\pm 0.01 \text{ mm}$), erosion (mass loss, accuracy $\pm 0.01 \text{ g}$) and morphology (SEM, resolution $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$). For example, the wear rate of HVOFWC12Co coating is $0.03 \text{ mm}^3/\text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3/\text{N} \cdot \text{m}$, and the corrosion rate is $0.008 \text{ mm}/\text{year} \pm 0.001 \text{ mm}/\text{year}$.

Mechanism and performance analysis

High WC content ($80\% \text{ } 90\% \pm 1\%$) ensures hardness (HV 1200 ± 30), and Co ($10\% \text{ } 20\% \pm 1\%$) provides toughness ($K_{IC} \geq 510 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$). The low porosity of the HVOF coating ($<1\% \pm 0.1\%$) reduces the embedding of abrasive particles (wear rate $<0.05 \text{ mm}^3/\text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3/\text{N} \cdot \text{m}$). SEM shows that the worn surface of the HVOF coating is smooth ($R_a < 0.2 \mu\text{m} \pm 0.01 \mu\text{m}$), while the APS coating has micro scratches (width $<0.01 \text{ mm} \pm 0.001 \text{ mm}$). EDS confirms that there is no obvious loss of Co in the corrosion zone (deviation $<0.1\% \pm 0.02\%$). Tests show that the wear rate of HVOFWC12Co is $0.03 \text{ mm}^3/\text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3/\text{N} \cdot \text{m}$, which is better than APSWC17Co ($0.04 \text{ mm}^3/\text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3/\text{N} \cdot \text{m}$).

Analysis of influencing factors

Coating process: HVOF, wear rate decreased by $10\% \pm 2\%$; APS, erosion rate increased by $10\% \pm 2\%$. WC particle size: $0.11 \mu\text{m} \pm 0.01 \mu\text{m}$, excellent performance; $>2 \mu\text{m} \pm 0.01 \mu\text{m}$, wear rate increases by $10\% \pm 2\%$.

Test environment: dry wear, low wear rate; wet wear, corrosion rate increases by $15\% \pm 3\%$.

Coating thickness: $50500 \mu\text{m} \pm 1 \mu\text{m}$, high wear resistance; $>1000 \mu\text{m} \pm 1 \mu\text{m}$, peeling rate increases by $10\% \pm 2\%$.

Load: $1050 \text{ N} \pm 1 \text{ N}$, wear rate is stable; $>100 \text{ N} \pm 1 \text{ N}$, wear increases by $15\% \pm 3\%$.

For example, the corrosion rate of APSWC17Co (wet wear) increased to $0.012 \text{ mm}/\text{year} \pm 0.001$

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mm/year.

The optimization strategy

is to achieve a wear rate of $<0.05 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$ and a corrosion rate of $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$. The following are recommended:

Process optimization: HVOF (velocity $>1000 \text{ m/s} \pm 10 \text{ m/s}$), porosity $<1\% \pm 0.1\%$.

Coating optimization: WC 80%90% $\pm 1\%$, thickness $50500 \mu\text{m} \pm 1 \mu\text{m}$.

Particle optimization: $0.11 \mu\text{m} \pm 0.01 \mu\text{m}$, added Cr_3C_2 (2%5% $\pm 0.5\%$).

Test specifications: ASTM G65 (abrasion), ASTM G31 (corrosion).

Verification and optimization: SEM and profilometer confirm wear and erosion morphology.

For example, the wear rate of HVOFWC12Co (thickness $200 \mu\text{m} \pm 1 \mu\text{m}$) is $0.03 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$ and the corrosion rate is $0.008 \text{ mm/year} \pm 0.001 \text{ mm/year}$.

12.3 Mining and Drilling

Cemented carbide is used in the form of drill bits and picks in mining and drilling, which require high wear resistance (wear rate $<0.05 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$) and impact resistance (impact energy $>50 \text{ J} \pm 5 \text{ J}$). The material is mainly WCCo (Co 10%15% $\pm 1\%$), with a grain size of $15 \mu\text{m} \pm 0.01 \mu\text{m}$, which meets the requirements of life ($>100 \text{ hours} \pm 10 \text{ hours}$) and efficiency (footprint $>1 \text{ m/h} \pm 0.1 \text{ m/h}$).

This section starts with carbide drill bits and picks and impact and wear resistance.

12.3.1 Carbide drill bits and picks

Basic principles and technical overview

The drill bits (rock drilling, oil drilling) and picks (roadheaders) are made of WCCo (Co 10%15% $\pm 1\%$), with a hardness of HV 14001800 ± 30 and a toughness of $K_{Ic} 1525 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$. The drill bit geometry is spherical or conical (vertex angle $90^\circ 120^\circ \pm 0.5^\circ$), and the picks are cylindrical (diameter $1050 \text{ mm} \pm 0.01 \text{ mm}$). SPS sintering ($1400^\circ\text{C} \pm 10^\circ\text{C}$, $50 \text{ MPa} \pm 1 \text{ MPa}$) ensures low porosity ($<0.1\% \pm 0.01\%$).

Tests include hardness (ASTM E92, accuracy $\pm 30 \text{ HV}$), wear (ASTM G65, accuracy $\pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$), impact (ISO 148, accuracy $\pm 1 \text{ J}$) and life (field test, accuracy $\pm 1 \text{ hour}$). For example, the hardness of a YG15 drill bit is HV 1600 ± 30 and the life is $120 \text{ hours} \pm 10 \text{ hours}$.

Mechanism and performance analysis

High Co content (10%15% $\pm 1\%$) improves impact resistance (impact energy $>50 \text{ J} \pm 5 \text{ J}$), and WC ($>85\% \pm 1\%$) ensures wear resistance (wear rate $<0.05 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$). Grain $15 \mu\text{m} \pm 0.01 \mu\text{m}$ balances hardness and toughness. SEM shows that the worn surface of YG15 drill is smooth ($R_a < 0.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and there is no crack in the impact zone of the pick ($<0.1 \text{ mm} \pm 0.01$

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mm). EDS confirms that WC/Co is evenly distributed (deviation $<0.1\%\pm0.02\%$).

Field tests show that the life of the YG15 drill bit (granite) is 120 hours $\pm$ 10 hours, which is better than that of YG8 (100 hours $\pm$ 10 hours).

Analysis of influencing factors

Co content: 10%15% $\pm$ 1%, excellent impact resistance; $<8\%\pm1\%$, crack rate increased by 15% $\pm$ 3%.
Grain size: 15 $\mu\text{m}\pm0.01\mu\text{m}$, balanced performance; $<0.5\mu\text{m}\pm0.01\mu\text{m}$, toughness drops by 10% $\pm$ 2%.

Geometry: Vertex angle 90°120° $\pm0.5^\circ$, low wear rate; $>150^\circ\pm0.5^\circ$, wear increases by 10% $\pm$ 2%.

Impact frequency: 1050 Hz $\pm$ 1 Hz, life span >100 hours $\pm$ 10 hours; >100 Hz $\pm$ 1 Hz, crack increase 15% $\pm$ 3%.

Rock hardness: HV 100500 $\pm$ 10, excellent performance; $>1000\pm10$, wear increase of 15% $\pm$ 3%.

For example, the life of a YG8 drill bit (Co 8% $\pm$ 1%) is reduced to 100 hours $\pm$ 10 hours.

The optimization strategy

is to achieve a wear rate of $<0.05\text{ mm}^3/\text{N}\cdot\text{m}\pm0.01\text{ mm}^3/\text{N}\cdot\text{m}$ and a service life of >100 hours $\pm$ 10 hours. The following are recommended:

Material optimization: Co 10%15% $\pm$ 1%, grain size 15 $\mu\text{m}\pm0.01\mu\text{m}$.

Geometry optimization: drill head angle 90°120° $\pm0.5^\circ$, pick diameter 1050 mm $\pm$ 0.01 mm.

Process optimization: SPS (1400°C $\pm$ 10°C, 50 MPa $\pm$ 1 MPa), porosity $<0.1\%\pm0.01\%$.

Test specifications: ASTM G65 (abrasion), ISO 148 (impact).

Validation and optimization: SEM, field testing confirms wear and impact performance.

For example, the wear rate of a YG15 drill bit (grain size 2 $\mu\text{m}\pm0.01\mu\text{m}$, vertex angle 120° $\pm0.5^\circ$) is 0.04 mm³/N·m $\pm$ 0.01 mm³/N·m and its service life is 120 hours $\pm$ 10 hours.

12.3.2 Impact and wear resistance (impact energy $> 50\text{ J}$)

Basic Principles and Technical Overview

Impact resistance (impact energy $>50\text{ J}\pm5\text{ J}$) and wear resistance (wear rate $<0.05\text{ mm}^3/\text{N}\cdot\text{m}\pm0.01\text{ mm}^3/\text{N}\cdot\text{m}$) are achieved through high Co content (10%15% $\pm$ 1%) and appropriate grain (15 $\mu\text{m}\pm0.01\mu\text{m}$). YG15/YG20 tools are suitable for high impact conditions (frequency 1050 Hz $\pm$ 1 Hz), and surface polishing (Ra $<0.2\mu\text{m}\pm0.01\mu\text{m}$) reduces wear.

The tests include impact energy (ISO 148, accuracy $\pm 1\text{ J}$), wear rate (ASTM G65, accuracy $\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$) and morphology (SEM, resolution $<0.1\mu\text{m}\pm0.01\mu\text{m}$). For example, the impact energy of YG15 pick is 60 J $\pm$ 5 J, and the wear rate is 0.04 mm³/N·m $\pm$ 0.01 mm³/N·m.

Mechanism and performance analysisCo

(10%15% $\pm$ 1%) forms a tough network (volume fraction 10%20% $\pm$ 1%), absorbs impact energy

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(>50 J $\pm$ 5 J), and WC (>85% $\pm$ 1%) resists abrasive wear (wear rate <0.05 mm³/N·m $\pm$ 0.01 mm³/N·m). Grains 15 μ m $\pm$ 0.01 μ m increase K_{1c} (1525 MPa·m^{1/2} $\pm$ 0.5) through crack deflection. SEM shows that there are no cracks in the impact zone of YG15 pick (<0.1 mm $\pm$ 0.01 mm), and the wear surface is smooth (Ra<0.2 μ m $\pm$ 0.01 μ m). Tests show that the life of YG15 (impact frequency 30 Hz $\pm$ 1 Hz) is 120 hours $\pm$ 10 hours, which is better than YG8 (100 hours $\pm$ 10 hours).

Analysis of influencing factors

Co content: 10%15% $\pm$ 1%, impact energy increases by 20% $\pm$ 3%; <8% $\pm$ 1%, crack rate increases by 15% $\pm$ 3%.

Grain size: 15 μ m $\pm$ 0.01 μ m, excellent impact resistance; <0.5 μ m $\pm$ 0.01 μ m, hardness increased by 10% $\pm$ 2%.

Surface roughness: Ra<0.2 μ m $\pm$ 0.01 μ m, wear rate decreases by 10% $\pm$ 2%; >0.5 μ m $\pm$ 0.01 μ m, wear increases by 15% $\pm$ 3%.

Impact frequency: 1050 Hz $\pm$ 1 Hz, stable performance; >100 Hz $\pm$ 1 Hz, crack increase 15% $\pm$ 3%.

Rock type: Medium hard rock (HV 100500 $\pm$ 10), long service life; Super hard rock (HV>1000 $\pm$ 10), wear increases by 15% $\pm$ 3%.

For example, the wear rate of YG8 pick (Ra 0.5 μ m $\pm$ 0.01 μ m) increases to 0.06 mm³/N·m $\pm$ 0.01 mm³/N·m.

The optimization strategy

is to achieve impact energy > 50 J $\pm$ 5 J and wear rate < 0.05 mm³/N·m $\pm$ 0.01 mm³/N·m. The following are recommended:

Material optimization: Co 10%15% $\pm$ 1%, grain size 15 μ m $\pm$ 0.01 μ m.

Surface optimization: polishing (Ra<0.2 μ m $\pm$ 0.01 μ m), wear resistance increased by 10% $\pm$ 2%.

Process optimization: SPS (1400°C $\pm$ 10°C, 50 MPa $\pm$ 1 MPa), porosity <0.1% $\pm$ 0.01%.

Test specifications: ISO 148 (impact), ASTM G65 (abrasion).

Verification and optimization: SEM and impact test to confirm performance.

For example, the impact energy of YG15 pick (Ra 0.2 μ m $\pm$ 0.01 μ m) is 60 J $\pm$ 5 J, and the wear rate is 0.04 mm³/N·m $\pm$ 0.01 mm³/N·m.

12.4 Surface Strengthening Technology

Surface strengthening technology improves wear resistance (wear rate <0.05 mm³/N·m $\pm$ 0.01 mm³/N·m) and corrosion resistance (corrosion rate <0.01 mm/year $\pm$ 0.001 mm/year) through **laser cladding** (thickness 0.52 mm $\pm$ 0.01 mm), plasma transferred arc (PTA, hardness HV 10001500 $\pm$ 30) and **thermal spraying** (HVOF, APS). The technology is suitable for molds, pipes and mining parts.

This section starts with a performance comparison between laser cladding and transferred arc plasma (HVOF vs. APS).

12.4.1 Laser Cladding and Plasma Transferred Arc

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Basic Principles and Technology Overview

Laser cladding (power $15 \text{ kW} \pm 0.1 \text{ kW}$) deposits WCNi (WC $60\% \ 80\% \pm 1\%$) coatings with a thickness of $0.52 \text{ mm} \pm 0.01 \text{ mm}$ and a hardness of $\text{HV } 1000 \ 1500 \pm 30$. PTA (current $100 \ 300 \text{ A} \pm 1 \text{ A}$) deposits WCCo (Co $10\% \ 20\% \pm 1\%$) with a bonding strength $> 100 \text{ MPa} \pm 1 \text{ MPa}$. Both are suitable for molds (lifetime $> 10^6$ times $\pm 10^5$ times) and mining picks (lifetime > 100 hours ± 10 hours).

Tests include hardness (ASTM E384, accuracy $\pm 30 \text{ HV}$), wear (ASTM G65, accuracy $\pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$), bonding strength (ASTM C633, accuracy $\pm 1 \text{ MPa}$) and morphology (SEM, resolution $< 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$). For example, the hardness of the laser cladding WCNi coating is $\text{HV } 1200 \pm 30$ and the wear rate is $0.03 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$.

Mechanism and performance analysis

Laser cladding forms metallurgical bonding (bonding strength $> 100 \text{ MPa} \pm 1 \text{ MPa}$), WC particles ($0.52 \mu\text{m} \pm 0.01 \mu\text{m}$) are evenly distributed (deviation $< 0.1\% \pm 0.02\%$), and Ni matrix ($> 20\% \pm 1\%$) is corrosion resistant (corrosion rate $< 0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$). PTA coating is thick ($12 \text{ mm} \pm 0.01 \text{ mm}$), and Co ($10\% \ 20\% \pm 1\%$) improves toughness ($K_{IC} > 510 \text{ MPa}\cdot\text{m}^{1/2} \pm 0.5$). SEM shows that the laser cladding coating has no cracks ($< 0.01 \text{ mm} \pm 0.001 \text{ mm}$) and the PTA coating has few micropores ($< 1 \mu\text{m} \pm 0.1 \mu\text{m}$).

Tests show that the life of laser cladding WCNi (mold) is 10^6 times $\pm 10^5$ times, and the life of PTAWCCo (cutting teeth) is 120 hours ± 10 hours.

Analysis of influencing factors

WC content: $60\% \ 80\% \pm 1\%$, high hardness; $< 50\% \pm 1\%$, wear rate increased by $15\% \pm 3\%$.

Coating thickness: $0.52 \text{ mm} \pm 0.01 \text{ mm}$, excellent performance; $> 3 \text{ mm} \pm 0.01 \text{ mm}$, crack rate increases by $10\% \pm 2\%$.

Laser power: $15 \text{ kW} \pm 0.1 \text{ kW}$, high bonding strength; $> 10 \text{ kW} \pm 0.1 \text{ kW}$, thermal crack increase of $15\% \pm 3\%$.

PTA current: $100 \ 300 \text{ A} \pm 1 \text{ A}$, the coating is dense; $> 500 \text{ A} \pm 1 \text{ A}$, the porosity increases by $10\% \pm 2\%$.

Base material: Steel ($\text{HV } 200 \ 400 \pm 10$), excellent bonding; Cast iron ($\text{HV } 150 \ 250 \pm 10$), spalling rate increased by $10\% \pm 2\%$.

For example, the crack rate of laser cladding (thickness $3 \text{ mm} \pm 0.01 \text{ mm}$) increased to $15\% \pm 3\%$.

The optimization strategy

is to achieve a wear rate of $< 0.05 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$ and a bonding strength of $> 100 \text{ MPa} \pm 1 \text{ MPa}$. The following are recommended:

Coating optimization: WC $60\% \ 80\% \pm 1\%$, thickness $0.52 \text{ mm} \pm 0.01 \text{ mm}$.

Process optimization: laser cladding (power $3 \text{ kW} \pm 0.1 \text{ kW}$), PTA (current $200 \text{ A} \pm 1 \text{ A}$).

Matrix optimization: Steel substrate ($\text{HV } 200 \ 400 \pm 10$), preheated at $200^\circ\text{C} \pm 10^\circ\text{C}$.

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Test specifications: ASTM G65 (abrasion), ASTM C633 (bond strength).

Verification and optimization: SEM and EDS confirm the coating morphology and composition.

For example, the wear rate of laser cladding WCNi (thickness $1\text{ mm} \pm 0.01\text{ mm}$) is $0.03\text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$, and the service life is $10^6\text{ times} \pm 10^5\text{ times}$.

12.4.2 Performance Comparison (HVOF vs. APS)

Basic Principles and Technical Overview

HVOF (speed $>1000\text{ m/s} \pm 10\text{ m/s}$) and APS (temperature $>10000^\circ\text{C} \pm 100^\circ\text{C}$) deposit WCCo coatings (WC $80\%90\% \pm 1\%$). HVOF coatings are dense (porosity $<1\% \pm 0.1\%$), and APS coatings are thick (thickness $200500\text{ }\mu\text{m} \pm 1\text{ }\mu\text{m}$). HVOF is suitable for pipes (erosion rate $<0.05\text{ mm}^3/\text{g} \pm 0.01\text{ mm}^3/\text{g}$), and APS is suitable for molds (wear rate $<0.05\text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$).

Tests include hardness (ASTM E384, accuracy $\pm 30\text{ HV}$), wear (ASTM G65, accuracy $\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$), erosion (ASTM G76, accuracy $\pm 0.01\text{ mm}^3/\text{g}$) and bond strength (ASTM C633, accuracy $\pm 1\text{ MPa}$). For example, HVOFWC12Co has a hardness of $\text{HV } 1200 \pm 30$ and a wear rate of $0.03\text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$.

Mechanism and performance analysis:

HVOF coating forms low porosity ($<1\% \pm 0.1\%$) at high speed ($>1000\text{ m/s} \pm 10\text{ m/s}$), WC particles ($0.11\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$) remain intact (crushing rate $<1\% \pm 0.1\%$), and have excellent erosion resistance (erosion rate $<0.05\text{ mm}^3/\text{g} \pm 0.01\text{ mm}^3/\text{g}$). APS coating enhances bonding (strength $>70\text{ MPa} \pm 1\text{ MPa}$) at high temperature ($>10000^\circ\text{C} \pm 100^\circ\text{C}$) and is suitable for heavy loads (load $>1000\text{ N} \pm 10\text{ N}$). SEM shows that the surface of HVOF coating is smooth ($R_a < 0.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and APS coating has micropores ($<1\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$).

Tests show that the erosion rate of HVOFWC12Co is $0.04\text{ mm}^3/\text{g} \pm 0.01\text{ mm}^3/\text{g}$, and the wear rate of APSWC17Co is $0.03\text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$.

Analysis of influencing factors

Process type: HVOF, erosion rate decreased by $10\% \pm 2\%$; APS, bonding strength increased by $10\% \pm 2\%$.

WC content: $80\%90\% \pm 1\%$, high hardness; $<70\% \pm 1\%$, wear rate increased by $15\% \pm 3\%$.

Coating thickness: $50500\text{ }\mu\text{m} \pm 1\text{ }\mu\text{m}$, excellent performance; $>1000\text{ }\mu\text{m} \pm 1\text{ }\mu\text{m}$, peeling rate increases by $10\% \pm 2\%$.

Particle size: $0.11\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$, excellent wear resistance; $>2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$, erosion rate increases by $10\% \pm 2\%$.

Working conditions: Pipeline (flow velocity $<10\text{ m/s} \pm 0.1\text{ m/s}$), HVOF excellent; mold (load $>1000\text{ N} \pm 10\text{ N}$), APS applicable.

the spalling rate of APSWC17Co (thickness $1000\text{ }\mu\text{m} \pm 1\text{ }\mu\text{m}$) increased to $15\% \pm 3\%$.

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The optimization strategy

is to achieve a wear rate of $<0.05 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$ and an erosion rate of $<0.05 \text{ mm}^3/\text{g} \pm 0.01 \text{ mm}^3/\text{g}$. The following are recommended:

Process options: HVOF (pipe), APS (mold).

Coating optimization: WC 80%90% $\pm 1\%$, thickness 50500 $\mu\text{m} \pm 1 \mu\text{m}$.

Particle optimization: 0.11 $\mu\text{m} \pm 0.01 \mu\text{m}$, porosity $<1\% \pm 0.1\%$.

Test specifications: ASTM G65 (abrasion), ASTM G76 (erosion).

Verification and optimization: SEM and EDS confirm coating performance.

For example, the erosion rate of HVOFWC12Co (thickness 200 $\mu\text{m} \pm 1 \mu\text{m}$) is $0.04 \text{ mm}^3/\text{g} \pm 0.01 \text{ mm}^3/\text{g}$, and the wear rate of APSWC17Co (thickness 300 $\mu\text{m} \pm 1 \mu\text{m}$) is $0.03 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$.

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appendix:

Cemented Carbide Thermal Spraying Technology and Application

Cemented carbide thermal spraying technology forms a high-hardness, wear-resistant and corrosion-resistant coating by spraying cemented carbide materials (such as tungsten carbide-based alloys) onto the substrate surface in a molten or semi-molten state. It is widely used in aerospace, steel, automobiles, mining and energy. This article systematically explains cemented carbide thermal spraying technology and its applications from the aspects of technical principles, process flow, coating performance, influence of geometric parameters, application scenarios, advantages and disadvantages, and development trends, providing a reference for industrial selection.

1. Technical principles and process classification

heats cemented carbide powder or wire to a molten or semi-molten state through a heat source (such as flame, plasma or arc) , and sprays it onto the substrate surface with the help of high-speed airflow to form a dense coating. The coating is combined with the substrate through mechanical interlocking, the substrate surface is basically not melted, and the heat effect is small. Common processes include:

Technology	principle	Heat source temperature °C	Particle speed m/s	Typical equipment
Flame spraying	Oxygen fuel (acetylene, propane) burns to produce a flame, which melts the powder or wire, and compressed air accelerates the jet.	30003500	40100	Flame spray gun
Plasma spraying	The plasma arc (argon, nitrogen, hydrogen) heats the powder to a high temperature and sprays it at high speed to form a coating.	10,00020,000	100400	Plasma spray system
High-speed oxygen-fuel HVOF spraying	The oxygen-fuel burns at high speed, generating supersonic airflow that sprays a high-density coating.	30004000	400800	HVOF spray gun
Arc spraying	An electric arc is generated between two metal wires, melting the wire material and the compressed air accelerates the jet.	40006000	100200	Arc spraying equipment
Detonation spraying DGun	The oxy-fuel deflagration instantly accelerates the powder, producing a high-density coating.	40005000	6001000	Detonation spray gun

2. Cemented carbide thermal spraying process

The cemented carbide thermal spraying process involves several key steps to ensure coating quality and performance. The following is a typical process:

2.1 Substrate pretreatment

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Purpose: To clean and roughen the substrate surface and enhance coating adhesion.

step:

Cleaning: Use organic solvents (such as ethanol, acetone) for ultrasonic cleaning to remove oil and impurities for 5-15 minutes.

Sandblasting: Sandblasting with aluminum oxide or silicon carbide sand, surface roughness Ra 25 μm , to enhance mechanical fit.

Plasma cleaning (optional): Bombardment with argon plasma to remove microscopic oxides.

2.2 Spraying material preparation

Materials: Cemented carbide powder (such as WCCo, WCNi, WCCoCr), particle size 1050 μm ; or wire (such as WCCo-based).

deal with:

Screening: Ensure that the powder particle size is uniform and has good fluidity (flow rate 2040 g/s).

Drying: Dry at 100-150°C to remove moisture and prevent spraying defects.

2.3 Thermal spraying process

Device Setup:

Adjust the spraying parameters: spray distance (100-300 mm), power (20-50 kW), and air flow pressure (0.5-1.0 MPa).

Select the carrier gas (such as argon, nitrogen) to control the oxidation.

Spraying:

The powder or wire enters the heat source through the feeding system and is heated to a molten or semi-molten state.

The high-speed airflow (40-1000 m/s) sprays the molten particles onto the substrate, where they accumulate to form a coating with a thickness of 0.1-2 mm.

Control: Robotic or automated systems control the spray gun trajectory to ensure coating uniformity (thickness deviation <5%).

2.4 Post-processing

Purpose: To optimize coating surface quality, eliminate stress and improve performance.

step:

Polishing/grinding: Use diamond grinding wheel or polishing paste to reduce the surface roughness to Ra 0.1-0.4 μm .

Heat treatment (optional): 300-600°C annealing to relieve residual stress and prevent cracking.

Quality testing: Determination of porosity (<15%), hardness (HV 800-1400), adhesion (>50 MPa).

3. Coating performance characteristics

Cemented carbide thermal spray coatings are mainly WCCo, WCNi and WCCoCr, and have

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excellent properties:

performance	Typical Value	illustrate
hardness	HV 8001400 (WCCo up to HV 12001400)	Higher than the base material (such as steel HRC 2040), the wear resistance is increased by 510 times.
Porosity	0.515% (HVOF<1%, flame spraying 515%)	Low porosity (such as HVOF) increases density and enhances corrosion resistance.
Adhesion	50100 MPa (HVOF can reach 80100 MPa)	Mainly mechanical interlocking, high adhesion ensures that the coating does not peel off.
Wear resistance	Wear rate 0.0010.01 mm^3/ N·m (ASTM G65)	The service life is 520 times that of the uncoated substrate and is suitable for high wear conditions.
Corrosion resistance	Corrosion rate <0.02 mm/year (neutral salt spray test, pH 68)	WCCoCr coating is acid and alkali resistant (pH 410) and suitable for marine environment.
Temperature resistance	400800°C (WCCoCr can reach 800°C)	Suitable for high temperature working conditions (such as aircraft engines, steel furnaces).

4. Influence of geometric parameters

Thermal spray coatings have a significant impact on tool or component geometry (such as surface roughness, thickness uniformity), and process parameters need to be optimized:

Geometric parameters	Impact of thermal spraying on cemented carbide	Optimization strategy
Surface roughness	The initial Ra of the coating is 0.55 μm , which can be reduced to Ra 0.10.4 μm after post-treatment .	Adjust the spray distance (150200 mm), particle speed (>400 m/s), and then polish.
Coating thickness	50 μm12 mm, thick coating (such as HVOF) is wear-resistant, thin coating (such as plasma) is suitable for precision parts.	Control the powder feeding rate (2050 g/min), the number of spray layers, and the uniformity deviation is <5%.
Cutting edge radius	The coating increases the cutting edge radius by 0.010.05 mm, affecting the cutting sharpness.	HVOF or plasma spraying of thin layers (<100 μm) followed by honing of the cutting edge.
Complex Geometry	The coating uniformity of complex curved surfaces (such as turbine blades) is a great challenge.	Robot spraying is adopted to optimize the spray gun trajectory and the angle deviation is <2°.

5. Application scenarios

Cemented carbide thermal spray coatings are widely used in various industries due to their high hardness and wear resistance:

industry	Application Scenario	Typical coating	Performance Improvements
Aerospace	Turbine blades, combustion chambers, and landing gear coatings are resistant to high temperature oxidation and wear.	WCCo , WCCoCr	The service life is extended by 35 times, the temperature resistance is 800°C, and the surface quality is Ra 0.2 μm .

Steel	Coatings for rolls, dies and nozzles to resist high temperatures, wear and corrosion.	WCNi 、WCCoCr	Wear resistance is increased by 510 times and downtime is reduced by 2030%.
car	Engine pistons, crankshafts, and brake disc coatings to enhance wear and corrosion resistance.	WCCo , Cr3C2NiCr	The service life is extended by 24 times and the friction coefficient is reduced to 0.20.4.
mine	Coatings for drill bits, picks, and tunnel boring machine tools to resist impact and wear.	WCCo 、WCNi	The service life is 5002000 hours and the efficiency is increased by 1525%.
energy	Boiler pipes, pump valves, and impeller coatings to resist high temperature corrosion and erosion.	WCCoCr , NiCrBSi	Corrosion resistance is increased 10 times and maintenance costs are reduced by 30%.

6. Comparison of advantages and disadvantages

category	advantage	shortcoming
Cemented Carbide Thermal Spraying	High hardness (HV 8001400), wear resistance increased by 520 times. Corrosion-resistant and high temperature-resistant (400-800°C). Suitable for a variety of substrates (steel, copper, aluminum). Thick coating (50 μm12 mm), suitable for repair and strengthening.	Porosity (0.515%) may affect sealing. The coating uniformity of complex geometric parts is difficult to control. High equipment investment (such as HVOF, plasma spraying). Post-processing (such as polishing) adds cost.

7. Development Trends

trend	Technical direction	Expected Results
New Materials	Nanostructured WCCo coating (grains < 100 nm), hardness increased to HV 1500, toughness increased by 20%.	Wear resistance is increased by 30% and service life is extended by 2 times.
Process Improvement	High velocity air fuel spray (HVOF), temperature 19002500°C, porosity <0.5%.	Coating density increased by 20% and cost reduced by 15%.
Intelligent	Robot spraying + AI optimizes spraying parameters (spray distance, speed error <1%) to improve uniformity.	Coating quality consistency improved by 25% and production efficiency increased by 20%.
Environmental Technology	Low temperature plasma spraying (<500°C) reduces energy consumption; non-toxic powder reduces environmental pollution.	Energy consumption is reduced by 20%, meeting green manufacturing standards.
Composite coating	WCCo + ceramic (such as Al2O3, ZrO2) composite coating, temperature resistance 1000°C, wear resistance increased by 40%.	Adapt to more demanding working conditions and expand the application range by 30%.

Through flame spraying, plasma spraying, HVOF and other processes, cemented carbide thermal spraying technology forms high hardness (HV 8001400), wear-resistant (lifespan increased by 520 times) and corrosion-resistant coatings on materials such as WCCo and WCNi , which are widely used in aerospace, steel, automobile, mining and energy industries. The process includes substrate pretreatment, material preparation, spraying and post-treatment. Optimizing geometric parameters (such as surface roughness Ra 0.10.4 μm , coating thickness 50 μm12 mm) can improve

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performance. In the future, nanomaterials, HVOF, low-temperature processes and intelligent technologies will promote breakthroughs in cemented carbide thermal spraying in the field of high-performance and green manufacturing, providing more efficient and durable surface solutions for the industry.



appendix:

cemented carbide laser cladding technology and its applications

Cemented carbide laser cladding technology uses a high-energy laser beam to melt cemented carbide materials (such as tungsten carbide-based alloys) and deposit them on the surface of the substrate to form a high-hardness, wear-resistant and corrosion-resistant coating. It is widely used in aerospace, automotive, energy, mining and mold manufacturing.

cladding technology and its applications from the aspects of technical principles, process flow, coating performance, influence of geometric parameters, application scenarios, advantages and disadvantages, and development trends, providing a reference for industrial selection.

1. Technical principles and process classification

Laser cladding is a surface modification technology that uses a laser beam to melt cemented carbide powder or wire to form a metallurgically bonded coating with the micro-melting zone on the substrate surface . The coating has a low dilution rate (<510%), high density (porosity <1%) and excellent performance. Cemented carbide (such as WCCo , WCNi) is a common material for laser cladding due to its high hardness and wear resistance . Process classification includes:

Process Type	principle	Laser Type	Feeding method	Features
Powder synchronous feeding	The laser beam melts the powder fed synchronously, forming a molten pool with the substrate surface, which cools rapidly to form a coating.	CO ₂ , fiber laser, semiconductor laser	Air flow or mechanical powder feeding	High degree of automation, no porosity, suitable for complex geometries.
Pre-set powder cladding	The powder is applied to the substrate in advance, and the laser beam scans and melts to form a coating.	Nd:YAG , fiber laser	Pre-set powder layer	The process is simple, but the coating uniformity is slightly poor.
Extreme High Speed Laser Cladding (EHLA)	Ultra-high scanning speed (>20 m/min), powder preheating in the air flow, and fast deposition of thin coatings.	Semiconductor Laser	High-speed air flow powder feeding	The coating is thin (20100 μm) and highly efficient.
Wire Cladding	The laser beam melts the carbide wire and bonds it to the substrate surface.	Fiber laser, disk laser	Wire feeding	High material utilization rate, suitable for large area coating.

2. Cemented Carbide Laser Cladding Process

The laser cladding process involves multiple steps to ensure coating quality and performance. The following is a typical process:

2.1 Substrate pretreatment

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Purpose: To clean and roughen the substrate surface and enhance coating adhesion.

step:

Cleaning: Ultrasonic cleaning with ethanol or acetone for 5-15 minutes to remove oil and oxides.

Sandblasting: Sandblasting with aluminum oxide sand, surface roughness $Ra\ 25\ \mu m$, to improve mechanical fit.

Laser Cleaning (optional): Removes microscopic impurities and reduces porosity using pulsed lasers.

2.2 Spraying material preparation

Material: Cemented carbide powder (such as WCCo, WCCoCr, WCNi), particle size $1050\ \mu m$, WC content 7090 wt %.

deal with:

Screening: Ensure that the powder particle size is uniform and has good fluidity (flow rate 2040 g/s).

Drying: Dry at 120-150°C for 2 hours to remove moisture and prevent spraying defects.

2.3 Laser cladding process

Device Setup

Laser: CO2 laser (110 kW), fiber laser (120 kW) or semiconductor laser (210 kW).

Parameters: laser power 15 kW, scanning speed 0.53.5 m/min, powder feeding rate 1050 g/min, spray distance 1020 mm.

Atmosphere: Argon or nitrogen protection to prevent oxidation.

Cladding

The laser beam forms a molten pool (temperature 10,000-20,000°C) into which powder or wire is fed simultaneously.

The molten pool is cooled rapidly (10^5 to 10^6 K/s) to form a metallurgical bonding coating with a thickness of 0.022 mm.

An automated system (e.g., a six-axis robot) controls the laser trajectory with a uniformity deviation of <3%.

Process optimization: adjust laser power, scanning speed and powder feeding rate to control dilution rate (<10%) and porosity (<1%).

2.4 Post-processing

Purpose: To optimize coating surface quality and eliminate stress.

step:

Polishing/grinding: Use diamond grinding wheel to reduce the surface roughness to $Ra\ 0.050.2\ \mu m$.

Heat treatment (optional): 400-600°C annealing to relieve residual stress and prevent cracking.

Quality inspection: microscopic inspection of porosity, scratch test for adhesion (>50 MPa),

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hardness test (HV 8001400).

3. Coating performance characteristics

Cemented carbide laser cladding coatings are mainly WCCo and WCNi , with excellent properties:

performance	Typical Value	illustrate
hardness	HV 8001400 (WCCo up to HV 12001400)	Higher than the base material (such as steel HRC 2040), the wear resistance is increased by 515 times.
Porosity	<1% (EHLA can reach 0.30.5%)	Low porosity improves coating density and corrosion resistance.
Adhesion	50100 MPa (metallurgical bonding)	It is superior to thermal spraying (mechanical bonding) and has strong anti-stripping performance.
Wear resistance	Wear rate 0.0010.005 mm^3/ N·m (ASTM G65)	The service life is 515 times that of the substrate and is suitable for high wear conditions.
Corrosion resistance	Corrosion rate <0.01 mm/year (neutral salt spray test, pH 68)	WCCoCr coating is acid and alkali resistant (pH 410) and suitable for marine environment.
Temperature resistance	500900°C (WCCoCr can reach 900°C)	Suitable for high temperature working conditions (such as aircraft engines, molds).

4. Influence of geometric parameters

Laser cladding coating has a significant impact on the geometric parameters of tools or components (such as surface roughness and coating thickness), and the process parameters need to be optimized:

Geometric parameters	Laser Cladding Impact	Optimization strategy
Surface roughness	The initial Ra is 0.52 μm , which can be reduced to Ra 0.050.2 μm after post-treatment .	Increase the scanning speed (>1.5 m/min), optimize the laser power (<3 kW), and then polish.
Coating thickness	0.022 mm, thin coating (EHLA) is suitable for precision parts, thick coating is suitable for wear-resistant parts.	Control the powder feeding rate (1030 g/min), number of layers, and thickness deviation <3%.
Cutting edge radius	The coating increases the cutting edge radius by 0.0050.03 mm, affecting the cutting sharpness.	Use EHLA or thin layer cladding (<50 μm) and then hone the cutting edge.
Complex Geometry	The coating uniformity of complex curved surfaces (such as turbine blades) is a great challenge.	Using coaxial powder feeding and robot control trajectory, the angle deviation is <1°.

5. Application scenarios

Cemented carbide laser cladding coatings are widely used in many industries due to their high performance:

industry	Application Scenario	Typical coating	Performance Improvements

Aerospace	Repair of turbine blades, combustion chambers, and landing gear to resist high temperature wear and corrosion.	WCCo , WCCoCr	The service life is extended by 36 times, the temperature resistance is 900°C, and the surface quality is Ra 0.1 μm .
car	Coatings for brake discs, crankshafts, and molds reduce wear and fine dust emissions.	WCCo , WCNi	Wear resistance is increased by 510 times and fine dust emissions are reduced by 3050%.
energy	Coatings for boiler pipes, pumps and valves, and drilling tools to resist erosion and corrosion.	WCCoCr , NiCrBSi	Corrosion resistance is increased by 10 times and maintenance costs are reduced by 2030%.
mine	Coatings for drill bits, picks, and tunnel boring machine tools to resist impact and wear.	WCCo , WCNi	Service life 500-2000 hours, efficiency increased by 20%.
Mold manufacturing	The surface of stamping molds and injection molds is strengthened to extend their service life.	WCCo , Stellite 6	The mold life is extended by 25 times, and the surface hardness is HV 10001200.

Examples:

Brake disc coating: WCCo coating is produced through the EHLA process with a thickness of 50100 μm , which reduces fine dust emissions by 40% and increases wear resistance by 5 times, making it better than traditional chrome plating (Web ID 3).

Turbine blade repair: WCCoCr coating, hardness HV 1200, temperature resistance 900°C, life extended by 3 times, repair costs reduced by 50% (Web ID 4, 5).

6. Comparison of advantages and disadvantages

category	advantage	shortcoming
Carbide Laser Cladding	High hardness (HV 8001400), wear resistance increased by 515 times. Metallurgical bonding, strong adhesion (50100 MPa). Low dilution rate (<10%), the matrix properties remain unchanged. Suitable for complex geometry and repair, with a high degree of automation.	The equipment cost is high (laser investment is 100.5 million yuan). High operating precision is required and professionals are needed. The coating thickness is limited (<2 mm), not suitable for ultra-thick coatings. Micro cracks may exist and parameters need to be optimized.

7. Development Trends

trend	Technical direction	Expected Results
New Materials	Nano WCCo coating (grains <50 nm), hardness HV 1500, toughness increased by 30%.	Wear resistance is increased by 40% and service life is extended by 2 times.
Process Improvement	EHLA process, scanning speed 50100 m/min, coating thickness 20100 μm .	Efficiency increased by 50% and cost reduced by 20%.
Intelligent	AI optimizes cladding parameters (power and speed errors <1%) and monitors the dynamics of the molten pool in real time.	Coating quality consistency is improved by 30% and defect rate is reduced by 50%.
Environmental	Green laser (20% lower energy consumption), non-toxic powder,	Comply with green manufacturing standards and

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Technology	reduced exhaust emissions.	reduce environmental pollution by 30%.
Composite coating	WCCo + high entropy alloy (CoCrFeMnNi), temperature resistance 1000°C, corrosion resistance increased by 50%.	Adapt to extreme working conditions and expand the application range by 40%.

8. Conclusion

Cemented carbide laser cladding technology uses powder synchronous feeding, pre-setting powder, EHLA and other processes to form high hardness (HV 8001400), wear-resistant (lifespan increased by 515 times) and corrosion-resistant coatings on materials such as WCCo and WCNi . It is widely used in aerospace, automobile, energy, mining and mold manufacturing. The process includes substrate pretreatment, material preparation, cladding and post-treatment. Optimizing geometric parameters (such as surface roughness Ra 0.050.2 μm and thickness 0.022 mm) can improve performance. Compared with thermal spraying, laser cladding has the advantages of metallurgical bonding, low dilution rate and precise control, but the equipment cost is higher. In the future, nanomaterials, EHLA, intelligence and green technology will promote breakthroughs in cemented carbide laser cladding in the field of high-performance and environmentally friendly manufacturing, providing efficient and reliable surface solutions for the industry.



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appendix:



What are carbide ball teeth ?

Cemented carbide ball teeth are a high-performance wear-resistant component with tungsten carbide (WC) as the core material. They are manufactured through advanced powder metallurgy processes and are designed for industrial environments with high wear, high impact and corrosion. With its excellent hardness, wear resistance, high temperature resistance and corrosion resistance, cemented carbide ball teeth are widely used in mining, tunneling, construction engineering, energy exploration, road construction and other fields. It can effectively resist abrasive wear and impact loads under extreme working conditions, significantly extend the service life of equipment components and reduce maintenance frequency. This article comprehensively introduces the performance and value of cemented carbide ball teeth from the aspects of material properties, types and technical indicators, manufacturing processes, uses and application scenarios, product advantages, technical challenges and improvement directions.

1. Material composition and characteristics of cemented carbide ball teeth

1.1 Carbide ball gear material composition

The formulation of the carbide button teeth is precisely designed to achieve the optimal balance of hardness, toughness and corrosion resistance:

Hard phase

Tungsten carbide (WC, 80 - 95%) provides ultra-high hardness and wear resistance. Some formulas are doped with titanium carbide (TiC, 15%) or tantalum carbide (TaC, 0.5 - 2%) to improve high temperature stability and oxidation resistance.

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Adhesive Phase

Cobalt (Co, 5 - 15%), enhances toughness and impact resistance; Nickel (Ni, 5 - 10%) is used in corrosion-resistant formulations suitable for acidic or humid environments.

additive

Trace amounts of chromium (Cr, 0.1 - 1%), vanadium (V, 0.050.5%), and molybdenum (Mo, 0.1 - 0.8%) are used to refine grains, inhibit grain growth, and improve corrosion resistance and high-temperature oxidation resistance.

1.2 Key characteristics of cemented carbide ball gear

The performance of carbide button teeth comes from their optimized microstructure and material formulation:

hardness

HRA 86 - 92 (HV 1200 - 1700), far exceeding high manganese steel (HRC 20 - 50) or high chromium cast iron (HRC 50 - 60), is suitable for resisting high abrasive wear.

Fracture toughness

6.5 - 10 MPa·m^{1/2}, better than ordinary cemented carbide (57 MPa·m^{1/2}), and the impact fracture resistance is improved by 30%.

Wear resistance

The wear rate is 0.01 - 0.02 mm³/ N·m (ASTM G65), which is 1.52 times lower than high chromium cast iron and the service life is extended by 310 times.

Compression strength

4000 - 6000 MPa, resistant to high shock loads (up to 5000 N).

density

13.8 - 15.2 g/cm³, medium weight, suitable for inlay or brazing.

Corrosion resistance

In a neutral or slightly acidic environment (pH 49), the corrosion rate is <0.07 mm/year; nickel-based formulations or coatings can withstand pH 210 with a corrosion rate of <0.05 mm/year.

Temperature resistance

The operating temperature ranges from 20°C to 800°C, and the coating formula can withstand instantaneous temperatures of 1000°C, making it suitable for high-temperature wear scenarios.

1.3 Microstructure advantages of cemented carbide ball teeth

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The carbide ball teeth adopt fine grain (0.52 micron) or ultra-fine grain (0.20.5 micron) structure, which brings the following advantages:

High hardness and strength: Small grains increase grain boundary density, follow the Hall-Petch effect, and improve wear resistance.

Excellent toughness: Grain refinement disperses stress, reduces the risk of crack propagation, and improves impact resistance by 20-30 % .

Wear resistance and stability: reduce wear and tear, maintain surface integrity and extend service life.

2. Types and technical indicators of cemented carbide ball teeth

There are many types of cemented carbide button teeth, covering a variety of geometric shapes and uses. The following is a comprehensive classification, technical indicators and application table (reference ISO standards, ASTM specifications and manufacturer data).

2.1 Types and uses of cemented carbide ball teeth

type	describe	Main uses and application scenarios	Typical Specifications
Spherical teeth	Standard spherical design with large contact area, suitable for high wear conditions.	Roadheaders (shield cutter heads), rotary drilling rigs (pile foundations), and coal mining machines (cutters) are used for excavating rocks, coal seams, and gravel.	Diameter 830 mm, height 1040 mm, HRA 8689, life 2000-6000 hours.
Conical teeth	Conical tip, strong penetrating power, suitable for hard rock crushing.	Rock drills (hard rock drilling), tunnel boring machines (hard strata), rotary drilling rigs (rock strata pile foundations), used for excavation of granite and basalt.	Diameter 625 mm, height 1550 mm, HRA 8992, life 1000-4000 hours.
Wedge-shaped teeth	Wedge-shaped cutting edge for high impact and shear conditions.	Coal mining machine (coal seam cutting), tunnel boring machine (soft rock), road milling machine (asphalt layer), used for coal seam, soft rock and asphalt milling.	Diameter 1030 mm, height 1540 mm, HRA 8689, life 1500-5000 hours.
Flat teeth	Flat top design, strong wear resistance, suitable for continuous wear environment.	Roadheaders (clay, sand layers), rotary drilling rigs (soft soil pile foundations), coal mining machines (thin coal seams), used for excavation in clay, gravel and soft soil.	Diameter 1035 mm, height 1035 mm, HRA 8689, life 2000-6000 hours.
Cylindrical teeth	The cylindrical structure balances wear resistance and toughness, and is suitable for medium-hard formations.	Roadheaders (medium hard rock), rotary drilling rigs (mixed strata), and coal mining machines (medium coal seams) are used for sandstone and shale excavation.	Diameter 825 mm, height 1540 mm, HRA 8790, life 2000-5000 hours.
Mushroom Teeth	Hemispherical top, strong impact resistance, suitable for high-frequency impact.	Rock drills (hard rock impact), tunnel boring machines (fault zone), coal mining machines (hard gangue), used for excavation of hard rock and gangue coal seams.	Diameter 620 mm, height 1535 mm, HRA 8992, life span 1000-4000 hours.
Ball teeth for pick	Specially designed for pick teeth to optimize cutting efficiency and wear resistance.	Coal mining machines (comprehensive coal mining), roadheaders (coal-rock mixed layers), and anchor diggers (tunnel excavation) are used for excavation of coal seams and coal-rock mixed strata.	Diameter 1030 mm, height 1540 mm, HRA 8689, life 2000-6000 hours.

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Rotary digging teeth	Specially designed for rotary drilling rigs, suitable for a variety of formations.	Rotary drilling rigs (pile foundation construction), foundation engineering (bridges, subways), used for pile foundation construction in clay, gravel, soft rock and hard rock.	Diameter 1035 mm, height 2050 mm, HRA 8790, life span 1500-5000 hours.
Milling teeth	Optimizes milling efficiency and is suitable for road repair.	Road milling machines (asphalt, concrete pavement), cold recyclers (pavement renovation), used for asphalt and concrete milling.	Diameter 825 mm, height 1535 mm, HRA 8689, life span 1000-4000 hours.
Down-the-hole drill teeth	High-strength design, suitable for deep hole impact drilling.	Down-the-hole drill (mine blasting), geological exploration (core sampling), tunnel construction (hard rock), used for drilling in granite and basalt.	Diameter 620 mm, height 1540 mm, HRA 8992, life span 1000-3000 hours.
Cone drill teeth	Designed specifically for rotary drill bits to withstand extreme impact and abrasion.	Oil drilling (deep well drilling), natural gas exploration (hard formation), mining (hard rock), used for hard rock and shale drilling.	Diameter 825 mm, height 1035 mm, HRA 8992, life span 1000-4000 hours.
Shield cutter teeth	Specially designed for shield machines, suitable for complex strata.	Shield machines (subways, tunnels) and roadheaders (urban underground projects) are used for tunneling in clay, gravel, soft rock and hard rock.	Diameter 1030 mm, height 1540 mm, HRA 8790, life span 2000-6000 hours.

2.2 Technical indicators of cemented carbide ball gear

size

Diameter: 6 - 35 mm (8 - 30 mm is common).

Height: 10 - 50 mm (15 - 40 mm is common).

Tolerance: ± 0.05 mm (high-precision machining).

weight

Single piece 0.05 - 0.5 kg, suitable for inlay or brazing.

Surface roughness:

Ra 0.4 - 1.2 μm , reduce material adhesion and friction.

Hardness Grade:

Standard: HRA 86 - 89 (general tunnelling, coal mining).

High hardness: HRA 89 - 92 (hard rock, oil drilling).

Material formula:

WCCo (general purpose): Cobalt content 6 - 12%, HRA 87 - 91, high toughness.

WCNi (corrosion resistant type): Nickel content 5 - 10%, resistant to acid and alkali environments.

WCTiCTaC (high temperature type): temperature resistance 800 - 1000°C.

Impact frequency:

50 - 150 Hz (rock drilling, down-the-hole drilling).

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10 - 50 Hz (tunneling, coal mining).

Installation method:

Brazing: High temperature brazing (900 - 1100°C), bond strength >200 MPa.

Mechanical mounting: cold or hot pressing, installation time <10 minutes.

Bolt fixing: for removable parts.

Surface treatment:

Polishing: Ra 0.20.8 μm , enhanced fatigue resistance.

coating:

TiN : Hardness HV 2000 - 2500, wear resistance increased by 2 times.

TiAlN : Temperature resistant to 900°C, suitable for high-temperature excavation.

AlCrSi / TiN : temperature resistance 1000°C, life extended 3 times.

DLC: Friction coefficient 0.10.2, suitable for gravel formations.

Working parameters:

Working pressure: 10 - 100 MPa (excavation, drilling).

Rotation speed: 50 - 300 rpm (roadheaders, rotary drilling rigs).

Impact energy: 100 - 500 J (rock drilling, down-the-hole drilling).

Standards Compliance:

ISO 9001 quality management system.

ASTM B771 (wear test), ISO 3878 (hardness test).

3. Manufacturing process

The carbide ball gear is manufactured using advanced powder metallurgy technology to ensure that the material properties, geometric accuracy and surface quality meet top standards.

3.1 Raw material preparation

High-purity tungsten carbide (WC, purity>99.95%), cobalt (Co, purity>99.9%) and additives (such as TiC , TaC , Cr) are selected. The powder is mixed through wet grinding process (medium is alcohol or deionized water, ball milling for 2472 hours), and the average particle size is controlled at 0.21 microns. VC or Cr₃C₂ (0.10.5%) is added as a grain inhibitor to prevent grain growth during high-temperature sintering.

3.2 Forming

Spray drying: prepare flowable particles and improve the uniformity and strength of green bodies.

Cold isostatic pressing (CIP): The powder is pressed into a green body at 200 - 400 MPa with a density of 50-60% of the theoretical value.

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Precision molding: High-precision molds (tolerance ± 0.1 mm) are used to form spherical, conical or other geometric shapes.

3.3 Sintering

Pre-sintering

900 - 1100°C, removal of organic additives.

Hot Isostatic Pressing (HIP)

1350 - 1500°C, 100 - 200 MPa, argon atmosphere, sintering for 24 hours, density 99.8 - 100%.

Cooling control

Gradual cooling (1020°C/min) to avoid micro cracks caused by thermal stress.

3.4 Post-processing

Precision Grinding

Use diamond grinding wheel or CBN tool to process to tolerance ± 0.05 mm and surface roughness Ra 0.41.2 μm .

Surface strengthening

Sandblasting, polishing or coating (TiN, TiAlN, AlCrSi / TiN, DLC) improves wear and heat resistance.

Quality Inspection

Hardness test: HRA/HV, error ± 0.5 .

Microstructural analysis: Scanning electron microscopy (SEM) was used to examine the grain size (0.22 μm).

Dimension measurement: three-dimensional measuring instrument, accuracy ± 0.005 mm.

Non-destructive testing: Ultrasonic testing to check for internal defects.

4. Purpose and application scenarios

Carbide ball teeth are widely used in the following fields and scenarios due to their excellent wear resistance, impact resistance and corrosion resistance:

4.1 Mining and quarrying

Carbide Tunnel Boring Machine Picks

Used for tunnel boring machine cutter heads, drilling sandstone, shale, and granite, with a service life of 2000 - 6000 hours and a maintenance period of 1224 months, and is used in open-pit and underground mines.

Carbide coal mining machine picks

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Used for comprehensive coal mining, cutting coal seams and gangue, with a service life of 2000 - 6000 hours, suitable for long wall mining and thin coal seam mining.

Carbide rock drilling and down-the-hole drilling

Used in rock drills and down-the-hole drills for drilling hard rock and basalt, with a service life of 1000 - 4000 hours, and is used in mine blasting and geological exploration.

Carbide Roller Drill Bits

Used for oil and gas drilling, drilling hard rock and shale, with a service life of 1000-4000 hours, suitable for deep well drilling.

4.2 Tunnel and foundation engineering

Carbide shield machine cutter

Used for subway and tunnel excavation, cutting clay, gravel, soft rock and hard rock, with a service life of 2000 - 6000 hours, and is used in urban underground projects.

Carbide rotary drilling rig pile foundation ball teeth

Used for bridge and subway pile foundation construction, excavation of clay, gravel and rock formations, with a service life of 1500 - 5000 hours, suitable for complex formations.

Carbide bolter tunnel boring ball teeth

Used for coal mine lanes, tunnel excavation, cutting coal-rock mixed layers, with a service life of 2000-5000 hours.

4.3 Building and road construction

Road milling machine

Used for milling asphalt and concrete pavement, with a service life of 1000 - 4000 hours, and is used in highway and airport runway repair.

Cold recycling machine

Used for road renovation and cutting old road materials, with a service life of 1500 - 4000 hours, suitable for road maintenance.

Concrete crushing

Used for dismantling reinforced concrete structures, with a service life of 1000 - 3000 hours, and is applied to building demolition.

4.4 Energy and geological exploration

Oil and gas drilling

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Used for roller drill bits, drilling hard rock and shale, with a service life of 1000 - 4000 hours, and is used in deep wells and horizontal wells.

Geological Exploration

Used for core sampling, drilling granite and basalt, with a service life of 1000 - 3000 hours, suitable for mineral exploration.

Geothermal drilling

Used for geothermal well drilling and cutting high-temperature formations, with a service life of 1000 - 4000 hours and a temperature resistance of 800°C.

4.5 Other special purposes

Port and marine engineering

Used in dredging equipment to cut seabed gravel and clay, with a service life of 2000 - 5000 hours, resistant to seawater corrosion (pH 68), and applied to waterway dredging.

Forestry and Agriculture

Used in wood crushers, soil tillage equipment, cutting hardwood, gravel, life span 1500 - 4000 hours, suitable for forestry felling, land reclamation.

Railway construction

Used in ballast crusher to cut ballast and rock, with a service life of 2000 - 5000 hours, and is used in high-speed railway construction.

5. Product advantages

Carbide button teeth take the lead in the wear-resistant component market with their excellent performance:

Ultra-long life

Wear resistance and hardness extend the life by 310 times and reduce the cost per use by 3060%.

Efficient cutting

Supports high impact (100 - 500 J) and rotation speed (50 - 300 rpm), increasing digging efficiency by 2050%.

High reliability

Compression strength of 4000 - 6000 MPa, withstands extreme impact and wear, reduces equipment downtime.

Flexible customization

A variety of types (spherical, conical, wedge-shaped, etc.), sizes (diameter 635 mm) and coatings

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(TiN , TiAlN) to suit different working conditions.

Environmental adaptability

High temperature resistance (800 - 1000°C), corrosion resistance (pH 210), adaptable to hard rock, clay and humid environment.

Green Manufacturing

High durability reduces parts replacement and waste, meeting sustainable development goals.

6. Technical challenges and improvement directions

6.1 Technical Challenges

Processing difficulty

Cemented carbide has high hardness (HRA 8692), which places extremely high demands on processing equipment and tools. Diamond grinding wheels or CBN tools wear quickly, and it is difficult to stabilize the processing accuracy (tolerance $\leq \pm 0.05$ mm).

Fragility risk

High-hardness materials may produce microcracks or breakage under high impact (>500 J) or improper installation, which will affect their service life.

Thermal management issues

High-temperature tunnelling (>800°C) may lead to softening of the binder phase or spalling of the coating, especially in hard rock formations.

Adaptability to complex formations

Mixed formations (clay, hard rock, gravel) place high demands on the geometry and materials of the ball teeth and are prone to rapid wear or breakage.

Extreme working conditions limitations

Under ultra-high temperature (>1000°C) or strong acid environment (pH<2), the performance of traditional coatings and bonding phases deteriorates and the service life is shortened by 5070%.

6.2 Technical improvement direction

Advanced processing technology

Develop laser micromachining and electrospark machining, with an accuracy of ± 0.03 mm, a 30% reduction in tool wear, and are suitable for complex geometries (such as conical and wedge-shaped teeth).

Toughness Enhanced Design

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Adopting gradient structure (high surface hardness HRA 90 - 92, high internal toughness fracture toughness $> 10 \text{ MPa} \cdot \text{m}^{1/2}$) or CoNi composite bonding phase, the impact resistance is improved by 20 - 30% and the risk of cracking is reduced.

Efficient thermal management

Develop adaptive coatings (such as TiAlN / AlCrSi , temperature resistance 1100°C , thickness $25 \mu\text{m}$) to reduce thermal softening; optimize the heat dissipation design of the gear body to reduce the operating temperature by $100\text{-}150^{\circ}\text{C}$.

Complex formation optimization

Design multifunctional geometry (such as ball-cone composite teeth, cutting angle optimized to $15^{\circ}\text{--}30^{\circ}$) to improve the adaptability of switching between gravel and hard rock; develop PCD (polycrystalline diamond) inlaid teeth, with hardness increased to HV 8000 and life extended by 20 times.

Extreme working conditions adaptation

Research and develop nano multilayer coatings (such as AlCrSi / TiN , hardness HV 3500) or ceramic-based composite materials (WSiC), with temperature resistance increased to 1200°C and strong acid (pH 12) corrosion rate $<0.03 \text{ mm/year}$.

Intelligent design

AI is used to simulate impact force (error $<5\%$) and wear behavior, optimize tooth shape (spherical radius error $<0.05 \text{ mm}$) and installation angle (deviation $<1^{\circ}$), and improve cutting stability; self-diagnostic ball teeth are developed to monitor wear and temperature in real time, extending life by 10-20 % .

7. Conclusion

Carbide ball teeth have become key wear-resistant components in mining, tunneling, construction engineering, energy exploration, road construction and other fields with their high hardness (HRA 8692), excellent toughness ($6.510 \text{ MPa} \cdot \text{m}^{1/2}$) and ultra-long life (10006000 hours). Its rich variety (spherical teeth, conical teeth, wedge teeth, rotary teeth , etc.) and precise specifications (diameter 635 mm , tolerance $\pm 0.05 \text{ mm}$) meet the diverse needs from soft soil excavation to hard rock drilling. Technical indicators show that its life is 310 times that of traditional materials, cutting efficiency is increased by 2050%, and it can withstand extreme impact and wear. Through advanced powder metallurgy processes and coating technologies (such as TiAlN , DLC), ball teeth perform well in harsh environments such as high temperature ($800\text{--}1000^{\circ}\text{C}$) and corrosion (pH 10). In the future, through laser processing, PCD inlay, nano coating, AI optimization and intelligent design, carbide ball gears will further improve performance, expand application scenarios, and provide solid support for the efficient, reliable and sustainable development of the global industry.

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Carbide pick cutter details

Carbide picks are a high-performance cutting tool widely used in mining, tunneling, road construction, coal mining and geological exploration. With tungsten carbide (WC) and other cemented carbide materials as the core, it is made through precision manufacturing technology. It has ultra-high hardness, excellent wear resistance and impact resistance, and can efficiently cut hard materials such as rocks, coal seams, and concrete. With its long life and high efficiency, cemented carbide picks significantly improve the operating efficiency of tunneling equipment and mining machinery and reduce maintenance costs. The following is a comprehensive introduction to cemented carbide picks from the aspects of material properties, basic specifications, manufacturing processes, uses and application scenarios, advantages, challenges and solutions, and future development.

1. Material composition and characteristics

1.1 Composition

The material formulation of carbide picks is optimized to balance hardness, toughness and corrosion

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resistance:

Hard phase

Tungsten carbide (WC, 80 - 95%) provides excellent hardness and wear resistance. Some formulas add titanium carbide (TiC, 15%) or tantalum carbide (TaC, 0.5 - 2%) to enhance high temperature stability and oxidation resistance.

Adhesive Phase

Cobalt (Co, 5 - 15%) is the main binder, improving toughness and impact resistance. Nickel (Ni, 5 - 10%) is used in specific formulations to improve corrosion resistance and is suitable for wet or acidic environments.

additive

Trace amounts of chromium (Cr, 0.1 - 1%), vanadium (V, 0.05 - 0.5%) or molybdenum (Mo, 0.1 - 0.8%) are used to refine grains, inhibit grain growth and enhance resistance to corrosion and high-temperature oxidation.

1.2 Key Features

The performance of cemented carbide picks is due to their optimized microstructure:

hardness

HRA 8591 (HV 1100 - 1600), far exceeding high manganese steel (HRC 20 - 50) or high chromium cast iron (HRC 50 - 60), is suitable for cutting high hardness rocks and coal seams.

Fracture toughness

610 MPa·m^{1/2}, which is better than ordinary cemented carbide (57 MPa·m^{1/2}) and is not easy to break under high impact.

Wear resistance

Wear rate 0.015 - 0.025 mm³/N·m (ASTM G65), 1.52 times lower than high chromium cast iron.

Compression strength

3500 - 5500 MPa, able to withstand high cutting forces.

density

13.5 - 15.0 g/cm³, balance of strength and weight.

Corrosion resistance

In neutral or slightly acidic environments (pH 4-9), the corrosion rate is <0.08 mm/year; nickel-based formulas can withstand pH 12-14.

Temperature resistance

The working temperature is from 20°C to 700°C, and some formulas can withstand 900°C for a short time, which is suitable for high-temperature excavation environments.

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1.3 Microstructure advantages

Carbide picks usually have fine grain (0.52 micron) or ultra-fine grain (0.2 - 0.5 micron) structures. Compared with traditional carbide (25 micron), its advantages include:

Enhanced hardness: Small grains increase the grain boundary area, improving deformation resistance and wear resistance.

Improve toughness: Grain refinement disperses stress and reduces the risk of crack growth.

Cutting stability: Fine grain structure reduces wear and spalling, keeps cutting edge sharp and prolongs cutting life.

2. Basic specifications

There are various specifications of cemented carbide picks. The following are common specifications and parameters (refer to industry standards and manufacturer data):

Geometry:

Conical: The most common, suitable for tunnel boring machines and coal mining machines, with high cutting efficiency.

Bullet shape: used for high-hardness rock formations to enhance penetration.

Flat top shape: used in coal seams or soft rocks to reduce cutting resistance.

Knife or chisel shape: used for special excavation or crushing needs.

size:

Diameter (tooth tip): 8 - 50 mm (20 - 35 mm is common).

Length (overall): 50 - 150 mm (80 - 120 mm typical).

Tolerance: ± 0.05 mm (high-precision machining).

weight:

Individual pieces weigh 0.1 - 1.5 kg, suitable for mounting or mechanical fixing.

Surface roughness:

Ra 0.4 - 1.0 μm , reduces friction and material adhesion.

Hardness Grade:

Standard: HRA 85 - 88 (coal seams, soft rock).

High hardness: HRA 88 - 91 (hard rock, granite).

Material formula:

WCCo (general purpose): Cobalt content 6 - 12%, HRA 86 - 90, high toughness.

WCNi (corrosion resistant): Nickel content 5 - 10%, suitable for humid environments.

WCTiCTaC (high temperature type): temperature resistance 700 - 900°C.

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Installation method:

Inlay fixation: embedded in the tooth seat, bonding strength > 150 MPa.

Brazing: High temperature brazing (900 - 1100°C), bond strength > 200 MPa.

Mechanical clamping: quick replacement, suitable for high-frequency maintenance scenarios.

Surface treatment:

Polishing: Ra 0.2 - 0.4 μm , enhanced fatigue resistance.

Coating: TiN (hardness HV 2000 - 2500), TiAlN (temperature resistance 900°C), DLC (friction coefficient 0.1 - 0.2).

Standards Compliance:

ISO 9001 quality management system.

ASTM B771 (abrasion test), ISO 3878 (hardness test).

Typical product examples:

Coal mining machine picks: diameter 25 - 35 mm, length 90 - 120 mm, HRA 86 - 89, life 3000 - 6000 hours.

TBM picks: diameter 20 - 40 mm, length 80 - 100 mm, HRA 88 - 91, suitable for hard rock.

Drilling machine picks: diameter 15 - 30 mm, length 70 - 100 mm, HRA 85 - 88, impact resistant.

3. Manufacturing process

The manufacturing of cemented carbide picks relies on powder metallurgy technology to ensure performance, precision and surface quality.

3.1 Raw material preparation

High purity tungsten carbide (WC, purity > 99.95%), cobalt (Co, purity > 99.9%) and other additives (such as TiC, TaC). The powder is mixed by wet grinding process (alcohol or deionized water, ball milling for 2472 hours), and the average particle size is controlled at 0.21 microns. VC or Cr3C2 (0.10.5%) is added as a grain inhibitor.

3.2 Forming

Cold Isostatic Pressing (CIP)

are pressed into green compacts at 200 - 400 MPa with a density of 50 - 60% of theoretical.

Precision Molding

High-precision molds (tolerance ± 0.1 mm) are used for complex shapes such as cones or bullet heads.

Spray drying

Prepare flowable particles and improve the uniformity of green bodies.

3.3 Sintering

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Pre-sintering

900 - 1100°C, removal of organic additives.

Hot Isostatic Pressing (HIP)

1350 - 1500°C, 100 - 200 MPa, argon atmosphere, sintering for 24 hours, density 99.8 - 100%.

Cooling control

Gradual cooling (10 - 20°C/min) to avoid thermal stress cracks.

3.4 Post-processing

Precision Grinding

Diamond grinding wheel processing, tolerance ± 0.05 mm, roughness Ra 0.4 - 1.0 μm .

Surface strengthening

Sandblasting, polishing or coating (TiN, TiAlN, DLC) improves wear and heat resistance.

Quality Inspection

Hardness test (HRA/HV), microstructure analysis (SEM), dimension measurement (3D measuring instrument), non-destructive testing (ultrasound).

4. Purpose and application scenarios

Carbide picks are widely used in the following fields and scenarios due to their excellent wear resistance, impact resistance and cutting efficiency:

4.1 Mines and coal mining

Comprehensive coal mining

Drum picks used for coal mining machines, cutting coal seams and gangue (hardness < 100 MPa), with a service life of 3000 - 6000 hours, suitable for long wall mining and fully mechanized mining working faces.

Tunnel boring machine cutter

On a tunnel boring machine (TBM) or roadheader, it cuts sandstone and granite (hardness 100 - 200 MPa), with a service life of 2000 - 4000 hours, and is used in mine roadways and tunnel construction.

Open pit mining

Used in rotary drilling rigs or continuous miners to cut hard ores such as iron ore and copper ore, and can withstand high impact and wear.

4.2 Tunnels and underground engineering

Shield machine pick

On the shield machine cutterhead, it cuts soil, rock or mixed strata, withstands high torque and wear, and is used in subways, railway tunnels and underwater tunnels.

Hard rock tunneling

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Used in hard rock tunnel boring machines (HRM) to cut granite and basalt, with a lifespan 46 times longer than steel picks.

Anchor drilling rig

Auxiliary drilling and support, resistant to rock wear, suitable for underground engineering stability.

4.3 Road construction and infrastructure engineering

Rotary drilling rig

Used for pile foundation construction, cutting concrete, gravel or soft rock, with a service life of 4000 - 7000 hours, and is used in bridges and high-rise building foundations.

Road milling

On milling machines, cutting asphalt or concrete pavement, withstanding high temperatures and wear, suitable for road repair.

Continuous wall construction

Used in grab bucket or hydraulic slot milling machine to cut soil and rock layers, and is applied to deep foundation pits and anti-seepage walls.

4.4 Geological Exploration and Energy Development

Geological Drilling

Used in core drilling rigs to cut hard rock formations to obtain geological samples, and can withstand high torque and wear.

Oil and Gas

On drilling rigs or rotary drill bits, they cut deep rocks and withstand high temperatures, high pressures and corrosive environments.

Geothermal development

Used for geothermal well drilling, cutting high-temperature rock formations, temperature resistant to 700°C.

4.5 Other special purposes

Port and marine engineering

On dredging equipment, it cuts seabed sand or coral reefs and withstands seawater corrosion and wear.

Forestry and Agriculture

Used in forestry reclamation machines or land leveling equipment to cut hard soil and tree roots.

Military and special engineering

In military engineering machinery or special tunneling equipment, high-strength materials are cut to meet high reliability requirements.

5. Advantages

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Carbide picks play an important role in industrial applications due to their unique properties:

Ultra-long life

Wear resistance and hardness extend life by 36 times, reducing replacement frequency.

Efficient cutting

High hardness and toughness support high-speed cutting, improving excavation efficiency by 20 - 40%.

High cost performance

The initial cost is high, but the payback period is 6 - 18 months, and the overall cost is reduced by 30 - 50%.

Flexible customization

Various shapes, sizes and formulas to meet the needs of different geological conditions and working conditions.

Environmental adaptability

It is wear-resistant, corrosion-resistant and high-temperature resistant, and can adapt to complex environments from wet coal seams to high-temperature rock formations.

Green Manufacturing

High durability reduces material consumption and complies with the trend of sustainable development.

6. Challenges and Solutions

6.1 Challenges

High manufacturing cost: High purity raw materials and sophisticated processes lead to higher costs.

Processing difficulty: Ultra-high hardness increases processing complexity and diamond tools wear quickly.

Impact fracture risk: High-hardness materials may break under extreme impact.

Extreme working condition limitations: Performance degrades under extremely high temperatures (>900°C) or strong acids (pH<2).

6.2 Solution

Cost optimization: optimize the ratio and sintering parameters to reduce consumption by 10-20 % ; use automated production to reduce labor costs.

Processing improvements: Introducing laser processing or electrospark processing can increase efficiency by 30% and extend tool life by 2 times.

Improved toughness: Improved impact resistance by 20 - 30% through gradient structures or new binder phases (e.g. CoNi alloys).

Performance improvement: Develop new coatings (such as AlCrSi / TiN , temperature resistance 1000°C) or composite materials to adapt to harsh working conditions.

7. Future Development

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With its high hardness (HRA 85 - 91), excellent toughness ($610 \text{ MPa} \cdot \text{m}^{1/2}$) and ultra-long service life (2000 - 7000 hours), cemented carbide picks are ideal cutting tools for mining, tunneling, road construction, geological exploration and energy development. Its diverse specifications (diameter 8 - 50 mm, length 50 - 150 mm) and precision manufacturing process meet the needs of a wide range of areas from soft coal seams to hard rock formations. Technical data show that its service life is 36 times that of traditional steel picks, and the overall cost is reduced by 30 - 50%.

Looking into the future, the development of cemented carbide picks will focus on the following directions:

Intelligent Manufacturing

AI and big data are introduced to optimize formulas and processes, with performance prediction accuracy >99% and production efficiency increased by 20%.

New Materials

Explore graphene coatings (friction coefficient 0.05), polycrystalline diamond (PCD, life increased by 15 times) or ceramic composites to enhance wear resistance and high temperature resistance.

Green Production

Develop recycling technology to increase the recycling rate of waste picks to 85% and reduce resource consumption.

Modular design

Launched the quick-change pick module, shortening maintenance time by 50% and improving excavation efficiency.

With the advancement of material science and manufacturing technology, carbide picks will play a greater role in intelligent tunneling, green mining and efficient engineering, providing strong impetus for the sustainable development of global industry.



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appendix:

What is a Carbide Drill ?

The carbide drill is a high-performance cutting tool with tungsten carbide (WC) as the core material. It is manufactured through advanced powder metallurgy technology and is specially designed for drilling high-hardness and high-strength materials. With its excellent hardness, wear resistance, high temperature resistance and corrosion resistance, carbide drills are widely used in metal processing, mining, construction engineering, energy industry, aerospace, automobile manufacturing, electronic precision manufacturing and other fields. It can efficiently drill hard steel, stainless steel, titanium alloy, cast iron, ceramics, composite materials, etc., significantly improving processing efficiency, precision and tool life. This article comprehensively introduces the performance and value of carbide drills from the aspects of material properties, types and technical indicators, manufacturing processes, uses and application scenarios, product advantages, technical challenges and improvement directions.

1. Material composition and characteristics of cemented carbide drill bits

1.1 Carbide drill bit material composition

The formulation of carbide drills is precisely designed to achieve the optimal balance of hardness, toughness and corrosion resistance:

Hard phase

Tungsten carbide (WC, 80 - 95%) provides ultra-high hardness and wear resistance. Some formulas are doped with titanium carbide (TiC, 1 - 5%) or tantalum carbide (TaC, 0.5 - 2%) to improve high temperature stability and oxidation resistance.

Adhesive Phase

Cobalt (Co, 5 - 15%), enhances toughness and impact resistance; Nickel (Ni, 5 - 10%) is used in corrosion-resistant formulations suitable for acidic or humid environments.

additive

Trace amounts of chromium (Cr, 0.1 - 1%), vanadium (V, 0.05 - 0.5%), and molybdenum (Mo, 0.1 - 0.8%) are used to refine grains, inhibit grain growth, and improve corrosion resistance and high-temperature oxidation resistance.

1.2 Key features of carbide drills

The performance of carbide drills comes from their optimized microstructure and material formulation:

hardness

HRA 86 - 92 (HV 1200 - 1700), 23 times higher than high speed steel (HSS, HRC 60 - 65), suitable for drilling materials with hardness up to HRC 60.

Fracture toughness

6.510 MPa·m^{1/2}, which is better than ordinary cemented carbide (57 MPa·m^{1/2}), and the impact

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fracture resistance is improved by 30%.

Wear resistance

The wear rate is 0.01 - 0.02 mm³/ N·m (ASTM G65), which is 1.52 times lower than high chromium cast iron, and the cutting life is extended by 310 times.

Compression strength

4000 - 6000 MPa, able to withstand high cutting forces (maximum cutting force up to 5000 N).

density

13.8 - 15.2 g/cm³, moderate weight, suitable for high-speed rotation.

Corrosion resistance

In a neutral or slightly acidic environment (pH 49), the corrosion rate is <0.07 mm/year; nickel-based formulations or coatings can withstand pH 210 with a corrosion rate of <0.05 mm/year.

Temperature resistance

The working temperature ranges from 20°C to 800°C. The coating formula can withstand instantaneous temperatures of 1000°C, making it suitable for dry or high temperature processing.

1.3 Microstructure advantages of cemented carbide drill bits

Carbide drills have fine grain (0.52 micron) or ultra-fine grain (0.2 - 0.5 micron) structures, which bring the following advantages:

High hardness and strength: Small grains increase grain boundary density, follow the Hall-Petch effect, and improve wear resistance.

Excellent toughness: Grain refinement disperses stress, reduces the risk of crack propagation, and improves impact resistance by 20-30 % .

Cutting stability: reduce wear and tear, keep the cutting edge sharp, and extend processing accuracy and life.

2. Types and technical indicators of cemented carbide drill bits

There are a wide variety of carbide drills, covering a variety of geometries, uses and processing requirements. The following is a comprehensive classification, technical indicators and usage table (reference ISO standards, ASTM specifications and manufacturer data).

2.1 Types and uses of cemented carbide drills

type	describe	Main uses and application scenarios	Typical Specifications
Straight shank twist drill Twist Drill	Standard spiral groove design, universal cutting tool, suitable for a variety of materials.	Automobile manufacturing (cylinder blocks, crankshafts), machining (gears, bearings), mold manufacturing (mold steel), drilling steel, cast iron, aluminum alloys.	Diameter 1 - 30 mm, length 50 - 150 mm, point angle 118°/135°, HRA 8790, life 2000 - 5000 holes.
Conical drill Taper Drill	The tapered cutter body optimizes deep hole chip evacuation and is	Aerospace (titanium alloy parts), oil drilling tools (casing), mold manufacturing (deep hole molds), drilling titanium alloy, stainless	Diameter 5 - 30 mm, length 100 - 300 mm, point angle 135°, HRA 89 - 92, life 1000 - 3000 holes.

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type	describe	Main uses and application scenarios	Typical Specifications
	suitable for high depth drilling.	steel, alloy steel.	
Step drill Step Drill	Multi-level diameter design completes multi-size hole processing at one time, reducing the number of steps.	Automotive manufacturing (thin sheet bolt holes), pipeline installation (flanges), construction (steel plates), drilling of thin sheet steel, aluminum, stainless steel.	Diameter 4 - 40 mm, length 50 - 120 mm, point angle 118°, HRA 86 - 89, life 1500 - 4000 holes.
Center drill Center Drill	Short and rigid, it can process the positioning holes to ensure the accuracy of subsequent drilling.	Machining (CNC positioning), mold manufacturing (precise positioning), aerospace (high-precision parts), drilling steel, stainless steel, alloy steel.	Diameter 1 - 10 mm, length 30 - 60 mm, point angle 60°/90°, HRA 87 - 90, life 3000 - 6000 holes.
Micro Drill Micro Drill	Ultra-small diameter, specially designed for high-precision micro-hole processing.	Electronics (PCB boards), medical devices (bone screws), watchmaking (micro parts), drilling of copper, carbide, and ceramics.	Diameter 0.13 mm, length 20 - 50 mm, point angle 135°, HRA 88 - 91, life 1000 - 3000 holes.
Deep hole drilling Deep Hole Drill	High aspect ratio, equipped with internal cooling system, suitable for ultra-deep hole processing.	Aerospace (turbine blades), oil and gas (drill pipes), energy equipment (heat exchangers), drilling titanium alloys, stainless steel, and nickel-based alloys.	Diameter 5 - 30 mm, length 100 - 500 mm, point angle 135°, HRA 89 - 92, life 1000 - 3000 holes.
Flat bottom drill Flat Bottom Drill	Flat-bottom tool tip for machining flat-bottom holes, reducing subsequent milling.	Automobile manufacturing (threaded bottom hole), mechanical processing (plane hole), mold manufacturing (precision hole), drilling steel, cast iron, aluminum alloy.	Diameter 320 mm, length 50-100 mm, point angle 135°, HRA 8790, life 2000-5000 holes.
Three- edge drill ThreeFlute Drill	Three cutting edges design reduces vibration and improves hole roundness.	Aerospace (high-precision holes), mold manufacturing (finishing), machining (bearing holes), drilling stainless steel, titanium alloy, hard steel.	Diameter 5 - 20 mm, length 50 - 120 mm, point angle 135°, HRA 89 - 92, life 1500 - 4000 holes.
Reaming Drill R eamer Drill	Finish existing holes to improve hole diameter accuracy and surface quality.	Mechanical manufacturing (bearing holes), hydraulic equipment (valve bodies), aerospace (connection holes), drilling steel, stainless steel, cast iron.	Diameter 5 - 40 mm, length 50 - 150 mm, point angle 118°, HRA 87 - 90, life 2000 - 5000 holes.
Gun Drill Gun Drill	Ultra-deep hole processing, equipped with high pressure cooling, single-edge design.	Medical equipment (orthopedic equipment), energy equipment (heat exchange tubes), aerospace (deep hole parts), drilling titanium alloy, stainless steel, hard steel.	Diameter 2 - 30 mm, length 200 - 1000 mm, point angle 135°, HRA 89 - 92, life 1000 - 3000 holes.

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type	describe	Main uses and application scenarios	Typical Specifications
Interchangeable drill head Indexable Drill	The cutter head can be replaced quickly, reducing downtime and is suitable for mass production.	Automobile manufacturing (mass hole processing), mechanical processing (assembly line), construction (steel structure), drilling steel , cast iron, aluminum alloy.	Diameter 1040 mm, length 100-200 mm, point angle 135°, HRA 8790, life 3000-6000 holes.
Impact drill bit SDS Impact Drill	Combines rotation and impact, specially designed for masonry materials.	Construction engineering (concrete walls), tunnel construction (rock), renovation (brick walls), drilling of concrete , granite, masonry.	Diameter 6 - 25 mm, length 100 - 300 mm, HRA 86 - 89, life 500 - 2000 holes.
Composite material special drill Composite Drill	Low helix angle and sharp cutting edge reduce delamination and edge chipping.	Aerospace (CFRP wings), automotive (composite body), wind power (blades), drilling carbon fiber , glass fiber, composite materials.	Diameter 3 - 20 mm, length 50 - 120 mm, point angle 135°, HRA 89 - 92, life 1000 - 3000 holes.
Ceramic drill bits Ceramic Drill	Ultra-high hardness, specially designed for extremely hard materials.	Electronics (ceramic substrates), medical (ceramic implants), aviation (ceramic coatings), drilling of ceramics , glass, and cemented carbide.	Diameter 1 - 20 mm, length 50 - 100 mm, point angle 140°, HRA 90 - 92, life 500 - 2000 holes.
Point Drill Spot Drill	Short blade design, processing shallow holes or pits, optimizing subsequent drilling positioning.	Machining (CNC pre-drilling), mold manufacturing (positioning pits), aerospace (high-precision pre-holes), drilling steel , stainless steel, alloy steel.	Diameter 1 - 10 mm, length 30 - 60 mm, point angle 90°/120°, HRA 87 - 90, life 3000 - 6000 holes.
Countersink Countersink Drill	Countersunk holes are processed to be suitable for screw installation.	Automobile manufacturing (body screw holes), construction (steel structure connections), furniture manufacturing (wooden boards), drilling steel , aluminum alloys, wood.	Diameter 5 - 20 mm, length 50 - 100 mm, point angle 90°, HRA 86 - 89, life 2000 - 5000 holes.
Combination Drill Step & Countersink Drill	Integrated step and countersunk functions to complete multi-process hole processing at one time.	Aerospace (composite material connection holes), automotive (thin plate installation), machining (multi-function holes), drilling steel , aluminum, composite materials.	Diameter 5 - 30 mm, length 50 - 120 mm, point angle 118°, HRA 8790, life span 1500 - 4000 holes.
Sintered drill Brazed Drill	Carbide tip brazed to steel shank , suitable for heavy-duty machining.	Mining (hard rock), construction (reinforced concrete), energy (pipelines), drilling of rock , concrete, alloy steel.	Diameter 10 - 50 mm, length 100 - 300 mm, HRA 86 - 89, life 1000 - 3000 holes.

2.2 Technical indicators

size

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Diameter: 0.1 - 100 mm (130 mm is common).

Total length: 10 - 1000 mm (50 - 150 mm is common).

Cutting length: 5 - 500 mm (deep hole drilling up to 20 - 50D, D is the diameter).

Tolerance: ± 0.01 mm (precision machining, grade IT6/IT8).

weight

Each piece weighs 0.012 kg and is suitable for handheld devices or CNC machines.

Surface roughness

Ra 0.2 - 0.8 μm , reduces chip adhesion and friction heat.

Hardness Grade

Standard: HRA 86 - 89 (general metalworking).

High hardness: HRA 89 - 92 (carbide, ceramic).

Material formula

WCCo (general purpose): Cobalt content 612%, HRA 8791, high toughness.

WCNi (corrosion resistant type): Nickel content 510%, resistant to acid and alkali environments.

WCTiCTaC (high temperature type): temperature resistance 800 - 1000°C.

Point Angle

118°: Soft metal (such as aluminum, copper), low cutting resistance.

135°: Hard steel, stainless steel, reduces wandering.

140°: Titanium alloy, ceramic, high stability.

Helix Angle

25 - 30°: General purpose, balanced chip evacuation and rigidity.

35 - 40°: Soft materials, faster chip evacuation.

15 - 20°: Hard material, increases drill bit rigidity.

Installation

Round shank: standard chuck, run-out < 0.01 mm.

Hexagonal shank: quick change chuck.

SDS shank: impact drill, suitable for masonry.

Surface treatment

Polishing: Ra 0.1 - 0.4 μm , reduce friction heat.

coating

TiN : Hardness HV 2000 - 2500, wear resistance increased by 2 times.

TiAlN : Temperature resistant to 900°C, suitable for dry processing.

AlCrSi / TiN : temperature resistance 1000°C, life extended 3 times.

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DLC: Friction coefficient 0.1 - 0.2, suitable for aluminum alloys and composite materials.

Cutting data

Cutting speed: 20 - 200 m/min (steel 50 - 100 m/min, titanium alloy 20 - 40 m/min, aluminum alloy 100 - 200 m/min).

Feed rate: 0.05 - 0.3 mm/rev (0.05 - 0.1 mm/rev for precision machining).

Maximum drilling depth: 5 - 50D (up to 50D with internal coolant).

Standards Compliance

ISO 9001 quality management system.

ISO 1832 (Specification for cutting tools).

ASTM B771 (wear test), ISO 3878 (hardness test).

3. Manufacturing process

The manufacture of cemented carbide drills adopts advanced powder metallurgy technology to ensure that material properties, geometric accuracy and surface quality meet top standards.

3.1 Raw material preparation

High-purity tungsten carbide (WC, purity>99.95%), cobalt (Co, purity>99.9%) and additives (such as TiC , TaC , Cr) are selected. The powder is mixed through wet grinding process (the medium is alcohol or deionized water, ball milling for 24-72 hours), and the average particle size is controlled at 0.21 microns. VC or Cr₃C₂ (0.10.5%) is added as a grain inhibitor to prevent grain growth during high-temperature sintering.

3.2 Forming

Cold Isostatic Pressing (CIP): Powders are pressed into green bodies at 200 - 400 MPa with a density of 50 - 60% of the theoretical value.

Precision moulding: High-precision moulds (tolerance ± 0.1 mm) are used to mould twist drill slots or complex geometries.

Spray drying: prepare flowable particles and improve the uniformity and strength of green bodies.

3.3 Sintering

Pre-sintering: 900 - 1100°C to remove organic additives.

Hot isostatic pressing (HIP): 1350 - 1500°C, 100 - 200 MPa, argon atmosphere, sintering for 24 hours, density 99.8 - 100%.

Cooling control: Gradual cooling (10 - 20°C/min) to avoid micro cracks caused by thermal stress.

3.4 Post-processing

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Precision grinding: using diamond grinding wheels or CBN tools, machining to a tolerance of ± 0.01 mm, surface roughness Ra 0.2 - 0.8 μm , cutting edge sharpness (edge radius $< 5 \mu m$).

Groove processing: CNC grinding machine processes spiral grooves with a groove depth error of < 0.05 mm to optimize chip removal.

Surface strengthening: sandblasting, polishing or coating (TiN, TiAlN, AlCrSi / TiN, DLC) to improve wear resistance and heat resistance.

Quality Inspection:

Hardness test: HRA/HV, error ± 0.5 .

Microstructural analysis: Scanning electron microscopy (SEM) was used to examine the grain size (0.22 μm).

Dimension measurement: three-dimensional measuring instrument, accuracy ± 0.002 mm.

Non-destructive testing: Ultrasonic testing to check for internal defects.

4. Product advantages

Carbide drills take the lead in the cutting tool market with their excellent performance:

Ultra-long life: Wear resistance and hardness extend the life by 310 times and reduce the single processing cost by 3060%.

Efficient machining: Supports high-speed cutting (20 - 200 m/min) and high feed rate (0.05 - 0.3 mm/rev), improving machining efficiency by 20 - 50%.

High precision: aperture accuracy ± 0.01 mm, surface roughness Ra 0.2 - 0.8 μm , meeting the high requirements of aviation and electronics.

Flexible customization: Diverse types (twist, deep hole, micro, etc.), sizes (0.1 - 100 mm) and coatings (TiN, TiAlN) to suit different working conditions.

Environmental adaptability: high temperature resistance (800 - 1000°C), corrosion resistance (pH 210), adaptable to dry, wet and chemical environments.

Green Manufacturing: High durability reduces tool changes and waste, meeting sustainable development goals.

5. Technical challenges and improvement directions

5.1 Technical Challenges

Processing difficulty

Cemented carbide has high hardness (HRA 86 - 92), which places extremely high demands on processing equipment and tools. Diamond grinding wheels or CBN tools wear quickly, and it is difficult to stabilize the processing accuracy (tolerance $< \pm 0.01$ mm).

Fragility risk

High-hardness materials may produce microcracks or fractures under high impact or excessive feed rate (> 0.3 mm/rev), which will affect the service life.

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Thermal management issues

High-speed cutting (>100 m/min) generates a lot of frictional heat, which may cause softening of the cutting edge or peeling of the coating, especially in dry machining.

Complex material adaptability

Composite materials (such as CFRP), ceramics and super-hard alloys ($HRC > 60$) have high requirements on drill bit geometry and coating, and are prone to delamination, edge collapse or rapid wear.

Extreme working conditions limitations

Under extremely high temperatures ($>1000^{\circ}\text{C}$) or strong acid environments ($\text{pH} < 2$), the performance of traditional coatings and bonding phases deteriorates, shortening their life by 50 - 70%.

5.2 Technical improvement direction

Advanced processing technology

Develop laser micromachining and electrospark machining, with an accuracy of ± 0.005 mm and a 30% reduction in tool wear, suitable for complex geometries (such as three-edge drills and gun drills).

Toughness Enhanced Design

Adopting gradient structure (high surface hardness $HRA\ 90 - 92$, high internal toughness fracture toughness $> 10\ \text{MPa}\cdot\text{m}^{1/2}$) or CoNi composite bonding phase, the impact resistance is improved by 20 - 30% and the risk of fracture is reduced.

Efficient thermal management

Optimize the internal cooling system (coolant pressure 10 - 20 MPa, flow rate 5 - 15 L/min) to reduce the temperature in the cutting zone by 100 - 200°C ; develop adaptive coatings (such as TiAlN / AlCrSi, temperature resistance 1100°C) to reduce thermal softening.

Composite material optimization

Designing drill bits with low helix angles ($15 - 20^{\circ}$) and sharp cutting edges (edge radius $< 3\ \mu\text{m}$) can reduce CFRP delamination by 30%; developing PCD (polycrystalline diamond) cutter heads with hardness increased to HV 8000 and life extended by 20 times.

Extreme working conditions adaptation

Research and develop nano-multilayer coatings (such as AlCrSi / TiN, thickness $25\ \mu\text{m}$, hardness HV 3500) or ceramic-based composite materials (WCSiC), with temperature resistance increased to 1200°C and strong acid ($\text{pH}\ 12$) corrosion rate < 0.03 mm/year.

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Intelligent design

AI is used to simulate cutting forces (error <5%) and wear behavior, optimize point angle (118° - 140°) and groove type (groove depth error <0.03 mm), and improve processing stability; self-diagnostic drills are developed to monitor temperature and wear in real time, extending life by 10 - 20%.

6. Conclusion

Carbide drills are the preferred cutting tools in metal processing, mining, construction engineering, energy industry, aerospace, electronic manufacturing and other fields due to their high hardness (HRA 86 - 92), excellent toughness ($6.510 \text{ MPa} \cdot \text{m}^{1/2}$) and ultra-long life (2000 - 10000 holes). Their comprehensive variety (twist drills, deep hole drills, micro drills, impact drills, ceramic drills, etc.) and precise specifications (diameter 0.1100 mm, accuracy $\pm 0.01 \text{ mm}$) meet the diverse needs from PCB micro-holes to deep-hole rock drilling. Technical indicators show that their life is 310 times that of high-speed steel drills, processing efficiency is increased by 20 - 50%, and the hole diameter accuracy reaches IT6/IT8 level.

Through advanced powder metallurgy and coating technologies (such as TiAlN and DLC), the drill performs well in harsh environments such as high temperature (800-1000 ° C) and corrosion (pH 210). In the future, through laser processing, PCD tool heads, nano-coatings, AI optimization and intelligent design, carbide drills will further improve performance and expand application scenarios, providing solid support for the efficient, precise and sustainable development of the global industry .

Carbide Tunnel Boring Machine Picks

Carbide TBM picks are a type of efficient cutting tool designed for tunnel boring machines (TBM) or mining equipment, intended to crush and excavate hard rocks, complex formations or mixed geological conditions. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with advanced manufacturing processes and optimized design, to provide excellent hardness, wear resistance, impact resistance, heat resistance and corrosion resistance, ensuring high efficiency and reliability under extreme working conditions (such as deep wells, high pressure, high temperature or corrosive environments). As a key component at the front end of the tunnel boring machine, the pick directly affects construction efficiency, equipment life, engineering safety and cost control, and plays an irreplaceable role in modern infrastructure construction, resource mining, special engineering and emerging fields. According to the latest information on the entire network and industry development, the following content comprehensively expands the characteristics, technical details and applications of the pick.

1. Physical and chemical properties of cemented carbide roadheader picks

Cemented carbide picks use tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\%\pm 1\%$) as the bonding phase, and trace additives (such as Cr_3C_2 $0.5\% - 2\%\pm 0.1\%$, VC $<1\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$) to optimize grain size, wear resistance and high temperature performance. Prepared by powder metallurgy process, commonly used methods include spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C}\pm 10^\circ\text{C}$, pressure $45-55\text{ MPa}\pm 1\text{ MPa}$, holding time $5-10\text{ min}\pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C}\pm 10^\circ\text{C}$, pressure $150-200\text{ MPa}\pm 5\text{ MPa}$, holding time $30-60\text{ min}\pm 5\text{ min}$), ensuring that the material reaches $99.9\%\pm 0.1\%$ of the theoretical density and porosity $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$), and the microstructure uniformity reaches $95\%\pm 2\%$ (metallographic analysis).

The geometric design of the pick is diverse, with common shapes including conical (vertex angle $60^\circ-90^\circ\pm 5^\circ$), wedge (edge angle $30^\circ-45^\circ\pm 2^\circ$) and ball head (radius of curvature $5-10\text{ mm}\pm 0.5\text{ mm}$), with a carbide layer embedded at the tip (thickness $2-7\text{ mm}\pm 0.2\text{ mm}$, up to $10\text{ mm}\pm 0.5\text{ mm}$ in some places), and the base is made of high-strength alloy steel (such as 40CrMo, 42CrMo or new high-manganese steel, quenching hardness HRC $40-52\pm 2$). The installation method includes high-frequency induction welding (temperature $1200-1300^\circ\text{C}\pm 20^\circ\text{C}$, welding strength $>600\text{ MPa}\pm 50\text{ MPa}$), plasma arc welding or mechanical clamping (clamping force $>10\text{ kN}\pm 1\text{ kN}$), fixed on the cutting head of the tunnel boring machine ($50-100\text{ picks}\pm 5$ per meter of cutting head, depending on the diameter). The design integrates cutting mechanics, heat conduction, stress distribution and fluid mechanics optimization. The pick geometry (entry angle $30^\circ-45^\circ\pm 5^\circ$, back tilt angle $5^\circ-15^\circ\pm 2^\circ$) and slag groove (groove depth $5-12\text{ mm}\pm 0.5\text{ mm}$, groove width $10-20\text{ mm}\pm 1\text{ mm}$, inclination angle $15^\circ-30^\circ\pm 2^\circ$) significantly improve excavation efficiency, heat dissipation performance and slag discharge capacity. It is suitable for hard rock with compressive strength of $100-300\text{ MPa}$, soft rock with water content $>20\%\pm 5\%$, or mixed formations with sand content $>10\%\pm 2\%$.

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2. Characteristics and working principle of cemented carbide roadheader picks

2.1 Material properties

WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50, depending on additives), and its hexagonal crystal structure imparts excellent resistance to wear, erosion and high-temperature oxidation (oxidation starting temperature >800°C±20°C); Co enhances toughness through solid solution strengthening and plastic deformation (K_{Ic} 12-16 MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5), and effectively absorbs impact energy (>50 J±5 J, instantaneous peak value >150 J±10 J). Fine grains optimize microstructure, wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m (preferably <0.03 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³ (determined by Archimedes method), coefficient of thermal expansion (CTE) 6×10⁻⁶ /°C±0.5×10⁻⁶ /°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, H₂S resistance >2000 hours ±100 hours); TaC improves high temperature hardness (>900°C±20°C maintains 90%±2% of initial hardness).

2.2 Working Principle

of the rotation of the tunnel boring machine (speed 500-1200 rpm±50 rpm, depending on the equipment power) and the thrust (50-150 kN±5 kN, up to 300 kN±10 kN), the pick cuts into the rock surface to form continuous grooves, and breaks the rock through extrusion (contact pressure 200-400 MPa±20 MPa) and shear (shear strength 50-100 MPa±5 MPa). The tip carbide layer bears the main wear and thermal load (surface temperature 500-700°C±50°C, instantaneously up to 900°C±50°C), while the steel matrix provides structural support (tensile strength >1000 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life >10⁶ times±10⁵ times, cyclic load >200 MPa±20 MPa).

2.3 Performance test: Under the conditions of granite (hardness 7 Mohs, compressive strength 150-200 MPa), basalt (hardness 7-8 Mohs, compressive strength 200-250 MPa) and quartzite (hardness 7 Mohs, compressive strength 180-220 MPa), the optimized pick life exceeds 500-800 hours ± 50 hours (depending on geological conditions), and the cutting efficiency reaches 5-15 m³/h ± 1 m³/h (maximum up to 20 m³/h ± 1 m³/h, power >1000 kW±50 kW). SEM analysis showed no obvious cracking on the surface, the wear depth was <0.05 mm±0.01 mm (preferably <0.03 mm±0.01 mm), X-ray diffraction (XRD) verified the high crystallinity of the WC phase (>95%±2%), energy dispersive spectroscopy (EDS) confirmed the uniform distribution of Cr₂O₃ and TaC, and thermal imaging showed that the thermal stress distribution was <100 MPa±10 MPa.

3. Factors affecting the performance of cemented carbide roadheader picks

3.1 Co content

6%-12%±1% achieves the best balance between hardness and toughness, <6%±1% leads to a 10%±2% increase in crack rate, >12%±1% reduces hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶ /°C±0.5×10⁻⁶ /°C), and 8%-10%±0.5% is preferred to balance

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performance and cost (cost per kg increases by 5%-10%±1%).

3.2 Grain size

0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $< 0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), 1-1.5 $\mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness rock (compressive strength 100-150 MPa), $> 2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases the wear rate by 15%±3%, the reduction of grain boundaries leads to a decrease in toughness by 10%±2%, and the processing difficulty increases by 5%±1%.

3.3 Tip angle: $30^\circ\text{-}45^\circ \pm 5^\circ$ optimizes cutting efficiency (cutting force $< 10 \text{ kN} \pm 1 \text{ kN}$, energy consumption $< 50 \text{ kWh/m}^3 \pm 5 \text{ kWh/m}^3$), $> 50^\circ \pm 5^\circ$ reduces cutting capacity by 10%±2% and increases heat accumulation (temperature rise $> 50^\circ\text{C} \pm 10^\circ\text{C}$), $< 30^\circ \pm 5^\circ$ easily leads to a 5%±1% risk of edge chipping (edge chipping rate $> 2\% \pm 0.5\%$).

3.4 Surface treatment

The carbide layer thickness of $2\text{-}5 \text{ mm} \pm 0.1 \text{ mm}$ significantly improves wear resistance (life extension of 20%±3%, cost increase of 10%±2%), $< 2 \text{ mm} \pm 0.1 \text{ mm}$ leads to a 20%±3% reduction in life, $> 5 \text{ mm} \pm 0.1 \text{ mm}$ increases manufacturing costs by 15%±2%. TiN or TiAlN coating (thickness $0.5\text{-}1 \mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature $400\text{-}500^\circ\text{C} \pm 20^\circ\text{C}$) reduces the friction coefficient ($< 0.3 \pm 0.05$), improves heat resistance ($> 700^\circ\text{C} \pm 20^\circ\text{C}$) and oxidation resistance (oxygen content $< 0.5\% \pm 0.1\%$).

3.5 Heat treatment

by quenching the base steel (hardness HRC 40-52±2, depth $1\text{-}2.5 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850\text{-}900^\circ\text{C} \pm 20^\circ\text{C}$), the life of the unquenched base is reduced by 15%±3%, and the residual stress is reduced by 5%±1% (stress $< 50 \text{ MPa} \pm 5 \text{ MPa}$) by tempering ($200\text{-}250^\circ\text{C} \pm 10^\circ\text{C}$, 2-4 hours±0.5 hours).

3.6 Working Environment

A water content $> 10\% \pm 2\%$ or a sand content $> 5\% \pm 1\%$ increases wear by 5%±1% (wear rate increase $0.01 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.005 \text{ mm}^3 / \text{N} \cdot \text{m}$). A temperature $> 600^\circ\text{C} \pm 50^\circ\text{C}$ reduces hardness by 3%±1% (HV decrease 50-70±10). An environment containing H_2S or CO_2 (concentration $> 0.1\% \pm 0.02\%$) increases the corrosion rate to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$.

3.7 Equipment parameters: propulsion speed $0.5\text{-}2 \text{ m/h} \pm 0.1 \text{ m/h}$, torque $1000\text{-}5000 \text{ kN}\cdot\text{m} \pm 100 \text{ kN}\cdot\text{m}$, power $500\text{-}1500 \text{ kW} \pm 50 \text{ kW}$ directly affect the life and efficiency of the pick. Excessive parameters ($>$ upper limit 10%±1%) shorten the life by 15%±2%.

4. Application of cemented carbide roadheader picks

4.1 Tunnel Engineering

Used for hard rock excavation in subways (such as Beijing Subway Line 17, Shenzhen Metro Line 14), highways (such as the Shiquanhe Tunnel of the Sichuan-Tibet Railway), and railway tunnels, with a pressure resistance of 100-300 MPa and a service life of 500-1000 hours ± 50 hours. It supports complex geological conditions such as fault zones (displacement $> 1 \text{ m} \pm 0.1 \text{ m}$), high stress

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areas ($> 30 \text{ MPa} \pm 5 \text{ MPa}$) or water gushing areas (water pressure $> 1 \text{ MPa} \pm 0.1 \text{ MPa}$), and complies with EN 1997-1 and JTG 3370.1 standards. 2024 case: The excavation speed of the Yalong River Tunnel of the Sichuan-Tibet Railway using picks reached $1.8 \text{ m/h} \pm 0.1 \text{ m/h}$.

4.2 Mining

Applied to coal seam (compressive strength 50-100 MPa), copper mine (150-200 MPa), iron ore (200-250 MPa) and rare earth ore (180-220 MPa) mining, impact resistance ($> 50 \text{ J}$, peak value can reach $150 \text{ J} \pm 10 \text{ J}$) to ensure efficient excavation, suitable for deep well ($> 1500 \text{ m} \pm 100 \text{ m}$) or open-pit mine (excavation depth $> 700 \text{ m} \pm 50 \text{ m}$) operations, in line with ISO 11228-1 and AS 2294 standards. In 2023, the Escondida copper mine in Chile adopted a pick life of $800 \text{ hours} \pm 50 \text{ hours}$.

4.3 Hydropower Construction

Used for diversion tunnels (diameter $5\text{-}12 \text{ m} \pm 0.5 \text{ m}$), pressure pipelines and underground power stations (such as the Three Gorges Project, Baihetan Hydropower Station) excavation, water erosion resistance ($> 2500 \text{ hours} \pm 100 \text{ hours}$) and pressure resistance to support long-term operation ($> 1.2 \times 10^4 \text{ hours} \pm 10^3 \text{ hours}$), accuracy of $\pm 0.05 \text{ mm}$, in line with IEC 60041 and GB 50287 standards.

4.4 Urban Underground Pipeline Gallery

It is used for excavation in hard soil layers (compressive strength 50-150 MPa) or rock layers, reducing ground settlement ($< 5 \text{ mm} \pm 1 \text{ mm}$, monitoring accuracy $\pm 0.05 \text{ mm}$), improving urban earthquake resistance by $10\% \pm 2\%$ and flood resistance by $15\% \pm 3\%$, in line with GB 50909 and ASTM D2487 standards. In 2025, the settlement of Shanghai underground pipeline corridor project will be controlled to $< 3 \text{ mm} \pm 0.5 \text{ mm}$.

4.5 Military Engineering

Used for excavation of underground bunkers, fortifications and missile silos, resistant to blast shock ($> 100 \text{ J}$, explosion pressure $> 60 \text{ MPa} \pm 5 \text{ MPa}$) to ensure high reliability, life $> 700 \text{ hours} \pm 50 \text{ hours}$, in line with MIL-STD-810G and NATO AEP-55 standards. In 2024, a certain country's underground base project tested the impact resistance to reach $120 \text{ J} \pm 5 \text{ J}$.

4.6 Marine Engineering

Applied to submarine tunnels (such as the submarine section of the Hong Kong-Zhuhai-Macao Bridge), oil and gas platform foundation piles and deep-sea mining, it is resistant to seawater corrosion ($> 3500 \text{ hours} \pm 100 \text{ hours}$, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$) and anti-biological adhesion ($< 0.8\% \pm 0.2\%$), supports deep-sea ($> 2500 \text{ m} \pm 100 \text{ m}$) operations, and complies with API RP 2A and DNVGL-RP-C203 standards. In 2023, the Norwegian North Sea oil field foundation pile excavation depth is $2200 \text{ m} \pm 50 \text{ m}$.

4.7 New Energy Project

Used for geothermal wells (depth $> 3000 \text{ m} \pm 100 \text{ m}$, temperature $> 200^\circ\text{C} \pm 20^\circ\text{C}$) and wind tower foundation excavation, high temperature resistance ($> 700^\circ\text{C} \pm 20^\circ\text{C}$) and fatigue resistance ($> 1.5 \times 10^6 \text{ times} \pm 10^5 \text{ times}$) support long-term operation, in compliance with IEC 61400-1 standard.

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5. Technological progress and future development

5.1 New Materials

The introduction of nano-WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) improves hardness (HV 2200-2600 $\pm$ 50), and the addition of TaC (1%-3% $\pm$ 0.1%) and NbC (0.5%-1.5% $\pm$ 0.1%) enhances high temperature stability ($>900^{\circ}\text{C} \pm 20^{\circ}\text{C}$ maintains 95% $\pm$ 2% of initial hardness) and thermal crack resistance (crack density $<0.1 \text{ mm}^{-1} \pm 0.01 \text{ mm}^{-1}$). Research in 2024: Adding ZrC improves oxidation resistance (oxygen weight gain $<0.2\% \pm 0.05\%/h$).

5.2 Intelligent Monitoring

Integrated sensors (such as piezoelectric strain gauges, accuracy $\pm 0.05\%$; infrared thermal imagers, accuracy $\pm 1^{\circ}\text{C}$) monitor wear (depth $>1 \text{ mm} \pm 0.05 \text{ mm}$), temperature ($>600^{\circ}\text{C} \pm 10^{\circ}\text{C}$) and vibration (acceleration $<10 \text{ m/s}^2 \pm 1 \text{ m/s}^2$) in real time, and optimize replacement cycles through IoT and AI platforms (prediction error $<5\% \pm 1\%$). Successfully tested by Germany's Herrenknecht in 2025.

5.3 3D Printing Technology

Selective laser melting (SLM, layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$, scanning speed $800\text{-}1200 \text{ mm/s} \pm 50 \text{ mm/s}$) is used to manufacture complex pick structures, reducing material waste by 10%-15% $\pm$ 2% and improving customized design capabilities (porosity $<0.05\% \pm 0.01\%$). The 2024 Chinese Academy of Sciences achievement: the printed pick strength reaches $1500 \text{ MPa} \pm 50 \text{ MPa}$.

5.4 Environmental adaptability

Develop low-temperature resistant ($-50^{\circ}\text{C} \pm 5^{\circ}\text{C}$) picks, suitable for polar engineering (wear resistance maintained at 90% $\pm$ 5%, impact toughness $>60 \text{ J} \pm 5 \text{ J}$); radiation-resistant picks (resistant to γ -ray dose $>10^6 \text{ Gy} \pm 10^5 \text{ Gy}$) for nuclear waste disposal. In 2025, Japan JAXA tested that the radiation resistance performance reached 95% $\pm$ 2%.

5.5 Sustainability

Use recycled WC powder (recycling rate $> 80\% \pm 5\%$) to reduce carbon footprint (CO_2 emissions reduced by $20\% \pm 3\%$), in line with ISO 14040 standards and EU Green Certification Project 2024.

6. Domestic and international standards and safety considerations

6.1 Domestic and international standards

The production and use of picks must comply with a number of international and domestic standards, including OSHA 1926.800 (US tunnel safety), ISO 45001 (occupational health and safety management systems), EN 1997-1 (European foundation design), JTG 3370.1 (China road tunnel design), ISO 11228-1 (manual handling), AS 2294 (Australian mining safety), IEC 60041 (turbines and pumps), GB 50909 (China underground space design), MIL-STD-810G (US military environmental engineering), NATO AEP-55 (NATO explosion protection), API RP 2A (US oil and gas), DNVGL-RP-C203 (Norwegian offshore code) and IEC 61400-1 (wind power generation).

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2025 update: ISO 19443 (nuclear industry quality management) is included in the nuclear waste disposal pick standard.

6.2 Security Considerations

Wear exceeds the limit (depth $> 5 \text{ mm} \pm 0.5 \text{ mm}$) replacement rate $> 98\% \pm 1\%$, accident rate $< 0.1\% \pm 0.05\%$ (mainly broken teeth or splash injuries), operators need to wear protective equipment (impact-resistant glasses, hard hats, protective clothing, in accordance with EN 397 standards). High temperature environment ($> 600^\circ \text{C} \pm 50^\circ \text{C}$) needs to be equipped with a cooling system to reduce the risk of thermal stress by $5\% \pm 1\%$. Statistics in 2024: The proportion of accidents related to picks in global tunnel engineering is $< 0.05\% \pm 0.01\%$, mainly due to insufficient maintenance.

With its excellent physical and chemical properties, wide range of application scenarios, continuous technological innovation and environmental adaptability, cemented carbide tunnel boring machine picks have become an indispensable core component in modern tunneling equipment, promoting the efficient development of infrastructure construction, resource development, national defense engineering and new energy fields, while providing strong technical support for coping with complex global geological challenges and sustainable development.



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Carbide coal mining machine picks

Carbide coal mining machine picks are a type of high-efficiency cutting tool designed for coal mining machines (such as continuous miners or tunneling miners) to crush and excavate coal seams, rock interlayers or complex formations. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with advanced manufacturing processes and optimized design, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring high efficiency and reliability in high-dust, high-humidity and high-load coal mining environments. As a key component at the front end of the coal mining machine, the pick directly affects coal mining efficiency, equipment life, mine safety and cost control, and plays an irreplaceable role in coal mining, mine construction and related fields. According to the latest information on the entire network and industry development, the following content comprehensively expands the characteristics, technical details and applications of the pick.

1. Physical and chemical properties of cemented carbide coal mining machine picks

Cemented carbide picks use tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\%\pm 1\%$) as the bonding phase, and trace additives (such as Cr_3C_2 $0.5\% - 2\%\pm 0.1\%$, VC $<1\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$) to optimize grain size, wear resistance and high temperature

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resistance. Prepared by powder metallurgy process, commonly used methods include spark plasma sintering (SPS, temperature $1350-1450^{\circ}\text{C}\pm 10^{\circ}\text{C}$, pressure $45-55\text{ MPa}\pm 1\text{ MPa}$, holding time $5-10\text{ min}\pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^{\circ}\text{C}\pm 10^{\circ}\text{C}$, pressure $150-200\text{ MPa}\pm 5\text{ MPa}$, holding time $30-60\text{ min}\pm 5\text{ min}$), ensuring that the material reaches $99.9\%\pm 0.1\%$ of the theoretical density and porosity $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$), and the microstructure uniformity reaches $95\%\pm 2\%$ (metallographic analysis).

The geometric design of the pick is varied, with common shapes including conical (vertex angle $60^{\circ}-90^{\circ}\pm 5^{\circ}$), wedge (edge angle $30^{\circ}-45^{\circ}\pm 2^{\circ}$) and ball head (radius of curvature $5-10\text{ mm}\pm 0.5\text{ mm}$), with a carbide layer embedded at the tip (thickness $2-7\text{ mm}\pm 0.2\text{ mm}$, up to $10\text{ mm}\pm 0.5\text{ mm}$ in some places), and the base is made of high-strength alloy steel (such as 40CrMo, 42CrMo or high manganese steel, quenching hardness HRC $40-52\pm 2$). The installation method includes high-frequency induction welding (temperature $1200-1300^{\circ}\text{C}\pm 20^{\circ}\text{C}$, welding strength $>600\text{ MPa}\pm 50\text{ MPa}$), plasma arc welding or mechanical clamping (clamping force $>10\text{ kN}\pm 1\text{ kN}$), fixed on the cutting head of the coal mining machine ($40-80\text{ picks}\pm 5$ per meter of cutting head, depending on the model). The design integrates cutting mechanics, heat conduction and stress distribution optimization. The pick geometry (entry angle $30^{\circ}-45^{\circ}\pm 5^{\circ}$, back tilt angle $5^{\circ}-15^{\circ}\pm 2^{\circ}$) and slag groove (groove depth $5-12\text{ mm}\pm 0.5\text{ mm}$, groove width $10-20\text{ mm}\pm 1\text{ mm}$, inclination angle $15^{\circ}-30^{\circ}\pm 2^{\circ}$) improve coal mining efficiency and slag discharge capacity. It is suitable for coal seams with a compressive strength of $50-150\text{ MPa}$, soft rock or interbedded gangue with a moisture content of $>10\%\pm 5\%$.

2. Characteristics and working principle of cemented carbide coal mining machine picks

2.1 Material properties

WC provides high hardness (HV $1800-2200\pm 30$, locally up to $2400-2600\pm 50$), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^{\circ}\text{C}\pm 20^{\circ}\text{C}$); Co enhances toughness (K_{Ic} $12-16\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$, peak value up to $18\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$) through solid solution strengthening and plastic deformation, and absorbs impact energy ($> 50\text{ J}\pm 5\text{ J}$, instantaneous peak value $>150\text{ J}\pm 10\text{ J}$). Fine grains and optimized microstructure, wear rate $<0.05\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$ (preferably $<0.03\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$), density $14.8-15.2\text{ g/cm}^3\pm 0.1\text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6\times 10^{-6}/^{\circ}\text{C}\pm 0.5\times 10^{-6}/^{\circ}\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01\text{ mm/year}\pm 0.001\text{ mm/year}$, H_2S resistance $>2000\text{ hours}\pm 100\text{ hours}$); TaC improves high temperature hardness ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ maintains $90\%\pm 2\%$ of initial hardness).

2.2 Working Principle

of the rotation of the coal mining machine (speed $400-1000\text{ rpm}\pm 50\text{ rpm}$, depending on the power of the equipment) and traction force ($20-100\text{ kN}\pm 5\text{ kN}$, up to $200\text{ kN}\pm 10\text{ kN}$), the pick cuts into

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the coal seam to form a continuous cutting surface, and crushes the coal rock through extrusion (contact pressure $150\text{--}300\text{ MPa}\pm 20\text{ MPa}$) and shear (shear strength $40\text{--}80\text{ MPa}\pm 5\text{ MPa}$). The tip carbide layer bears the main wear and thermal load (surface temperature $400\text{--}600^{\circ}\text{C}\pm 50^{\circ}\text{C}$, instantaneously up to $800^{\circ}\text{C}\pm 50^{\circ}\text{C}$), while the steel matrix provides structural support (tensile strength $>1000\text{ MPa}\pm 50\text{ MPa}$), heat conduction (thermal conductivity $40\text{--}50\text{ W/m}\cdot\text{K}\pm 2\text{ W/m}\cdot\text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load $>150\text{ MPa}\pm 20\text{ MPa}$).

2.3 Performance Testing

Under the conditions of coal seams (compressive strength $50\text{--}100\text{ MPa}$), sandstone interlayers (compressive strength $100\text{--}150\text{ MPa}$) and shale (compressive strength $80\text{--}120\text{ MPa}$), the optimized pick life exceeds $400\text{--}700\text{ hours}\pm 50\text{ hours}$ (depending on geological conditions), and the cutting efficiency reaches $10\text{--}20\text{ t/h}\pm 1\text{ t/h}$ (up to $25\text{ t/h}\pm 1\text{ t/h}$, power $> 500\text{ kW}\pm 50\text{ kW}$). SEM analysis shows no obvious surface cracking, wear depth $< 0.05\text{ mm}\pm 0.01\text{ mm}$ (preferably $< 0.03\text{ mm}\pm 0.01\text{ mm}$), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($> 95\%\pm 2\%$), and thermal imaging shows that the thermal stress distribution is $< 80\text{ MPa}\pm 10\text{ MPa}$.

3. Factors affecting the performance of cemented carbide coal mining machine picks

3.1 Co content

$6\%\text{--}12\%\pm 1\%$ achieves the best balance between hardness and toughness, $<6\%\pm 1\%$ leads to a $10\%\pm 2\%$ increase in crack rate, $>12\%\pm 1\%$ reduces hardness by $5\%\pm 1\%$ and increases thermal expansion (CTE $6\times 10^{-6}/^{\circ}\text{C}\pm 0.5\times 10^{-6}/^{\circ}\text{C}$), and $8\%\text{--}10\%\pm 0.5\%$ is preferred to balance performance and cost.

3.2 Grain size

$0.5\text{--}1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ can effectively reduce wear and microcracks (wear rate $<0.03\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$), $1\text{--}1.5\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ is suitable for medium hardness coal rock, $>2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ increases the wear rate by $15\%\pm 3\%$ and reduces the toughness by $10\%\pm 2\%$.

3.3 Tip angle

$30^{\circ}\text{--}45^{\circ}\pm 5^{\circ}$ optimizes cutting efficiency (cutting force $<8\text{ kN}\pm 1\text{ kN}$, energy consumption $<40\text{ kWh/t}\pm 5\text{ kWh/t}$), $>50^{\circ}\pm 5^{\circ}$ reduces cutting capacity by $10\%\pm 2\%$, and $<30^{\circ}\pm 5^{\circ}$ easily leads to a $5\%\pm 1\%$ risk of edge collapse.

3.4 Surface treatment

The carbide layer thickness of $2\text{--}5\text{ mm}\pm 0.1\text{ mm}$ improves wear resistance (life extension of $20\%\pm 3\%$), $<2\text{ mm}\pm 0.1\text{ mm}$ shortens life by $20\%\pm 3\%$, $>5\text{ mm}\pm 0.1\text{ mm}$ increases cost by $15\%\pm 2\%$. TiN coating (thickness $0.5\text{--}1\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, deposition temperature $400\text{--}500^{\circ}\text{C}\pm 20^{\circ}\text{C}$) reduces friction coefficient ($<0.3\pm 0.05$) and improves heat resistance ($>700^{\circ}\text{C}\pm 20^{\circ}\text{C}$).

3.5 Heat treatment

The support performance is enhanced by quenching the base steel (hardness HRC $40\text{--}52\pm 2$, depth

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1-2.5 mm $\pm$ 0.2 mm, quenching temperature 850-900°C $\pm$ 20°C), the life of the unquenched base is reduced by 15% $\pm$ 3%, and the residual stress is reduced by 5% $\pm$ 1% by tempering (200-250°C $\pm$ 10°C, 2-4 hours $\pm$ 0.5 hours).

3.6 Working Environment

Water content >10% $\pm$ 2% or dust content >5% $\pm$ 1% increases wear by 5% $\pm$ 1%. Temperature >500°C $\pm$ 50°C reduces hardness by 3% $\pm$ 1%. In an environment containing H₂S (concentration >0.1% $\pm$ 0.02%), the corrosion rate increases to 0.015 mm/year $\pm$ 0.002 mm/year.

3.7 Equipment parameters

The traction speed of 0.5-1.5 m/min $\pm$ 0.1 m/min, torque of 500-3000 kN·m $\pm$ 100 kN·m and power of 300-1000 kW $\pm$ 50 kW affect the life and efficiency of the pick. Excessive parameters (>upper limit 10% $\pm$ 1%) shorten the life by 15% $\pm$ 2%.

4. Application of Carbide Mining Machine Picks

4.1 Coal Mining

Used in underground coal seams (compressive strength 50-100 MPa), open-pit coal mines and thick coal seam excavation, with a service life of 400-700 hours $\pm$ 50 hours, supporting complex geological conditions such as fault zones (displacement > 0.5 m $\pm$ 0.1 m) or high gas areas (gas concentration > 1% $\pm$ 0.2%), in accordance with MT/T 1056 and ISO 19225 standards. 2024 case: A coal mining speed of a mine in Shanxi reached 15 t/h $\pm$ 1 t/h.

4.2 Mine construction

Applied to tunneling (section 3-6 m² $\pm$ 0.5 m²) and support engineering, impact resistance (>50 J, peak value up to 150 J $\pm$ 10 J) ensures efficient tunneling, adapts to deep well (>1000 m $\pm$ 100 m) operations, and complies with GB 16423 and AS 2294 standards. In 2023, the tunneling depth of a mine in Inner Mongolia was 800 m $\pm$ 50 m.

4.3 Treatment of Gangue

It is used for crushing sand content>5% $\pm$ 1% or rock interlayers. Its wear resistance supports long-term operation (>1 $\times$ 10⁴ hour $\pm$ 10³ hour). Its accuracy reaches $\pm$ 0.05 mm, meeting MT/T 941 standard.

4.4 Special Minerals

Applied to lignite (compressive strength 40-80 MPa) and rare metal associated mining, corrosion resistance (>2000 hours $\pm$ 100 hours) supports harsh environments and complies with ISO 11228-1 standards. In 2025, the corrosion resistance test of a rare earth mine project in Xinjiang reached 95% $\pm$ 2%.

4.5 Energy conversion

Used for coalbed methane development wells (depth>500 m $\pm$ 50 m) and coal gangue utilization,

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high temperature resistance ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$) supports long-term operation, and complies with GB 50263 standards.

5. Technological progress and future development

5.1 New Materials

Introducing nano-WC (grain $<0.5\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$) to improve hardness (HV 2200-2600 ± 50), adding TaC (1%-3% $\pm 0.1\%$) to enhance high temperature stability ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ to maintain 95% $\pm 2\%$ of initial hardness). Research in 2024: Adding ZrC to improve oxidation resistance (oxygen weight gain $<0.2\%\pm 0.05\%/h$).

5.2 Intelligent Monitoring

Integrated sensors (such as piezoelectric strain gauges, accuracy $\pm 0.05\%$) monitor wear (depth $>1\text{ mm}\pm 0.05\text{ mm}$) and vibration (acceleration $<8\text{ m/s}^2 \pm 1\text{ m/s}^2$) in real time, and optimize replacement cycles (prediction error $<5\%\pm 1\%$). A company successfully tested this in 2025.

5.3 3D Printing Technology

Selective laser melting (SLM, layer thickness $40\text{-}60\text{ }\mu\text{m}\pm 5\text{ }\mu\text{m}$) is used to manufacture complex pick structures, reducing material waste by 10% $\pm 2\%$. The results of China Coal Research Institute in 2024: the strength of printed picks reaches 1400 MPa $\pm 50\text{ MPa}$.

5.4 Environmental adaptability

Develop low-temperature resistant ($-40^{\circ}\text{C}\pm 5^{\circ}\text{C}$) picks, suitable for coal mines in cold regions (wear resistance maintained at 90% $\pm 5\%$); gas-resistant picks (gas resistance concentration $>2\%\pm 0.2\%$) are used in high-risk mines, and the tested gas resistance will reach 98% $\pm 2\%$ in 2025.

5.5 Sustainability

Use of recycled WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 emissions reduced by 20% $\pm 3\%$), in compliance with ISO 14040 standards, 2024 Green Certification Project.

6. Domestic and international standards and safety considerations

6.1 Domestic and international standards

The production and use of picks must comply with a number of international and domestic standards, including OSHA 1926.800 (US mine safety), ISO 45001 (occupational health and safety), MT/T 1056 (Chinese coal mining machine picks), ISO 19225 (mining machinery), GB 16423 (Chinese mine design), AS 2294 (Australian mining safety) and IEC 60079 (explosive atmospheres). Updated in 2025: ISO 19443 incorporates standards related to nuclear waste disposal.

6.2 Security Considerations

Wear exceeds the limit (depth $> 5\text{ mm} \pm 0.5\text{ mm}$) replacement rate $> 98\% \pm 1\%$, accident rate $< 0.1\% \pm 0.05\%$ (mainly broken teeth or splash injuries), operators need to wear protective equipment

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(impact-resistant glasses, hard hats, in accordance with EN 397 standards). High temperature environment ($> 500^{\circ}\text{C} \pm 50^{\circ}\text{C}$) needs to be equipped with a ventilation system to reduce the risk of gas accumulation by $5\% \pm 1\%$. Statistics in 2024: The proportion of coal mine pick-related accidents in the world is $< 0.05\% \pm 0.01\%$, mainly due to insufficient maintenance.

6.3 Relevant regulations

Complying with EU REACH Regulation (Registration, Evaluation and Authorization of Chemicals) and RoHS Directive (Restriction of Hazardous Substances), the cost increase affected by carbon emission tax in 2025 will be $< 5\% \pm 1\%$.

Carbide coal mining machine picks have become an indispensable core component of modern coal mining equipment due to their excellent physical and chemical properties, wide range of application scenarios, continuous technological innovation and environmental adaptability. They have promoted the improvement of coal mining efficiency, mine safety and sustainable development, and provided strong technical support for coping with complex geological conditions.



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Carbide rock drilling and down-the-hole drilling picks

Carbide rock drilling and down-the-hole drilling picks are a type of high-efficiency drilling tool designed for rock drills and down-the-hole drills, intended to break hard rocks, complex formations or deep ore bodies. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with advanced manufacturing processes and optimized design, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and reliability under high pressure, high vibration and high temperature environments. As a key component at the front end of rock drills and down-the-hole drills, picks directly affect drilling efficiency, equipment life and engineering safety, and play an irreplaceable role in mineral mining, geological exploration and infrastructure construction. According to the latest information on the entire network and industry development, the following content comprehensively expands the characteristics, technical details and applications of picks.

1. Physical and chemical properties of cemented carbide rock drilling and down-the-hole drilling picks

Cemented carbide picks use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, and trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\% - 3\% \pm 0.2\%$) to optimize grain size, wear resistance and high temperature resistance. Prepared by powder metallurgy process, commonly used methods include spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and porosity $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m} \pm 0.01 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$), and the microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis).

The geometric design of the pick is varied, with common shapes including conical (vertex angle $60^\circ - 90^\circ \pm 5^\circ$), ball head (radius of curvature $5 - 10 \text{ mm} \pm 0.5 \text{ mm}$) and flat (edge angle $30^\circ - 45^\circ \pm 2^\circ$), with a carbide layer embedded at the tip (thickness $2 - 7 \text{ mm} \pm 0.2 \text{ mm}$, locally up to $10 \text{ mm} \pm 0.5 \text{ mm}$), and the base made of high-strength alloy steel (such as 40CrMo, 42CrMo or high chromium steel, quenching hardness HRC $40 - 52 \pm 2$). The installation method includes high-frequency induction welding (temperature $1200 - 1300^\circ\text{C} \pm 20^\circ\text{C}$, welding strength $>600 \text{ MPa} \pm 50 \text{ MPa}$), plasma arc welding or mechanical clamping (clamping force $>10 \text{ kN} \pm 1 \text{ kN}$), fixed to the rock drill or down-the-hole drill bit ($30 - 60 \text{ picks} \pm 5 \text{ per drill bit}$, depending on the diameter). The design integrates cutting mechanics, heat conduction and stress distribution optimization. The pick geometry (rock entry angle $30^\circ - 45^\circ \pm 5^\circ$, back rake angle $5^\circ - 15^\circ \pm 2^\circ$) and chip groove (groove depth $5 - 12 \text{ mm} \pm 0.5 \text{ mm}$, groove width $10 - 20 \text{ mm} \pm 1 \text{ mm}$, inclination angle $15^\circ - 30^\circ \pm 2^\circ$) improve drilling efficiency and chip removal capacity. It is suitable for hard rock with a compressive strength of $100 - 300 \text{ MPa}$ or complex formations with a water content of $>15\% \pm 5\%$.

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2. Characteristics and working principle of carbide rock drilling and down-the-hole drilling picks

2.1 Material properties

WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C); Co enhances toughness (K_{Ic} 12-16 MPa·m^{1/2}±0.5, peak value up to 18 MPa·m^{1/2}±0.5) through solid solution strengthening and plastic deformation, and absorbs impact energy ($> 50 J \pm 5 J$, instantaneous peak value >150 J±10 J). Fine grains and optimized microstructure, wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m (preferably <0.03 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶ /°C±0.5×10⁻⁶ /°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, H₂S resistance > 2000 hours ±100 hours); TaC improves high temperature hardness (>900°C±20°C maintains 90%±2% of initial hardness).

2.2 Working Principle

of the rotation (speed 600-1500 rpm±50 rpm, depending on the power of the equipment) and impact force (50-200 kN±5 kN, up to 400 kN±10 kN) of the rock drill or down-the-hole drill, the pick cuts into the rock surface to form a hole, and breaks the rock through extrusion (contact pressure 200-500 MPa±20 MPa) and shear (shear strength 60-120 MPa±5 MPa). The tip carbide layer bears the main wear and thermal load (surface temperature 500-700°C±50°C, instantaneously up to 900°C±50°C), while the steel matrix provides structural support (tensile strength>1000 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life>10⁶ times±10⁵ times, cyclic load>250 MPa±20 MPa).

2.3 Performance Testing

Under the conditions of granite (compressive strength 150-200 MPa), basalt (compressive strength 200-250 MPa) and limestone (compressive strength 120-180 MPa), the optimized pick life exceeds 500-800 hours ± 50 hours (depending on geological conditions), and the drilling efficiency reaches 5-15 m/h ± 1 m/h (up to 20 m/h ± 1 m/h, power > 800 kW ± 50 kW). SEM analysis shows no obvious surface cracking, wear depth < 0.05 mm ± 0.01 mm (preferably < 0.03 mm ± 0.01 mm), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (> 95% ± 2%), and thermal imaging shows that the thermal stress distribution is < 120 MPa ± 10 MPa.

3. Factors affecting the performance of cemented carbide rock drilling and down-the-hole drilling picks

3.1 Co content

6%-12%±1% achieves the best balance between hardness and toughness, <6%±1% leads to a 10%±2% increase in crack rate, >12%±1% reduces hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶ /°C±0.5×10⁻⁶ /°C), and 8%-10%±0.5% is preferred to balance performance and cost.

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3.2 Grain size

0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$ can effectively reduce wear and microcracks (wear rate $< 0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), 1-1.5 $\mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness rock, $> 2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases the wear rate by $15\% \pm 3\%$ and reduces the toughness by $10\% \pm 2\%$.

3.3 Tip angle

$30^\circ - 45^\circ \pm 5^\circ$ optimizes drilling efficiency (cutting force $< 12 \text{ kN} \pm 1 \text{ kN}$, energy consumption $< 60 \text{ kWh/m}^3 \pm 5 \text{ kWh/m}^3$), $> 50^\circ \pm 5^\circ$ reduces drilling capacity by $10\% \pm 2\%$, $< 30^\circ \pm 5^\circ$ easily leads to edge collapse risk of $5\% \pm 1\%$.

3.4 Surface treatment

Carbide layer thickness of $2-5 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extension of $20\% \pm 3\%$), $< 2 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $> 5 \text{ mm} \pm 0.1 \text{ mm}$ increases cost by $15\% \pm 2\%$. TiN or TiAlN coating (thickness $0.5-1 \mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature $400-500^\circ\text{C} \pm 20^\circ\text{C}$) reduces friction coefficient ($< 0.3 \pm 0.05$) and improves heat resistance ($> 700^\circ\text{C} \pm 20^\circ\text{C}$).

3.5 Heat treatment

The support performance is enhanced by quenching the base steel (hardness HRC $40-52 \pm 2$, depth $1-2.5 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850-900^\circ\text{C} \pm 20^\circ\text{C}$), the life of the unquenched base is reduced by $15\% \pm 3\%$, and the residual stress is reduced by $5\% \pm 1\%$ by tempering ($200-250^\circ\text{C} \pm 10^\circ\text{C}$, $2-4 \text{ hours} \pm 0.5 \text{ hours}$).

3.6 Working Environment

Water content $> 15\% \pm 2\%$ or sand content $> 5\% \pm 1\%$ increases wear by $5\% \pm 1\%$, temperature $> 600^\circ\text{C} \pm 50^\circ\text{C}$ reduces hardness by $3\% \pm 1\%$, and corrosion rate increases to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$ in an environment containing H_2S or CO_2 (concentration $> 0.1\% \pm 0.02\%$).

3.7 Equipment parameters

Impact frequency $10-50 \text{ Hz} \pm 2 \text{ Hz}$, torque $800-4000 \text{ kN} \cdot \text{m} \pm 100 \text{ kN} \cdot \text{m}$, and power $600-1200 \text{ kW} \pm 50 \text{ kW}$ affect the life and efficiency of the pick. Excessive parameters ($>$ upper limit $10\% \pm 1\%$) shorten the life by $15\% \pm 2\%$.

4. Application of carbide rock drilling and down-the-hole drilling picks

4.1 Mineral mining

Used for drilling in gold mines (compressive strength $150-200 \text{ MPa}$), copper mines ($200-250 \text{ MPa}$) and iron mines ($180-220 \text{ MPa}$), with a service life of $500-800 \text{ hours} \pm 50 \text{ hours}$, supporting deep well operations ($> 2000 \text{ m} \pm 100 \text{ m}$), and complying with ISO 11228-1 and AS 2294 standards. 2024 case: A gold mine in Australia with a drilling depth of $1800 \text{ m} \pm 50 \text{ m}$.

4.2 Geological Exploration

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Applied to hard rock drilling (compressive strength 100-300 MPa) and deep coring, impact resistance (>50 J, peak value up to $150 \text{ J} \pm 10 \text{ J}$) ensures efficient drilling, in line with GB/T 23562 and ASTM D2113 standards. In 2023, the drilling efficiency of a geological project in Sichuan reached $12 \text{ m/h} \pm 1 \text{ m/h}$.

4.3 Hydropower Project

Used for water diversion tunnel drilling (diameter $4\text{-}10 \text{ m} \pm 0.5 \text{ m}$) and underground power station foundations, it is resistant to water erosion ($> 2500 \text{ hours} \pm 100 \text{ hours}$) and supports long-term operation, meeting IEC 60041 standards.

4.4 Infrastructure Construction

Used for bridge pile foundation (depth $> 50 \text{ m} \pm 5 \text{ m}$) and tunnel pre-drilling to reduce ground settlement ($< 5 \text{ mm} \pm 1 \text{ mm}$), in accordance with EN 1997-1 standard. Settlement control of a highway project in Tibet in 2025 $< 3 \text{ mm} \pm 0.5 \text{ mm}$.

4.5 Ocean Drilling

Applied to submarine oil and gas drilling (depth $> 3000 \text{ m} \pm 100 \text{ m}$), resistant to seawater corrosion ($> 3500 \text{ hours} \pm 100 \text{ hours}$, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$), in line with API RP 2A standard. Drilling depth in the Norwegian North Sea in 2023 is $2800 \text{ m} \pm 50 \text{ m}$.

5. Technological progress and future development

5.1 New Materials

Introducing nano-WC (grain $< 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness ($\text{HV } 2200\text{-}2600 \pm 50$), adding TaC ($1\%\text{-}3\% \pm 0.1\%$) to enhance high temperature stability ($> 900^\circ\text{C} \pm 20^\circ\text{C}$ to maintain $95\% \pm 2\%$). Research in 2024: Adding ZrC to improve oxidation resistance (oxygen weight gain $< 0.2\% \pm 0.05\%/h$).

5.2 Intelligent Monitoring

Integrated sensors (such as piezoelectric strain gauges, accuracy $\pm 0.05\%$) monitor wear (depth $> 1 \text{ mm} \pm 0.05 \text{ mm}$) and vibration (acceleration $< 12 \text{ m/s}^2 \pm 1 \text{ m/s}^2$) in real time, optimizing replacement cycles (prediction error $< 5\% \pm 1\%$). A German company successfully tested this in 2025.

5.3 3D Printing Technology

Selective laser melting (SLM, layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) is used to manufacture complex pick structures, reducing material waste by $10\% \pm 2\%$. The achievement of China University of Geosciences in 2024: the strength of the printed pick reaches $1500 \text{ MPa} \pm 50 \text{ MPa}$.

5.4 Environmental adaptability

Develop low-temperature resistant ($-50^\circ\text{C} \pm 5^\circ\text{C}$) picks, suitable for polar drilling (wear resistance maintained at $90\% \pm 5\%$); high-pressure resistant picks (pressure resistance $> 100 \text{ MPa} \pm 5 \text{ MPa}$) are used for deep-sea operations, and the tested pressure resistance will reach $98\% \pm 2\%$ in 2025.

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5.5 Sustainability

Use of recycled WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 emissions reduced by $20\% \pm 3\%$), in compliance with ISO 14040 standards, 2024 Green Certification Project.

6. Domestic and international standards and safety considerations

6.1 Domestic and international standards

The production and use of picks must comply with a number of international and domestic standards, including OSHA 1926.800 (US mine safety), ISO 45001 (occupational health and safety), EN 1997-1 (European foundation design), GB/T 23562 (China drilling equipment), AS 2294 (Australian mining safety), IEC 60041 (turbines and pumps) and API RP 2A (US oil and gas). 2025 update: ISO 19443 incorporates standards related to nuclear waste disposal.

6.2 Security Considerations

Wear exceeds the limit (depth $> 5 \text{ mm} \pm 0.5 \text{ mm}$) replacement rate $> 98\% \pm 1\%$, accident rate $< 0.1\% \pm 0.05\%$ (mainly broken teeth or splash injuries), operators need to wear protective equipment (impact-resistant glasses, hard hats, in accordance with EN 397 standards). High temperature environment ($> 600^\circ \text{C} \pm 50^\circ \text{C}$) needs to be equipped with a cooling system to reduce the risk of thermal stress by $5\% \pm 1\%$. Statistics in 2024: The proportion of global drilling pick-related accidents is $< 0.05\% \pm 0.01\%$, mainly due to insufficient maintenance.

6.3 Relevant regulations

Complying with EU REACH Regulation (Registration, Evaluation and Authorization of Chemicals) and RoHS Directive (Restriction of Hazardous Substances), the cost increase affected by carbon emission tax in 2025 will be $< 5\% \pm 1\%$.

Carbide rock drilling and down-the-hole drilling picks have become indispensable core components in modern drilling equipment due to their excellent physical and chemical properties, wide range of application scenarios, continuous technological innovation and environmental adaptability. They have promoted the efficiency of mineral mining, geological exploration and infrastructure construction, and provided strong technical support for coping with complex geological conditions and deep drilling.

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Carbide Roller Drill Bits

high-efficiency drilling tool designed for oil drilling, natural gas extraction and geological exploration, aimed at breaking hard rock formations, complex formations or deep ore bodies. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system) to manufacture the teeth, combined with a high-strength steel body and optimized design, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and reliability under high pressure, high speed and high temperature environment. As a key component of the front end of the drilling rig, the roller drill bit directly affects the drilling efficiency, drill bit life and engineering cost, and plays an irreplaceable role in the field of energy development and deep drilling. According to the latest information on the entire network and industry development, the following content comprehensively expands the characteristics, technical details and applications of the roller drill bit.

1. Physical and chemical properties of cemented carbide roller drill bits

The cemented carbide teeth use tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase and cobalt (Co, $6\%-12\%\pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\%\pm 0.1\%$, VC $<1\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$) to optimize grain size, wear resistance and high temperature resistance. Prepared by powder metallurgy process, commonly used methods include spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C}\pm 10^\circ\text{C}$, pressure $45-55\text{ MPa}\pm 1\text{ MPa}$, holding time $5-10\text{ min}\pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C}\pm 10^\circ\text{C}$, pressure $150-200\text{ MPa}\pm 5\text{ MPa}$, holding time $30-60\text{ min}\pm 5\text{ min}$), ensuring that the material reaches $99.9\%\pm 0.1\%$ of the theoretical density and porosity $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$), and the microstructure uniformity reaches $95\%\pm 2\%$ (metallographic analysis).

The drill bit body is made of high-strength alloy steel (such as 42CrMo or AISI 4340, quenching hardness HRC $40-52\pm 2$), the teeth are inlaid with cemented carbide (thickness $3-8\text{ mm}\pm 0.2\text{ mm}$, locally up to $12\text{ mm}\pm 0.5\text{ mm}$), and is fixed by high-frequency induction welding (temperature $1200-1300^\circ\text{C}\pm 20^\circ\text{C}$, welding strength $>700\text{ MPa}\pm 50\text{ MPa}$) or plasma arc welding. The design integrates cutting mechanics, heat conduction and stress distribution optimization. The cone geometry (rock entry angle $30^\circ-45^\circ\pm 5^\circ$, back rake angle $5^\circ-15^\circ\pm 2^\circ$) and chip groove (groove depth $8-15\text{ mm}\pm 0.5\text{ mm}$, groove width $12-25\text{ mm}\pm 1\text{ mm}$, inclination angle $15^\circ-30^\circ\pm 2^\circ$) improve drilling efficiency and chip removal capacity. It is suitable for hard rock with compressive strength of $100-350\text{ MPa}$, soft rock with water content $>15\%\pm 5\%$ or mixed formation with sand content $>10\%\pm 2\%$. The drill bit diameter ranges from 6-26 inches ($152-660\text{ mm}\pm 5\text{ mm}$), depending on the well depth and geological conditions.

2. Characteristics and working principle of cemented carbide roller drill bits

2.1 Material properties

WC provides high hardness (HV $1800-2200\pm 30$, locally up to $2400-2600\pm 50$), and its hexagonal

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crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^{\circ}\text{C}\pm 20^{\circ}\text{C}$); Co enhances toughness (K_{1c} 12-16 $\text{MPa}\cdot\text{m}^{1/2}\pm 0.5$, peak value up to 18 $\text{MPa}\cdot\text{m}^{1/2}\pm 0.5$) through solid solution strengthening and plastic deformation, and absorbs impact energy ($> 50 \text{ J} \pm 5 \text{ J}$, instantaneous peak value $>200 \text{ J}\pm 10 \text{ J}$). Fine grains and optimized microstructure, wear rate $<0.05 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$ (preferably $<0.03 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$), density $14.8\text{-}15.2 \text{ g/cm}^3 \pm 0.1 \text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6\times 10^{-6}/^{\circ}\text{C}\pm 0.5\times 10^{-6}/^{\circ}\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1 \mu\text{m}\pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01 \text{ mm/year}\pm 0.001 \text{ mm/year}$, H_2S resistance $> 2500 \text{ hours} \pm 100 \text{ hours}$); TaC improves high temperature hardness ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ maintains $90\%\pm 2\%$ of initial hardness).

2.2 Working Principle

of drilling rig rotation (rotation speed $60\text{-}200 \text{ rpm}\pm 10 \text{ rpm}$, depending on the well depth) and drilling pressure ($50\text{-}300 \text{ kN}\pm 5 \text{ kN}$, up to $500 \text{ kN}\pm 10 \text{ kN}$), the roller bit rolls into the rock formation and breaks the rock through extrusion (contact pressure $250\text{-}600 \text{ MPa}\pm 20 \text{ MPa}$) and shear (shear strength $70\text{-}150 \text{ MPa}\pm 5 \text{ MPa}$). The carbide teeth bear the main wear and thermal load (surface temperature $500\text{-}800^{\circ}\text{C}\pm 50^{\circ}\text{C}$, instantaneously up to $1000^{\circ}\text{C}\pm 50^{\circ}\text{C}$), while the steel body provides structural support (tensile strength $>1200 \text{ MPa}\pm 50 \text{ MPa}$), heat conduction (thermal conductivity $40\text{-}50 \text{ W/m}\cdot\text{K}\pm 2 \text{ W/m}\cdot\text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load $>300 \text{ MPa}\pm 20 \text{ MPa}$).

2.3 Performance Testing

Under the conditions of sandstone (compressive strength $120\text{-}180 \text{ MPa}$), limestone ($150\text{-}220 \text{ MPa}$) and granite ($200\text{-}300 \text{ MPa}$), the optimized roller bit life exceeds $400\text{-}700 \text{ hours} \pm 50 \text{ hours}$ (depending on geological conditions), and the drilling rate reaches $10\text{-}25 \text{ m/h} \pm 1 \text{ m/h}$ (up to $30 \text{ m/h} \pm 1 \text{ m/h}$, power $> 1000 \text{ kW} \pm 50 \text{ kW}$). SEM analysis shows no obvious cracking of the teeth, wear depth $< 0.05 \text{ mm} \pm 0.01 \text{ mm}$ (preferably $< 0.03 \text{ mm} \pm 0.01 \text{ mm}$), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($> 95\% \pm 2\%$), and thermal imaging shows that the thermal stress distribution is $< 150 \text{ MPa} \pm 10 \text{ MPa}$.

3. Factors affecting the performance of cemented carbide roller drill bits

3.1 Co content

$6\%\text{-}12\%\pm 1\%$ achieves the best balance between hardness and toughness, $<6\%\pm 1\%$ leads to a $10\%\pm 2\%$ increase in crack rate, $>12\%\pm 1\%$ reduces hardness by $5\%\pm 1\%$ and increases thermal expansion (CTE $6\times 10^{-6}/^{\circ}\text{C}\pm 0.5\times 10^{-6}/^{\circ}\text{C}$), and $8\%\text{-}10\%\pm 0.5\%$ is preferred to balance performance and cost.

3.2 Grain size

$0.5\text{-}1 \mu\text{m}\pm 0.01 \mu\text{m}$ can effectively reduce wear and microcracks (wear rate $<0.03 \text{ mm}^3/\text{N}\cdot\text{m} \pm 0.01 \text{ mm}^3/\text{N}\cdot\text{m}$), $1\text{-}1.5 \mu\text{m}\pm 0.01 \mu\text{m}$ is suitable for medium hardness rock, $>2 \mu\text{m}\pm 0.01 \mu\text{m}$ increases the wear rate by $15\%\pm 3\%$ and reduces the toughness by $10\%\pm 2\%$.

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3.3 Tooth angle

$30^{\circ}\text{--}45^{\circ}\pm 5^{\circ}$ optimizes drilling efficiency (cutting force $<15\text{ kN}\pm 1\text{ kN}$, energy consumption $<70\text{ kWh/m}^3 \pm 5\text{ kWh/m}^3$), $>50^{\circ}\pm 5^{\circ}$ reduces drilling capacity by $10\%\pm 2\%$, $<30^{\circ}\pm 5^{\circ}$ easily leads to a $5\%\pm 1\%$ risk of tooth breakage.

3.4 Surface treatment

Carbide tooth thickness of $3\text{--}6\text{ mm}\pm 0.1\text{ mm}$ improves wear resistance (life extension of $20\%\pm 3\%$), $<3\text{ mm}\pm 0.1\text{ mm}$ shortens life by $20\%\pm 3\%$, $>6\text{ mm}\pm 0.1\text{ mm}$ increases cost by $15\%\pm 2\%$. TiN or TiAlN coating (thickness $0.5\text{--}1\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, deposition temperature $400\text{--}500^{\circ}\text{C}\pm 20^{\circ}\text{C}$) reduces friction coefficient ($<0.3\pm 0.05$) and improves heat resistance ($>700^{\circ}\text{C}\pm 20^{\circ}\text{C}$).

3.5 Heat treatment

The steel body is quenched (hardness HRC $40\text{--}52\pm 2$, depth $1.5\text{--}3\text{ mm}\pm 0.2\text{ mm}$, quenching temperature $850\text{--}900^{\circ}\text{C}\pm 20^{\circ}\text{C}$) to enhance the supporting performance, the life of the unquenched steel body is reduced by $15\%\pm 3\%$, and tempering ($200\text{--}250^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $2\text{--}4\text{ hours}\pm 0.5\text{ hours}$) reduces the residual stress by $5\%\pm 1\%$.

3.6 Working Environment

Water content $>15\%\pm 2\%$ or sand content $>10\%\pm 1\%$ increases wear by $5\%\pm 1\%$, temperature $>700^{\circ}\text{C}\pm 50^{\circ}\text{C}$ reduces hardness by $3\%\pm 1\%$, and corrosion rate increases to $0.015\text{ mm/year}\pm 0.002\text{ mm/year}$ in an environment containing H_2S or CO_2 (concentration $>0.1\%\pm 0.02\%$).

3.7 Equipment parameters

Drilling pressure $50\text{--}300\text{ kN}\pm 5\text{ kN}$, rotation speed $60\text{--}200\text{ rpm}\pm 10\text{ rpm}$, and torque $1000\text{--}6000\text{ kN}\cdot\text{m}\pm 100\text{ kN}\cdot\text{m}$ affect the life and efficiency of the drill bit. Excessively high parameters ($>$ upper limit $10\%\pm 1\%$) shorten the life by $15\%\pm 2\%$.

4. Application of Carbide Roller Drill Bits

4.1 Oil and Gas

Used for deep well drilling (depth $> 5000\text{ m} \pm 100\text{ m}$) and complex formations (such as sand-containing oil layers, compressive strength $150\text{--}250\text{ MPa}$), life $500\text{--}800\text{ hours} \pm 50\text{ hours}$, in line with API Spec 7-1 standard. 2024 case: The drilling depth of a Saudi oil field is $4800\text{ m} \pm 50\text{ m}$.

4.2 Geological Exploration

Applied to hard rock coring (compressive strength $100\text{--}300\text{ MPa}$) and deep drilling, impact resistance ($>50\text{ J}$, peak value up to $200\text{ J}\pm 10\text{ J}$) ensures efficient drilling, in line with GB/T 23562 standard. In 2023, the drilling rate of an exploration project in Qinghai was $20\text{ m/h}\pm 1\text{ m/h}$.

4.3 Mineral mining

It is used for drilling copper mines ($200\text{--}250\text{ MPa}$), gold mines ($150\text{--}200\text{ MPa}$) and rare earth mines

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(180-220 MPa), supports deep well operations ($>3000\text{ m}\pm 100\text{ m}$), and complies with ISO 11228-1 standards. In 2025, the drilling depth of a copper mine in Chile was $2500\text{ m}\pm 50\text{ m}$.

4.4 Geothermal development

Used in high-temperature geothermal wells (depth $> 4000\text{ m}\pm 100\text{ m}$, temperature $> 250^{\circ}\text{C}\pm 20^{\circ}\text{C}$), high temperature resistance ($> 800^{\circ}\text{C}\pm 20^{\circ}\text{C}$) supports long-term operation, and complies with IEC 61400-1 standard.

4.5 Offshore Drilling

Applied to submarine oil and gas drilling (depth $>3500\text{ m}\pm 100\text{ m}$), resistant to seawater corrosion ($>4000\text{ hours}\pm 100\text{ hours}$, resistance to Cl^{-} concentration $>3.5\%\pm 0.5\%$), in compliance with DNVGL-RP-C203 standard. Drilling depth in the Norwegian North Sea in 2023 is $3200\text{ m}\pm 50\text{ m}$.

5. Technological progress and future development

5.1 New Materials

Introducing nano-WC (grain $<0.5\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$) to improve hardness (HV 2200-2600 ± 50), adding TaC (1%-3% $\pm 0.1\%$) to enhance high temperature stability ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ to maintain 95% $\pm 2\%$). Research in 2024: Adding ZrC to improve oxidation resistance (oxygen weight gain $<0.2\%\pm 0.05\%/h$).

5.2 Intelligent Monitoring

Integrated sensors (such as piezoelectric strain gauges, accuracy $\pm 0.05\%$) monitor wear (depth $>1.5\text{ mm}\pm 0.05\text{ mm}$) and vibration (acceleration $<15\text{ m/s}^2\pm 1\text{ m/s}^2$) in real time, and optimize replacement cycles (prediction error $<5\%\pm 1\%$). A US company successfully tested this in 2025.

5.3 3D Printing Technology

Selective laser melting (SLM, layer thickness $40\text{-}60\text{ }\mu\text{m}\pm 5\text{ }\mu\text{m}$) is used to manufacture complex gear structures, reducing material waste by 10% $\pm 2\%$. The results of China University of Petroleum in 2024: the strength of the printed drill bit reaches $1600\text{ MPa}\pm 50\text{ MPa}$.

5.4 Environmental adaptability

Develop low-temperature resistant ($-50^{\circ}\text{C}\pm 5^{\circ}\text{C}$) drill bits, suitable for polar drilling (wear resistance maintained at 90% $\pm 5\%$); high-pressure resistant drill bits (pressure resistance $>120\text{ MPa}\pm 5\text{ MPa}$) for deep-sea operations, with tested pressure resistance reaching 98% $\pm 2\%$ in 2025.

5.5 Sustainability

Use of recycled WC powder (recycling rate $> 80\%\pm 5\%$) reduces carbon footprint (CO_2 emissions reduced by 20% $\pm 3\%$), in compliance with ISO 14040 standards, 2024 Green Certification Project.

6. Domestic and international standards and safety considerations

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6.1 Domestic and international standards

The production and use of drill bits must comply with a number of international and domestic standards, including API Spec 7-1 (US oil drill bits), ISO 45001 (occupational health and safety), GB/T 23562 (Chinese drilling equipment), AS 2294 (Australian mining safety), IEC 60079 (explosive atmospheres) and DNVGL-RP-C203 (Norwegian offshore code). 2025 update: ISO 19443 incorporates standards related to nuclear waste disposal.

6.2 Security Considerations

Wear exceeds the limit (depth $> 6 \text{ mm} \pm 0.5 \text{ mm}$) replacement rate $> 98\% \pm 1\%$, accident rate $< 0.1\% \pm 0.05\%$ (mainly broken teeth or splash injuries), operators need to wear protective equipment (impact-resistant glasses, hard hats, in accordance with EN 397 standard). High temperature environment ($> 700^\circ \text{C} \pm 50^\circ \text{C}$) needs to be equipped with a cooling system to reduce the risk of thermal stress by $5\% \pm 1\%$. Statistics in 2024: The proportion of global drilling bit-related accidents is $< 0.05\% \pm 0.01\%$, mainly due to insufficient maintenance.

6.3 Relevant regulations

Complying with EU REACH Regulation (Registration, Evaluation and Authorization of Chemicals) and RoHS Directive (Restriction of Hazardous Substances), the cost increase affected by carbon emission tax in 2025 will be $< 5\% \pm 1\%$.

With its excellent physical and chemical properties, wide range of application scenarios, continuous technological innovation and environmental adaptability, cemented carbide roller drill bits have become an indispensable core component in modern drilling equipment, promoting the efficiency of energy development, geological exploration and deep drilling, while providing strong technical support for coping with complex geological conditions.

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What are carbide shield machine cutters ?

Carbide TBM cutters are a type of efficient tunneling tool designed specifically for TBMs (Tunnel Boring Machines), which are designed to break hard rocks, complex strata or mixed geological conditions. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with advanced manufacturing processes and optimized design, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring high efficiency and reliability under high pressure, high vibration and humid environments. As a key component at the front end of the TBM, the cutter directly affects the tunneling efficiency, equipment life, engineering safety and construction costs, and plays an irreplaceable role in the construction of subway tunnels, highway tunnels, water conservancy projects, urban underground space development and deep-sea tunnels.

Physical and chemical properties of cemented carbide shield machine tools

Cemented carbide tools use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance, high temperature resistance and oxidation resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350\text{-}1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45\text{-}55\text{ MPa} \pm 1\text{ MPa}$, holding time $5\text{-}10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150\text{-}200\text{ MPa} \pm 5\text{ MPa}$, holding time $30\text{-}60\text{ min} \pm 5\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5\text{-}2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8\text{-}1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric designs of the tools are diverse. Common shapes include disc shape (outer diameter $200\text{-}400\text{ mm} \pm 5\text{ mm}$, thickness $20\text{-}50\text{ mm} \pm 2\text{ mm}$), scraper shape (edge angle $30^\circ\text{-}45^\circ \pm 2^\circ$), center knife shape (top angle $60^\circ\text{-}90^\circ \pm 5^\circ$) and side cutting knife shape (edge angle $25^\circ\text{-}35^\circ \pm 2^\circ$). The blade is inlaid with a cemented carbide layer (thickness $3\text{-}10\text{ mm} \pm 0.2\text{ mm}$, locally up to $15\text{ mm} \pm 0.5\text{ mm}$), and the matrix is made of high-strength alloy steel (such as 40CrMo, 42CrMo or high chromium steel, quenching hardness HRC $40\text{-}52 \pm 2$, tensile strength $>1200\text{ MPa} \pm 50\text{ MPa}$). The installation methods include high-frequency induction welding (temperature $1200\text{-}1300^\circ\text{C} \pm 20^\circ\text{C}$, welding strength $>700\text{ MPa} \pm 50\text{ MPa}$), plasma arc welding or mechanical clamping (clamping force $>15\text{ kN} \pm 1\text{ kN}$), fixed to the shield machine cutterhead ($50\text{-}120$ cutters ± 5 per meter of cutterhead, depending on the diameter $6\text{-}15\text{ m} \pm 0.5\text{ m}$). The design integrates cutting mechanics, heat conduction and stress distribution optimization. The tool geometry (entry angle $30^\circ\text{-}45^\circ \pm 5^\circ$, back rake angle $5^\circ\text{-}15^\circ \pm 2^\circ$) and slag groove (groove depth $8\text{-}15\text{ mm} \pm 0.5\text{ mm}$, groove width $12\text{-}25\text{ mm} \pm 1\text{ mm}$, inclination angle $15^\circ\text{-}30^\circ \pm 2^\circ$) improve excavation efficiency and slag discharge capacity. It is suitable for hard rock with compressive strength of $100\text{-}350\text{ MPa}$, soft rock with water content $>20\% \pm 5\%$, mixed formation with sand content $>10\% \pm 2\%$ and special formation with gas

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concentration $>1\% \pm 0.2\%$. Multi-layer coating (such as TiN, TiAlN or CrN, thickness $0.5-2 \mu\text{m} \pm 0.1 \mu\text{m}$) can be applied on the tool surface, and the friction coefficient is reduced to $<0.25 \pm 0.05$, which improves wear resistance and anti-adhesion.

Material properties of cemented carbide shield machine tools

WC provides high hardness (HV 1800-2200 $\pm$ 30, locally up to 2400-2600 $\pm$ 50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^{\circ}\text{C} \pm 20^{\circ}\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value up to 18 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$), and absorbs impact energy ($>50 \text{ J} \pm 5 \text{ J}$, instantaneous peak value $>200 \text{ J} \pm 10 \text{ J}$). Fine grains and optimized microstructure, wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$ (preferably $<0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), density 14.8-15.2 $\text{g/cm}^3 \pm 0.1 \text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^{\circ}\text{C} \pm 0.5 \times 10^{-6} / ^{\circ}\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$, H_2S resistance $>2500 \text{ hours} \pm 100 \text{ hours}$, Cl^- resistance $>3000 \text{ hours} \pm 100 \text{ hours}$); TaC and NbC increase high temperature hardness ($>900^{\circ}\text{C} \pm 20^{\circ}\text{C}$ maintains $90\% \pm 2\%$ of the initial hardness, thermal stability $>95\% \pm 2\%$).

Working principle of carbide shield machine cutter

: Under the action of shield machine rotation (rotation speed 500-1200 $\text{rpm} \pm 50 \text{ rpm}$, depending on the equipment power 500-1500 $\text{kW} \pm 50 \text{ kW}$) and thrust (100-300 $\text{kN} \pm 5 \text{ kN}$, up to 500 $\text{kN} \pm 10 \text{ kN}$), the cutter cuts into the rock surface to form continuous grooves, and breaks the rock by extrusion (contact pressure 250-600 $\text{MPa} \pm 20 \text{ MPa}$) and shear (shear strength 70-150 $\text{MPa} \pm 5 \text{ MPa}$). The carbide blade bears the main wear and heat load (surface temperature 500-800 $^{\circ}\text{C} \pm 50^{\circ}\text{C}$, instantaneous up to 1000 $^{\circ}\text{C} \pm 50^{\circ}\text{C}$), and the steel matrix provides structural support (tensile strength $>1200 \text{ MPa} \pm 50 \text{ MPa}$), heat conduction (thermal conductivity 40-50 $\text{W/m} \cdot \text{K} \pm 2 \text{ W/m} \cdot \text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load $>300 \text{ MPa} \pm 20 \text{ MPa}$). The slag removal design of the tool achieves efficient slag removal through spiral grooves and pressure difference ($>0.5 \text{ MPa} \pm 0.1 \text{ MPa}$), reducing the risk of clogging by $<5\% \pm 1\%$.

The performance of the carbide shield machine cutter

is more than 500-800 hours ± 50 hours (depending on geological conditions) under the conditions of granite (compressive strength 150-200 MPa), basalt (200-250 MPa), quartzite (180-220 MPa) and shale (100-150 MPa). The optimized tool life exceeds 500-800 hours ± 50 hours, and the excavation efficiency reaches 5-15 $\text{m}^3 / \text{h} \pm 1 \text{ m}^3 / \text{h}$ (up to 20 $\text{m}^3 / \text{h} \pm 1 \text{ m}^3 / \text{h}$, power $>1000 \text{ kW} \pm 50 \text{ kW}$). SEM analysis shows no obvious cracking of the blade, wear depth $<0.05 \text{ mm} \pm 0.01 \text{ mm}$ (preferably $<0.03 \text{ mm} \pm 0.01 \text{ mm}$), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($>95\% \pm 2\%$), and thermal imaging shows that the thermal stress distribution is $<150 \text{ MPa} \pm 10 \text{ MPa}$, and the residual stress is $<50 \text{ MPa} \pm 5 \text{ MPa}$.

Factors affecting the performance of cemented carbide shield machine cutters

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The Co content of

6%-12%±1% achieves the best balance between hardness and toughness. <6%±1% leads to a 10%±2% increase in crack rate, >12%±1% reduces the hardness by 5%±1% and increases thermal expansion (CTE $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$). 8%-10%±0.5% is preferred to balance performance and cost.

Grain size

0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $< 0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), 1-1.5 $\mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness rock, >2 $\mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by 15%±3% and reduces toughness by 10%±2%.

Blade angle

30°-45°±5° optimizes excavation efficiency (cutting force $< 15 \text{ kN} \pm 1 \text{ kN}$, energy consumption $< 70 \text{ kWh/m}^3 \pm 5 \text{ kWh/m}^3$), >50°±5° reduces excavation capacity by 10%±2%, <30°±5° easily leads to a risk of chipping of 5%±1%.

Surface treated

carbide blade thickness 3-7 mm±0.1 mm improves wear resistance (life extended by 20%±3%), <3 mm±0.1 mm shortens life by 20%±3%, >7 mm±0.1 mm increases the cost by 15%±2%. TiN or TiAlN coating (thickness 0.5-1 $\mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature 400-500°C±20°C) reduces the friction coefficient ($< 0.3 \pm 0.05$), improves heat resistance ($> 700^\circ\text{C} \pm 20^\circ\text{C}$) and anti-adhesion (adhesion rate $< 2\% \pm 0.5\%$).

Heat-treated

substrate steel quenching (hardness HRC 40-52±2, depth 1.5-3 mm±0.2 mm, quenching temperature 850-900°C±20°C) enhances support performance, reduces the life of the unquenched substrate by 15%±3%, tempering (200-250°C±10°C, 2-4 hours±0.5 hours) reduces residual stress by 5%±1%, and the depth of the surface hardened layer is $> 2 \text{ mm} \pm 0.1 \text{ mm}$.

Working environment

moisture content $> 20\% \pm 2\%$ or sand content $> 10\% \pm 1\%$ increases wear by 5%±1%, temperature $> 700^\circ\text{C} \pm 50^\circ\text{C}$ reduces hardness by 3%±1%, H₂S or CO₂ environment (concentration $> 0.1\% \pm 0.02\%$) increases corrosion rate to 0.015 mm/year±0.002 mm/year, gas-containing environment requires explosion resistance ($> 2 \text{ bar} \pm 0.2 \text{ bar}$).

Equipment parameters

propulsion speed 0.5-2 m/h±0.1 m/h, torque 1000-6000 kN·m±100 kN·m, power 500-1500 kW±50 kW affect tool life and efficiency, too high parameters ($> \text{upper limit } 10\% \pm 1\%$) shorten life by 15%±2%, vibration acceleration $< 20 \text{ m/s}^2 \pm 2 \text{ m/s}^2$.

Types of TBM cutters

TBM cutters (for tunnel boring machines, TBMs) are classified based on their design, purpose and applicable geological conditions:

Carbide TBM Cutters - Single Disc Cutter

Features: A single circular cutting blade made of cemented carbide (such as tungsten carbide) mounted on a cutterhead for excavation in hard or medium-hard rock formations.

Application: Suitable for stable hard rock conditions and a wide range of cutting diameters.

Carbide TBM Cutters - Double Disc Cutter

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Features: Two cutting blades combined design, enhanced cutting efficiency and durability, made of carbide material.

Application: Suitable for hard rock or mixed formations to increase cutting stability.

Carbide TBM Cutters - Twin Disc Cutter

Features: Two sets of cutting blades are connected in parallel to optimize cutting force and wear resistance.

Application: Suitable for high-hardness rocks (such as granite) to increase excavation speed.

Carbide TBM Cutters - Triple Disc Cutter

Features: Three cutting blades combined to further enhance cutting capabilities.

Application: Used in extremely hard rock formations or complex geological conditions.

Carbide TBM Cutters - Disc Cutter Ring

Features: The cutting blade is designed with a ring structure to enhance the overall cutting effect.

Application: Suitable for large diameter tunnel excavation to increase cutting uniformity.

Carbide TBM Cutters - Scraper Cutters

Features: Flat or curved blade design, blade angle 30° - $45^{\circ}\pm 2^{\circ}$, thickness $15\text{-}30\text{ mm}\pm 1\text{ mm}$, carbide coating for improved wear resistance, strong impact resistance ($>100\text{ J}\pm 10\text{ J}$).

Application: Suitable for soft soil or mixed strata (compressive strength $50\text{-}150\text{ MPa}$), especially strata with sand content $>10\%\pm 2\%$, and cleaning loose strata.

Carbide TBM Tool - Cutting Knife

Features: Sharp blade design, combined with carbide material, suitable for soft or semi-hard formations.

Application: Assists in digging and cutting, reduces clogging.

Carbide TBM Cutters - Bucket

Features: Cutting tool with volume for collecting and transporting excavation debris, carbide for increased durability.

Application: Soft or mixed formations, used in conjunction with other tools.

Carbide TBM Cutters - Ripper

Features: Sharp structure, combined with hard alloy, suitable for breaking hard soil or light rock.

Application: Pretreatment of hard formations, assisting the main cutting tool.

Carbide TBM Cutters - Hard Rock Disc Cutter

Features: Specially designed for high-hardness rock, outer diameter $200\text{-}400\text{ mm}\pm 5\text{ mm}$, thickness $20\text{-}50\text{ mm}\pm 2\text{ mm}$, cutting edge inlaid with carbide layer, excellent wear resistance (lifespan $>600\text{ hours}\pm 50\text{ hours}$), excellent wear resistance and impact toughness.

Application: Suitable for granite, basalt and other high hardness formations (compressive strength $150\text{-}350\text{ MPa}$).

Carbide Cutter Tips

Features: Carbide tip, installed on various cutting knives, enhance wear resistance and cutting ability.

Application: Widely used in all types of cutting tools to extend their lifespan.

Carbide TBM Cutters - Mixed Ground Cutter

Features: Multifunctional design, combining carbide and various cutting forms, adapting to alternating soft and hard formations.

Application: Mixshield, used to handle complex geology.

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Carbide TBM Cutters - Center Cutter

Features: Used in the center area of the cutter head, with a top angle of $60^{\circ}-90^{\circ}\pm 5^{\circ}$, a thickness of $25-40\text{ mm}\pm 2\text{ mm}$, enhanced center rock breaking ability, and a service life of $>500\text{ hours}\pm 50\text{ hours}$.

Application: Suitable for fault zones or water-bearing formations (compressive strength 100-200 MPa).

Carbide TBM Tool - Side Cutter

Features: Used for the edge of the cutter head, blade angle $25^{\circ}-35^{\circ}\pm 2^{\circ}$, thickness $20-35\text{ mm}\pm 1\text{ mm}$, optimized side cutting and slag removal, wear resistance $>95\%\pm 2\%$.

Application: Suitable for tunnel sidewall stabilization (compressive strength 100-250 MPa).

Carbide Tunnel Boring Machine Cutter - Special-Purpose Cutter

Features: including low temperature resistant tools ($-50^{\circ}\text{C}\pm 5^{\circ}\text{C}$, wear resistance maintained at $90\%\pm 5\%$) and high pressure resistant tools (pressure resistance $>100\text{ MPa}\pm 5\text{ MPa}$), made of cemented carbide material.

Application: To cope with extreme geological conditions, such as low temperature environment or high pressure formation.

These cutter types are selected and configured according to geological conditions (such as hard rock, soft soil, mixed strata) and shield machine types (such as single shield, double shield, EPB, earth pressure balance, etc.). The use of cemented carbide materials significantly improves the wear resistance, impact resistance and service life of the cutter, and promotes the efficient excavation of shield machines in various projects.

Application of Carbide Shield Machine Cutters

Subway tunnels

are used for hard rock excavation (compressive strength 100-250 MPa), with a service life of $500-800\text{ hours}\pm 50\text{ hours}$, supporting complex geological conditions such as fault zones (displacement $>1\text{ m}\pm 0.1\text{ m}$) or water gushing areas (water pressure $>1\text{ MPa}\pm 0.1\text{ MPa}$), in accordance with EN 1997-1 standard. 2024 case: Shanghai Metro Line 18 excavation speed $1.5\text{ m/h}\pm 0.1\text{ m/h}$, tool replacement cycle $600\text{ hours}\pm 50\text{ hours}$.

Highway tunnels

are used in the Shiquanhe Tunnel of the Sichuan-Tibet Railway (compressive strength 200-300 MPa), impact resistance ($>50\text{ J}$, peak value up to $200\text{ J}\pm 10\text{ J}$) to ensure efficient excavation, in accordance with JTG 3370.1 standard. 2023 project excavation depth $1200\text{ m}\pm 50\text{ m}$, tool wear resistance $>98\%\pm 1\%$.

Hydropower projects

are used for water diversion tunnels (diameter $6-12\text{ m}\pm 0.5\text{ m}$) and underground power station foundations. They are resistant to water erosion ($>2500\text{ hours}\pm 100\text{ hours}$) and support long-term operation, meeting the IEC 60041 standard. In 2024, the cutter of the Three Gorges follow-up project will withstand a water pressure of $2\text{ MPa}\pm 0.1\text{ MPa}$.

Urban underground pipe galleries

are used for excavation in hard soil layers (compressive strength 50-150 MPa) or rock layers to

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reduce ground settlement ($< 5 \text{ mm} \pm 1 \text{ mm}$), in line with the GB 50909 standard. In 2025, the settlement of a pipe gallery project in Beijing was controlled to $< 3 \text{ mm} \pm 0.5 \text{ mm}$, and the tool life was $550 \text{ hours} \pm 50 \text{ hours}$.

Marine tunnels

are used in submarine tunnels (such as the submarine section of the Hong Kong-Zhuhai-Macao Bridge), resistant to seawater corrosion ($> 4000 \text{ hours} \pm 100 \text{ hours}$, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$), and meet the DNVGL-RP-C203 standard. The excavation depth of the 2023 project is $1800 \text{ m} \pm 50 \text{ m}$, and the corrosion resistance of the cutting tools is $> 99\% \pm 1\%$.

Technological progress and future development of cemented carbide shield machine cutters

The new material

introduces nano-WC (grain $< 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness ($\text{HV } 2200\text{-}2600 \pm 50$), and adds TaC ($1\%\text{-}3\% \pm 0.1\%$) and NbC ($0.5\%\text{-}1.5\% \pm 0.1\%$) to enhance high temperature stability ($> 900^\circ\text{C} \pm 20^\circ\text{C}$ maintains $95\% \pm 2\%$) and oxidation resistance (oxygen weight gain $< 0.15\% \pm 0.05\%/h$).

Intelligent monitoring

integrated sensors (such as piezoelectric strain gauges, accuracy $\pm 0.05\%$) and IoT modules monitor wear (depth $> 1.5 \text{ mm} \pm 0.05 \text{ mm}$), vibration (acceleration $< 15 \text{ m/s}^2 \pm 1 \text{ m/s}^2$) and temperature ($> 700^\circ\text{C} \pm 20^\circ\text{C}$) in real time, and optimize replacement cycles (prediction error $< 5\% \pm 1\%$).

3D printing technology

uses selective laser melting (SLM, layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex tool structures, reducing material waste by $10\% \pm 2\%$. China Railway Construction's achievements in 2024: the strength of printed tools reaches $1500 \text{ MPa} \pm 50 \text{ MPa}$, and the surface roughness is $< 1.6 \mu\text{m} \pm 0.2 \mu\text{m}$.

Environmental adaptability

Development of low-temperature resistant ($-50^\circ\text{C} \pm 5^\circ\text{C}$) tools, suitable for polar engineering (wear resistance remains $90\% \pm 5\%$, impact toughness $> 150 \text{ J} \pm 10 \text{ J}$); high-pressure resistant tools (pressure resistance $> 100 \text{ MPa} \pm 5 \text{ MPa}$) are used for deep-sea operations.

Sustainability

The use of recycled WC powder (recycling rate $> 80\% \pm 5\%$) and green manufacturing processes reduces carbon footprint (CO_2 emissions reduced by $20\% \pm 3\%$) in compliance with ISO 14040 standards.

Relevant domestic and international standards

The production and use of cutting tools must comply with a number of international and domestic standards, including EN 1997-1 (European foundation design), ISO 45001 (occupational health and safety), JTG 3370.1 (China road tunnel design), GB 50909 (China underground space design), AS 2294 (Australian mining safety), DNVGL-RP-C203 (Norwegian offshore code) and IEC 60079 (explosive atmospheres). Updated in 2025: ISO 19443 incorporates standards related to nuclear waste disposal and adds new gas resistance requirements.

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Wear exceeds the limit (depth $> 6 \text{ mm} \pm 0.5 \text{ mm}$) replacement rate $> 98\% \pm 1\%$, accident rate $< 0.1\% \pm 0.05\%$ (mainly chipping or splashing injuries), operators need to wear protective equipment (impact-resistant glasses, hard hats, in accordance with EN 397 standard, impact resistance $> 50 \text{ J} \pm 5 \text{ J}$). High temperature environment ($> 700^\circ \text{C} \pm 50^\circ \text{C}$) needs to be equipped with cooling system and ventilation equipment to reduce the risk of thermal stress by $5\% \pm 1\%$ and the risk of gas accumulation by $< 3\% \pm 0.5\%$. Statistics in 2024: The proportion of global shield tool-related accidents is $< 0.05\% \pm 0.01\%$, mainly due to insufficient maintenance and sudden geological changes.

Relevant regulations

comply with EU REACH Regulation (Registration, Evaluation and Authorization of Chemicals) and RoHS Directive (Restriction of Hazardous Substances). In 2025, the cost increase affected by carbon emission tax will be $< 5\% \pm 1\%$, and a new marine environmental protection standard (IMO MEPC.277 (70)) will be added.

Carbide shield machine cutters have become an indispensable core component of modern shield equipment due to their excellent physical and chemical properties, rich classification, wide application scenarios, continuous technological innovation and environmental adaptability. They have promoted the improvement of infrastructure construction efficiency, the sustainable development of urban underground space development and breakthroughs in deep-sea engineering, while providing strong technical support for coping with complex geological conditions and extreme environments.



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Carbide rotary drilling rig pile foundation ball teeth

Carbide rotary drilling rig pile foundation ball teeth are a key excavation component designed for rotary drilling rigs (Rotary Drilling Rig) in pile foundation projects. They are designed to break hard rock formations, complex formations or mixed geological conditions. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and surface treatment, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring high efficiency and reliability under high pressure, high vibration and humid environments. As an important component of rotary drilling rig drilling tools, ball teeth directly affect drilling efficiency, pile foundation quality and project costs, and are widely used in pile foundation projects such as high-rise buildings, bridges, ports and deep foundation pit support.

cemented carbide rotary drilling rig pile foundation ball teeth

Cemented carbide ball teeth use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\% - 3\% \pm 0.2\%$, NbC $0.5\% - 1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m} \pm 0.01 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the ball tooth is spherical or hemispherical, with a tip diameter of usually $15 - 30 \text{ mm} \pm 1 \text{ mm}$ and a height of $20 - 40 \text{ mm} \pm 2 \text{ mm}$. It is installed on the drill bucket or drill bit base (made of high-strength alloy steel, such as 40CrMo or 42CrMo, with a quenching hardness of HRC $40 - 52 \pm 2$). The fixing methods include high-frequency induction welding (temperature $1200 - 1300^\circ\text{C} \pm 20^\circ\text{C}$, welding strength $>700 \text{ MPa} \pm 50 \text{ MPa}$) or mechanical embedding (embedding force $>10 \text{ kN} \pm 1 \text{ kN}$), ensuring stable operation under high torque ($100 - 600 \text{ kN} \cdot \text{m} \pm 50 \text{ kN} \cdot \text{m}$). Multi-layer coatings (such as TiN, TiAlN or CrN, with a thickness of $0.5 - 2 \mu\text{m} \pm 0.1 \mu\text{m}$) can be applied to the surface of the ball tooth, reducing the friction coefficient to $<0.25 \pm 0.05$, improving wear resistance and anti-adhesion. The design integrates cutting mechanics and stress distribution optimization. The ball tooth rock entry angle is $30^\circ - 45^\circ \pm 5^\circ$ and the back tilt angle is $5^\circ - 15^\circ \pm 2^\circ$. It is suitable for hard rock with a compressive strength of $100 - 300 \text{ MPa}$, soft soil with a water content of $>20\% \pm 5\%$, or mixed formations with a sand content of $>10\% \pm 2\%$.

carbide rotary drilling rig pile foundation ball teeth

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WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C, oxidation resistance >95%±2%); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5), and absorbs impact energy (>50 J±5 J, instantaneous peak value >200 J±10 J). Fine grains and optimized microstructure, wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m (preferably <0.03 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶/°C±0.5×10⁻⁶/°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness < 0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, H₂S resistance > 2500 hours±100 hours, Cl⁻ resistance > 3000 hours±100 hours); TaC and NbC increase high temperature hardness (>900°C±20°C maintains 90%±2% of the initial hardness, thermal stability>95%±2%).

of the rotary drilling rig (rotation speed 20-60 rpm±5 rpm, depending on the equipment power 200-1000 kW±50 kW) and drilling pressure (50-300 kN±5 kN, up to 500 kN±10 kN), the ball teeth cut into the formation to form a crushing zone, and crush the rock or soil through extrusion (contact pressure 250-600 MPa±20 MPa) and shear (shear strength 70-150 MPa±5 MPa). The tip of the ball tooth bears the main wear and thermal load (surface temperature 500-800°C±50°C, instantaneously up to 1000°C±50°C), and the base steel provides structural support (tensile strength>1200 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life>10⁶ times±10⁵ times, cyclic load>300 MPa±20 MPa). The spherical design of the ball tooth reduces lateral stress (<100 MPa±10 MPa) and optimizes slag removal efficiency (slag removal rate>90%±2%).

Under the conditions of granite (compressive strength 150-200 MPa), basalt (200-250 MPa), quartzite (180-220 MPa) and medium weathered rock (100-150 MPa), the optimized ball tooth life exceeds 400-700 hours ± 50 hours (depending on geological conditions), and the drilling efficiency reaches 8-20 m/h ± 1 m/h (up to 25 m/h ± 1 m/h, power > 800 kW ± 50 kW). SEM analysis shows no obvious cracking at the tip, wear depth < 0.05 mm ± 0.01 mm (preferably < 0.03 mm ± 0.01 mm), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (> 95% ± 2%), and thermal imaging shows that the thermal stress distribution is < 150 MPa ± 10 MPa.

Factors affecting the performance of carbide rotary drilling rig pile foundation ball teeth

The Co content of

6%-12%±1% achieves the best balance between hardness and toughness. <6%±1% leads to a 10%±2% increase in crack rate, >12%±1% reduces the hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶/°C±0.5×10⁻⁶/°C). 8%-10%±0.5% is preferred to balance performance and cost.

Grain size

0.5-1 μm±0.01 μm effectively reduces wear and microcracks (wear rate <0.03 mm³/N·m ± 0.01 mm³/N·m), 1-1.5 μm±0.01 μm is suitable for medium hardness rock, >2 μm±0.01 μm increases

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wear rate by $15\% \pm 3\%$ and reduces toughness by $10\% \pm 2\%$.

Geometric angle

rock entry angle $30^\circ - 45^\circ \pm 5^\circ$ optimizes drilling efficiency (cutting force $< 15 \text{ kN} \pm 1 \text{ kN}$, energy consumption $< 60 \text{ kWh/m}^3 \pm 5 \text{ kWh/m}^3$), $> 50^\circ \pm 5^\circ$ reduces drilling capacity by $10\% \pm 2\%$, $< 30^\circ \pm 5^\circ$ easily leads to $5\% \pm 1\%$

risk of tooth collapse. **Surface treatment**

ball tooth thickness $3 - 6 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extension by $20\% \pm 3\%$), $< 3 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $> 6 \text{ mm} \pm 0.1$ The cost of mm increases by $15\% \pm 2\%$. TiN coating (thickness $0.5 - 1 \mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature $400 - 500^\circ\text{C} \pm 20^\circ\text{C}$) reduces the friction coefficient ($< 0.3 \pm 0.05$) and improves heat resistance ($> 700^\circ\text{C} \pm 20^\circ\text{C}$). The

heat-treated

base steel is quenched (hardness HRC $40 - 52 \pm 2$, depth $1.5 - 3 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850 - 900^\circ\text{C} \pm 20^\circ\text{C}$) to enhance the supporting performance, the life of the unquenched base is reduced by $15\% \pm 3\%$, and tempering ($200 - 250^\circ\text{C} \pm 10^\circ\text{C}$, $2 - 4 \text{ hours} \pm 0.5 \text{ hours}$) reduces the residual stress by $5\% \pm 1\%$. The moisture content

in the working environment

$> 20\% \pm 2\%$ or the sand content $> 10\% \pm 1\%$ increases the wear by $5\% \pm 1\%$, the temperature $> 700^\circ\text{C} \pm 50^\circ\text{C}$ reduces the hardness by $3\% \pm 1\%$, and the corrosion rate in the environment containing H_2S or CO_2 (concentration $> 0.1\% \pm 0.02\%$) increases to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$.

Equipment parameters such as

drilling pressure $50 - 300 \text{ kN} \pm 5 \text{ kN}$, speed $20 - 60 \text{ rpm} \pm 5 \text{ rpm}$, and torque $100 - 600 \text{ kN} \cdot \text{m} \pm 50 \text{ kN} \cdot \text{m}$ affect the life and efficiency of the ball teeth. Excessive parameters ($> \text{upper limit } 10\% \pm 1\%$) shorten the life by $15\% \pm 2\%$.

Carbide Drilling Rig Pile Foundation Buttons

Standard Buttons

are suitable for medium hardness rock (compressive strength $100 - 200 \text{ MPa}$), diameter $20 - 25 \text{ mm} \pm 1 \text{ mm}$, height $25 - 35 \text{ mm} \pm 2 \text{ mm}$, excellent wear resistance (life $> 500 \text{ hours} \pm 50 \text{ hours}$), commonly used in sandstone or medium weathered rock.

Reinforced Buttons

are suitable for hard rock (compressive strength $200 - 300 \text{ MPa}$), diameter $25 - 30 \text{ mm} \pm 1 \text{ mm}$, height $30 - 40 \text{ mm} \pm 2 \text{ mm}$, strong impact resistance ($> 100 \text{ J} \pm 10 \text{ J}$), suitable for basalt or granite.

Corrosion-resistant Buttons

are used in water-bearing or salt-bearing formations, with surface coating TiAlN (Cl^- resistance $> 3000 \text{ hours} \pm 100 \text{ hours}$), diameter $15 - 20 \text{ mm} \pm 1 \text{ mm}$, height $20 - 30 \text{ mm} \pm 2 \text{ mm}$, corrosion resistance $> 99\% \pm 1\%$, suitable for port pile foundations.

Special ball teeth

include low temperature resistant ($-50^\circ\text{C} \pm 5^\circ\text{C}$, wear resistance maintained at $90\% \pm 5\%$) and high temperature resistant ($> 900^\circ\text{C} \pm 20^\circ\text{C}$ maintained at $95\% \pm 2\%$) types, suitable for polar or high temperature formations.

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Application of

Carbide Rotary Drilling Rig Pile Foundation Ball Teeth High-rise buildings

are used for hard rock pile foundations (compressive strength 150-250 MPa), with a life of 500-700 hours $\pm$ 50 hours, supporting complex strata such as fault zones, in line with GB 50007 standards.

Bridge engineering

is used for river bridge pile foundations (compressive strength 200-300 MPa), with impact resistance (>50 J, peak $200 \text{ J} \pm 10 \text{ J}$) to ensure efficient drilling, in line with JTG 3362 standards.

Port construction

is used for submarine pile foundations, resistant to seawater corrosion (>4000 hours $\pm$ 100 hours, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$), meeting DNVGL-RP-C203 standards.

Deep foundation pit support

is used for strata with a compressive strength of 100-200 MPa, reducing settlement ($<5 \text{ mm} \pm 1 \text{ mm}$), in line with GB 50911 standards.

Polar Engineering

is used in low temperature environments ($-50^\circ\text{C} \pm 5^\circ\text{C}$), with wear resistance maintained at $90\% \pm 5\%$, and the drilling efficiency tested in 2025 at $10 \text{ m/h} \pm 1 \text{ m/h}$.

Technological progress and future development

New materials

introduce nano WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness ($\text{HV } 2200-2600 \pm 50$), add TaC and NbC to enhance high temperature stability ($>900^\circ\text{C} \pm 20^\circ\text{C}$ to maintain $95\% \pm 2\%$).

Intelligent monitoring

integrated sensor (accuracy $\pm 0.05\%$) real-time monitoring of wear (depth $>1.5 \text{ mm} \pm 0.05 \text{ mm}$) and vibration ($<15 \text{ m/s}^2 \pm 1 \text{ m/s}^2$), optimize replacement cycle (error $<5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40-60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex ball teeth, reducing material waste by $10\% \pm 2\%$.

Environmental adaptability

develops low temperature and high pressure resistant ball teeth (pressure resistance $>100 \text{ MPa} \pm 5 \text{ MPa}$).

Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 reduction $20\% \pm 3\%$) in compliance with ISO 14040 standards.

The relevant domestic and international standards

comply with GB 50007 (building foundations), JTG 3362 (highway bridges), GB 50911 (deep foundation pits) and DNVGL-RP-C203 (marine engineering rules).

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Carbide bolter tunnel boring ball teeth

The carbide bolter roadheader tunnel excavation ball teeth are a core excavation component designed for use in roadheaders (Roadheaders) in coal mines, tunnels and roadway construction. They are designed to crush hard rock formations, complex formations or coal-rock mixtures. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring high efficiency and reliability in high dust, high humidity and high vibration environments. As an important component of the cutting head of the bolter, the ball teeth directly affect the excavation efficiency, roadway quality and construction safety, and are widely used in coal mining, subway tunnels and mine construction. According to the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of the ball teeth.

cemented carbide bolter tunnel excavation ball teeth

Cemented carbide ball teeth use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\% - 3\% \pm 0.2\%$, NbC $0.5\% - 1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m} \pm 0.01 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the ball teeth is spherical or hemispherical, with a tip diameter of $15 - 25 \text{ mm} \pm 1 \text{ mm}$ and a height of $20 - 35 \text{ mm} \pm 2 \text{ mm}$. They are installed on the base of the bolter cutter head (made of high-strength alloy steel, such as 40CrMo or 42CrMo, with a quenching hardness of HRC $40 - 52 \pm 2$). The fixing methods include high-frequency induction welding (temperature $1200 - 1300^\circ\text{C} \pm 20^\circ\text{C}$, welding strength $>700 \text{ MPa} \pm 50 \text{ MPa}$) or mechanical embedding (embedding force $>10 \text{ kN} \pm 1 \text{ kN}$), ensuring stable operation under high torque ($200 - 800 \text{ kN} \cdot \text{m} \pm 50 \text{ kN} \cdot \text{m}$). Multi-layer coatings (such as TiN, TiAlN or CrN, with a thickness of $0.5 - 2 \mu\text{m} \pm 0.1 \mu\text{m}$) can be applied to the surface of the ball teeth to reduce the friction coefficient to $<0.25 \pm 0.05$, improve wear resistance and anti-adhesion (adhesion rate $<2\% \pm 0.5\%$). The design integrates cutting mechanics and stress distribution optimization. The ball tooth entry angle is $30^\circ - 45^\circ \pm 5^\circ$ and the back tilt angle is $5^\circ - 15^\circ \pm 2^\circ$. It is suitable for coal rock with a compressive strength of $50 - 250 \text{ MPa}$, soft rock with a water content of $>15\% \pm 5\%$, or special formations with a gas concentration of $>1\% \pm 0.2\%$.

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of cemented carbide bolter tunnel boring machine

WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C, oxidation resistance >95%±2%); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5), and absorbs impact energy (>50 J±5 J, instantaneous peak value >200 J±10 J). Fine grains and optimized microstructure, wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m (preferably <0.03 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶/°C±0.5×10⁻⁶/°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, H₂S resistance > 2500 hours±100 hours); TaC and NbC increase high temperature hardness (> 900 °C±20°C maintains 90%±2% of the initial hardness, thermal stability>95%±2%).

of the rotation of the bolter (speed 30-80 rpm±5 rpm, depending on the equipment power 300-1200 kW±50 kW) and cutting force (50-250 kN±5 kN, up to 400 kN±10 kN), the ball teeth cut into the coal rock or rock formation to form a crushing zone, and crush the material through extrusion (contact pressure 200-500 MPa±20 MPa) and shear (shear strength 60-120 MPa±5 MPa). The tip of the ball tooth bears the main wear and thermal load (surface temperature 500-800°C±50°C, instantaneously up to 1000°C±50°C), and the base steel provides structural support (tensile strength>1200 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life>10⁶ times±10⁵ times, cyclic load>250 MPa±20 MPa). The spherical design of the ball tooth reduces lateral stress (<100 MPa±10 MPa), optimizes slag removal efficiency (slag removal rate>90%±2%), and reduces the risk of dust accumulation<5%±1%.

In coal seams (compressive strength 50-100 MPa), sandstone (120-180 MPa), limestone (150-220 MPa) and shale (100-150 MPa), the optimized ball tooth life exceeds 400-600 hours ± 50 hours (depending on geological conditions), and the excavation efficiency reaches 5-15 m³/h ± 1 m³/h (up to 20 m³/h ± 1 m³/h, power >1000 kW±50 kW). SEM analysis shows no obvious cracking at the tip, wear depth <0.05 mm±0.01 mm (preferably <0.03 mm±0.01 mm), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (>95%±2%), and thermal imaging shows thermal stress distribution <150 MPa±10 MPa.

cemented carbide bolter tunnel boring teeth

Co content of

6%-12%±1% achieves the best balance between hardness and toughness, <6%±1% leads to an increase in crack rate of 10%±2%, >12%±1% reduces the hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶/°C±0.5×10⁻⁶/°C), and 8%-10%±0.5% is preferred to take into account both performance and cost.

Grain size

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0.5-1 $\mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $< 0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), 1-1.5 $\mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness rock, $> 2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by $15\% \pm 3\%$ and reduces toughness by $10\% \pm 2\%$.

Geometric angle

rock entry angle $30^\circ - 45^\circ \pm 5^\circ$ optimizes excavation efficiency (cutting force $< 15 \text{ kN} \pm 1 \text{ kN}$, energy consumption $< 50 \text{ kWh/m}^3 \pm 5 \text{ kWh/m}^3$), $> 50^\circ \pm 5^\circ$ reduces excavation capacity by $10\% \pm 2\%$, $< 30^\circ \pm 5^\circ$ easily leads to $5\% \pm 1\%$

risk of tooth collapse. **Surface treatment**

ball tooth thickness $3-6 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extended by $20\% \pm 3\%$), $< 3 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $> 6 \text{ mm} \pm 0.1 \text{ mm}$ The cost of mm increases by $15\% \pm 2\%$. TiN coating (thickness $0.5-1 \mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature $400-500^\circ\text{C} \pm 20^\circ\text{C}$) reduces the friction coefficient ($< 0.3 \pm 0.05$) and improves heat resistance ($> 700^\circ\text{C} \pm 20^\circ\text{C}$). The

heat-treated

base steel is quenched (hardness HRC $40-52 \pm 2$, depth $1.5-3 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850-900^\circ\text{C} \pm 20^\circ\text{C}$) to enhance the supporting performance. The life of the unquenched base is reduced by $15\% \pm 3\%$. Tempering ($200-250^\circ\text{C} \pm 10^\circ\text{C}$, 2-4 hours ± 0.5 hours) reduces the residual stress by $5\% \pm 1\%$. The moisture content

in the working environment

$> 15\% \pm 2\%$ or the dust content $> 10\% \pm 1\%$ increases the wear by $5\% \pm 1\%$. The temperature $> 700^\circ\text{C} \pm 50^\circ\text{C}$ reduces the hardness by $3\% \pm 1\%$. The corrosion rate in the environment containing H_2S or CO_2 (concentration $> 0.1\% \pm 0.02\%$) increases to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$. The environment containing gas requires explosion resistance ($> 2 \text{ bar} \pm 0.2 \text{ bar}$).

Equipment parameters:

cutting speed $0.5-2 \text{ m/min} \pm 0.1 \text{ m/min}$, torque $200-800 \text{ kN} \cdot \text{m} \pm 50 \text{ kN} \cdot \text{m}$, power $300-1200 \text{ kW} \pm 50 \text{ kW}$ affect the life and efficiency of the ball gear. Excessive parameters ($>$ upper limit $10\% \pm 1\%$) shorten the life by $15\% \pm 2\%$.

carbide bolter tunnel excavation ball teeth

Standard ball teeth

are suitable for coal seams or soft rocks (compressive strength $50-100 \text{ MPa}$), with a diameter of $15-20 \text{ mm} \pm 1 \text{ mm}$, a height of $20-25 \text{ mm} \pm 2 \text{ mm}$, excellent wear resistance (lifetime $> 400 \text{ hours} \pm 50 \text{ hours}$), and are commonly used in coal mine tunnels. In 2024, the excavation efficiency of a coal mine project was $10 \text{ m}^3 / \text{h} \pm 1 \text{ m}^3 / \text{h}$.

Reinforced ball teeth

are suitable for hard rocks (compressive strength $150-250 \text{ MPa}$), with a diameter of $20-25 \text{ mm} \pm 1 \text{ mm}$, a height of $25-35 \text{ mm} \pm 2 \text{ mm}$, strong impact resistance ($> 100 \text{ J} \pm 10 \text{ J}$), and are suitable for sandstone or limestone. In 2023, the life of a tunnel project was $500 \text{ hours} \pm 50 \text{ hours}$.

Corrosion-resistant ball teeth

are used in water-bearing or gas-bearing formations, with a surface coating of TiAlN (resistant to H_2S $> 2500 \text{ hours} \pm 100 \text{ hours}$), a diameter of $15-18 \text{ mm} \pm 1 \text{ mm}$, a height of $20-30 \text{ mm} \pm 2 \text{ mm}$, and a corrosion resistance of $> 98\% \pm 1\%$, suitable for wet tunnels. In 2025, a mine will withstand a water pressure of $1 \text{ MPa} \pm 0.1 \text{ MPa}$.

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Special ball teeth

include low-temperature resistant ($-20^{\circ}\text{C}\pm 5^{\circ}\text{C}$, wear resistance remains at $90\%\pm 5\%$) and high-temperature resistant ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ remains at $95\%\pm 2\%$) types, suitable for polar mines or high-temperature formations, with a test life of $550\text{ hours}\pm 50\text{ hours}$ in 2025.

carbide bolter tunnel excavation teeth

Coal mine tunnels

are used for coal seam excavation (compressive strength 50-100 MPa), with a service life of 400-600 hours ± 50 hours, supporting gas-containing strata (concentration $> 1\% \pm 0.2\%$), in accordance with MT 554 standards. In 2024, the excavation depth of a coal mine in Shanxi was $500\text{ m} \pm 50\text{ m}$.

Subway tunnels

are used in hard rock tunnels (compressive strength 150-250 MPa), and the impact resistance ($> 50\text{ J}$, peak $200\text{ J} \pm 10\text{ J}$) ensures efficient excavation, in accordance with EN 1997-1 standards. In 2023, the excavation speed of the Shanghai Metro project was $1\text{ m/min} \pm 0.1\text{ m/min}$.

Mine support

is used in strata with a compressive strength of 100-200 MPa, reducing the risk of collapse ($< 5\% \pm 1\%$), and meeting GB 16423 standards. In 2024, the stability of a mine tunnel is $>98\%\pm 1\%$.

The hydrological tunnel

is used in water-bearing strata, resistant to water erosion ($>2000\text{ hours}\pm 100\text{ hours}$), in line with IEC 60041 standard. In 2025, the water pressure resistance of a hydropower station project is $1.2\text{ MPa}\pm 0.1\text{ MPa}$.

Complex strata

are used in fault zones or sandy strata, with abrasion resistance $>95\%\pm 2\%$. In 2025, the excavation efficiency was tested to be $12\text{ m}^3/\text{h} \pm 1\text{ m}^3/\text{h}$.

Technological progress and future development

New materials

introduce nano WC (grain $<0.5\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$) to improve hardness ($\text{HV } 2200\text{-}2600\pm 50$), add TaC and NbC to enhance high temperature stability ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ to maintain $95\%\pm 2\%$). Research in 2024: Anti-oxidation of

ZrC coating (oxygen weight gain $<0.15\%\pm 0.05\%/\text{h}$). **Intelligent monitoring**

integrated sensor (accuracy $\pm 0.05\%$) real-time monitoring of wear (depth $>1.5\text{ mm}\pm 0.05\text{ mm}$) and vibration ($<15\text{ m/s}^2 \pm 1\text{ m/s}^2$), optimize replacement cycle (error $<5\%\pm 1\%$), and a company successfully tested it in 2025.

3D printing technology

uses SLM (layer thickness $40\text{-}60\text{ }\mu\text{m}\pm 5\text{ }\mu\text{m}$) to manufacture complex ball teeth, reducing material waste by $10\%\pm 2\%$, and the strength will reach $1400\text{ MPa}\pm 50\text{ MPa}$ in 2024.

Environmental adaptability:

Develop low-temperature and high-pressure resistant ball teeth (pressure resistance $> 80\text{ MPa} \pm 5\text{ MPa}$), with pressure resistance reaching $97\% \pm 2\%$ in 2025.

Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 reduction of $20\% \pm 3\%$), in compliance with ISO 14040 standards.

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Domestic and international standards Domestic and international standards comply with MT 554 (coal mine safety), EN 1997-1 (European foundations), GB 16423 (mine support) and IEC 60079 (explosive atmospheres). In 2025, new anti-gas standards will be added.



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Carbide Road Milling Machine Milling Teeth

Carbide road milling machine milling teeth are a high-efficiency cutting tool designed for road milling machines (Cold Planer) to process asphalt concrete, crushed stone base or aged road surfaces. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coating, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring high efficiency and reliability under high load, high temperature and high dust environment. As a key component of the road milling machine drum, the milling teeth directly affect the milling efficiency, road surface flatness and construction cost, and are widely used in highway maintenance, airport runway renovation and urban road maintenance. According to the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of milling teeth.

Physical and Chemical Properties of Cemented Carbide Road Milling Machine Milling Teeth

Cemented carbide milling teeth use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the milling teeth is usually pointed or rounded, with a tip diameter of $10-20\text{ mm} \pm 1\text{ mm}$ and a height of $20-40\text{ mm} \pm 2\text{ mm}$, mounted on a drum substrate (made of high-strength alloy steel, such as 40CrMo or 42CrMo, with a quenching hardness of HRC $40-52 \pm 2$). The fixing methods include high-frequency induction welding (temperature $1200-1300^\circ\text{C} \pm 20^\circ\text{C}$, welding strength $>700\text{ MPa} \pm 50\text{ MPa}$) or mechanical clamping (clamping force $>10\text{ kN} \pm 1\text{ kN}$), ensuring stable operation under high torque ($500-1500\text{ kN}\cdot\text{m} \pm 50\text{ kN}\cdot\text{m}$). Multi-layer coatings (such as TiN, TiAlN or CrN, thickness $0.5-2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the surface of the tooth tip, reducing the friction coefficient to $<0.25 \pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<2\% \pm 0.5\%$). The design integrates cutting mechanics and heat conduction optimization, with a tooth tip cutting angle of $20^\circ-40^\circ \pm 5^\circ$ and a back rake angle of $5^\circ-15^\circ \pm 2^\circ$. It is suitable for asphalt layers (compressive strength $5-15\text{ MPa}$), cement concrete ($20-50\text{ MPa}$) and mixed base layers.

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Characteristics of carbide road milling machine milling teeth

WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C, oxidation resistance >95%±2%); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5), and absorbs impact energy (>50 J±5 J, instantaneous peak value >200 J±10 J). Fine grains and optimized microstructure, wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m (preferably <0.03 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶/°C±0.5×10⁻⁶/°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), improving corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, Cl⁻ resistance > 3000 hours ±100 hours); TaC and NbC increase high temperature hardness (>900°C±20°C maintains 90%±2% of initial hardness, thermal stability >95%±2%).

Working principle of cemented carbide road milling machine milling teeth

of the road milling machine drum rotation (speed 100-300 rpm±10 rpm, depending on the equipment power 200-1000 kW±50 kW) and cutting force (50-200 kN±5 kN, up to 300 kN±10 kN), the milling teeth cut into the road surface to form a continuous milling surface, and crush the asphalt or concrete through extrusion (contact pressure 150-400 MPa±20 MPa) and shear (shear strength 50-100 MPa±5 MPa). The tooth tip bears the main wear and thermal load (surface temperature 400-700°C±50°C, instantaneously up to 900°C±50°C), the base steel provides structural support (tensile strength>1200 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life>10⁶ times±10⁵ times, cyclic load>200 MPa±20 MPa). The pointed design of the tooth tip optimizes cutting efficiency (milling depth 5-15 cm±1 cm), and the rounded design reduces vibration (acceleration <10 m/s² ± 1 m/s²).

Under the conditions of asphalt pavement (compressive strength 5-10 MPa), cement concrete (20-40 MPa) and mixed base (10-20 MPa), the optimized milling tooth life exceeds 300-500 hours ± 50 hours (depending on the hardness of the material), and the milling efficiency reaches 200-500 m²/h ± 20 m²/h (up to 600 m²/h ± 20 m²/h, power >800 kW±50 kW). SEM analysis shows no obvious cracking of the tooth tip, wear depth <0.05 mm±0.01 mm (preferably <0.03 mm±0.01 mm), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (>95%±2%), and thermal imaging shows that the thermal stress distribution is <120 MPa±10 MPa.

Factors affecting the performance of cemented carbide road milling machine milling teeth Co content of

6%-12%±1% achieves the best balance between hardness and toughness, <6%±1% leads to an increase in crack rate of 10%±2%, >12%±1% reduces the hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶/°C±0.5×10⁻⁶/°C), and 8%-10%±0.5% is preferred to take into account both performance and cost.

Grain size

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$0.5\text{--}1\ \mu\text{m}\pm 0.01\ \mu\text{m}$ effectively reduces wear and microcracks (wear rate $<0.03\ \text{mm}^3 / \text{N} \cdot \text{m} \pm 0.01\ \text{mm}^3 / \text{N} \cdot \text{m}$), $1\text{--}1.5\ \mu\text{m}\pm 0.01\ \mu\text{m}$ is suitable for medium hardness roads, $>2\ \mu\text{m}\pm 0.01\ \mu\text{m}$ increases wear rate by $15\%\pm 3\%$ and reduces toughness by $10\%\pm 2\%$.

Geometric angle

cutting angle $20^\circ\text{--}40^\circ\pm 5^\circ$ optimizes milling efficiency (cutting force $<15\ \text{kN}\pm 1\ \text{kN}$, energy consumption $<20\ \text{kWh}/\text{m}^3 \pm 2\ \text{kWh}/\text{m}^3$), $>45^\circ\pm 5^\circ$ reduces efficiency by $10\%\pm 2\%$, $<20^\circ\pm 5^\circ$ easily leads to $5\%\pm 1\%$ risk of tooth collapse.

Surface treatment

tooth tip thickness $3\text{--}5\ \text{mm}\pm 0.1\ \text{mm}$ improves wear resistance (life extension by $20\%\pm 3\%$), $<3\ \text{mm}\pm 0.1\ \text{mm}$ shortens life by $20\%\pm 3\%$, $>5\ \text{mm}\pm 0.1\ \text{mm}$ The cost of mm increases by $15\%\pm 2\%$. TiN coating (thickness $0.5\text{--}1\ \mu\text{m}\pm 0.1\ \mu\text{m}$, deposition temperature $400\text{--}500^\circ\text{C}\pm 20^\circ\text{C}$) reduces the friction coefficient ($<0.3\pm 0.05$) and improves heat resistance ($>700^\circ\text{C}\pm 20^\circ\text{C}$). The

heat-treated

base steel is quenched (hardness HRC $40\text{--}52\pm 2$, depth $1.5\text{--}3\ \text{mm}\pm 0.2\ \text{mm}$, quenching temperature $850\text{--}900^\circ\text{C}\pm 20^\circ\text{C}$) to enhance the supporting performance, the unquenched base life is reduced by $15\%\pm 3\%$, and tempering ($200\text{--}250^\circ\text{C}\pm 10^\circ\text{C}$, $2\text{--}4\ \text{hours}\pm 0.5\ \text{hours}$) reduces the residual stress by $5\%\pm 1\%$.

The working environment

temperature $>600^\circ\text{C}\pm 50^\circ\text{C}$ reduces the hardness by $3\%\pm 1\%$, the water content $>10\%\pm 2\%$ or the sand content $>5\%\pm 1\%$ increases the wear by $5\%\pm 1\%$, and the Cl^- - containing environment (concentration $>0.5\%\pm 0.1\%$) increases the corrosion rate to $0.015\ \text{mm}/\text{year}\pm 0.002\ \text{mm}/\text{year}$.

Equipment parameters

: milling speed $0.5\text{--}2\ \text{m}/\text{min}\pm 0.1\ \text{m}/\text{min}$, torque $500\text{--}1500\ \text{kN}\cdot\text{m}\pm 50\ \text{kN}\cdot\text{m}$, power $200\text{--}1000\ \text{kW}\pm 50\ \text{kW}$ affect tooth life and efficiency. Too high parameters ($>$ upper limit $10\%\pm 1\%$) shorten life by $15\%\pm 2\%$.

Types of carbide road milling machine milling teeth

Standard milling teeth

are suitable for asphalt pavement (compressive strength $5\text{--}10\ \text{MPa}$), with a diameter of $12\text{--}15\ \text{mm}\pm 1\ \text{mm}$, a height of $20\text{--}25\ \text{mm}\pm 2\ \text{mm}$, excellent wear resistance (lifespan $>350\ \text{hours}\pm 50\ \text{hours}$), and are commonly used in highway maintenance.

The reinforced milling teeth

are suitable for cement concrete (compressive strength $20\text{--}50\ \text{MPa}$), with a diameter of $15\text{--}20\ \text{mm}\pm 1\ \text{mm}$, a height of $25\text{--}40\ \text{mm}\pm 2\ \text{mm}$, strong impact resistance ($>100\ \text{J}\pm 10\ \text{J}$), and are suitable for airport runways.

Corrosion-resistant milling teeth

are used for salty or water-containing roads, with surface coating TiAlN (Cl^- resistance $>3000\ \text{hours}\pm 100\ \text{hours}$), diameter $10\text{--}12\ \text{mm}\pm 1\ \text{mm}$, height $20\text{--}30\ \text{mm}\pm 2\ \text{mm}$, corrosion resistance $>99\%\pm 1\%$, suitable for coastal roads.

Special milling teeth

include high temperature resistant ($>900^\circ\text{C}\pm 20^\circ\text{C}$ maintain $95\%\pm 2\%$) and wear resistant types, suitable for high temperature or highly abrasive roads.

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Application of carbide road milling machine milling teeth

Highway maintenance

is used for asphalt pavement milling (compressive strength 5-15 MPa), with a service life of 350-500 hours $\pm$ 50 hours, in line with JTJ 073 standards.

Airport runway

is used for cement concrete renovation (compressive strength 20-50 MPa), impact resistance (> 50 J, peak $200 \text{ J} \pm 10 \text{ J}$) to ensure efficient milling, in line with ICAO Annex 14 standards.

Urban roads

are used for mixed base (compressive strength 10-20 MPa), reduce dust ($< 5\% \pm 1\%$), and meet GB/T 23458 standards.

The coastal highway

is used for salty pavement, resistant to seawater corrosion (> 4000 hours $\pm$ 100 hours, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$), and complies with DNVGL-RP-C203 standard.

The special pavement is used for high temperature or high abrasion pavement, with a wear resistance of $> 95\% \pm 2\%$, and a milling efficiency of 400

$\text{m}^2 / \text{h} \pm 20 \text{ m}^2 / \text{h}$ in 2025 .

Development of carbide road milling machine milling teeth

New materials

introduce nano WC (grain $< 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness ($\text{HV } 2200\text{-}2600 \pm 50$), add TaC and NbC to enhance high temperature stability ($> 900^\circ\text{C} \pm 20^\circ\text{C}$ to maintain $95\% \pm 2\%$).

Intelligent monitoring

integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth $> 1.5 \text{ mm} \pm 0.05 \text{ mm}$) and vibration ($< 10 \text{ m/s}^2 \pm 1 \text{ m/s}^2$) in real time , and optimize replacement cycles (error $< 5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex tooth shapes, reducing material waste by $10\% \pm 2\%$.

Environmental adaptability

Development of high temperature and corrosion resistant teeth (pressure resistance $> 50 \text{ MPa} \pm 5 \text{ MPa}$), with heat resistance reaching $98\% \pm 2\%$ in 2025.

Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) to reduce carbon footprint (CO_2 reduction of $20\% \pm 3\%$), in compliance with ISO 14040 standards.

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Carbide cold recycling machine cutting teeth

The carbide cold recycler cutting teeth are a high-efficiency cutting tool designed specifically for cold recyclers (Cold Recycler), intended to process old asphalt pavements, base materials or mixed strata for on-site cold regeneration construction. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring high efficiency and reliability under high load, high humidity and high abrasion environments. As a key component of the cold recycler drum, the cutting teeth directly affect the regeneration efficiency, material uniformity and construction cost, and are widely used in highway maintenance, rural road renovation and industrial site leveling. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of the cutting teeth.

Physical and Chemical Properties of Cemented Carbide Cold Recycling Machine Cutting Teeth

Cemented carbide cutting teeth use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase and cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the cutting teeth is usually pointed or conical, with a tip diameter of $10-18\text{ mm} \pm 1\text{ mm}$ and a height of $20-35\text{ mm} \pm 2\text{ mm}$, mounted on a roller base (made of high-strength alloy steel, such as 40CrMo or 42CrMo, with a quenching hardness of HRC $40-52 \pm 2$). The fixing methods include high-frequency induction welding (temperature $1200-1300^\circ\text{C} \pm 20^\circ\text{C}$, welding strength $>700\text{ MPa} \pm 50\text{ MPa}$) or mechanical clamping (clamping force $>10\text{ kN} \pm 1\text{ kN}$), ensuring stable operation under high torque ($400-1200\text{ kN}\cdot\text{m} \pm 50\text{ kN}\cdot\text{m}$). Multi-layer coatings (such as TiN, TiAlN or CrN, with a thickness of $0.5-2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the surface of the tooth tip, reducing the friction coefficient to $<0.25 \pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<2\% \pm 0.5\%$). The design integrates cutting mechanics and heat conduction optimization, with a tooth tip cutting angle of $20^\circ-40^\circ \pm 5^\circ$ and a back rake angle of $5^\circ-15^\circ \pm 2^\circ$. It is suitable for asphalt layers (compressive strength $5-15\text{ MPa}$), gravel base layers ($10-30\text{ MPa}$) and

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water-containing mixed strata.

Characteristics of cutting teeth of cemented carbide cold regeneration machine

WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C, oxidation resistance >95%±2%); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5), and absorbs impact energy (>50 J±5 J, instantaneous peak value >200 J±10 J). Fine grains and optimized microstructure, wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m (preferably <0.03 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, Cl⁻ resistance > 3000 hours ±100 hours); TaC and NbC increase high temperature hardness (> 900 °C±20°C maintains 90%±2% of initial hardness, thermal stability >95%±2%).

Working principle of carbide cold recycler

cutting teeth: Under the action of cold recycler drum rotation (speed 80-250 rpm±10 rpm, depending on equipment power 200-800 kW±50 kW) and cutting force (50-150 kN±5 kN, up to 250 kN±10 kN), the cutting teeth cut into the old pavement or base to form recycled materials, and crush the asphalt or gravel through extrusion (contact pressure 150-350 MPa±20 MPa) and shear (shear strength 40-80 MPa±5 MPa). The tooth tip bears the main wear and thermal load (surface temperature 400-600°C±50°C, instantaneously up to 800°C±50°C), the base steel provides structural support (tensile strength>1200 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life>10⁶ times±10⁵ times, cyclic load>200 MPa±20 MPa). The pointed design of the tooth tip optimizes cutting efficiency (regeneration depth 5-20 cm±1 cm), and the conical design reduces vibration (acceleration <10 m/s² ± 1 m/s²).

The performance of the carbide cold regeneration machine cutting teeth is that

the optimized cutting teeth have a life of more than 300-450 hours ± 50 hours (depending on the hardness of the material) under the conditions of asphalt pavement (compressive strength 5-10 MPa), crushed stone base (10-20 MPa) and water-containing mixed layer (5-15 MPa), and the regeneration efficiency reaches 150-400 m²/h ± 20 m²/h (up to 500 m²/h ± 20 m²/h, power>600 kW±50 kW). SEM analysis shows that there is no obvious cracking at the tooth tip, the wear depth is <0.05 mm±0.01 mm (preferably <0.03 mm±0.01 mm), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (>95%±2%), and thermal imaging shows that the thermal stress distribution is <120 MPa±10 MPa.

Factors affecting the performance of

cemented carbide cold regeneration machine cutting teeth The Co content of

6%-12%±1% achieves the best balance between hardness and toughness, <6%±1% leads to an

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increase in crack rate of $10\% \pm 2\%$, $>12\% \pm 1\%$ reduces the hardness by $5\% \pm 1\%$ and increases thermal expansion (CTE $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$), and $8\% - 10\% \pm 0.5\%$ is preferred to take into account both performance and cost.

Grain size

$0.5 - 1 \mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $< 0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), $1 - 1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness roads, $> 2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by $15\% \pm 3\%$ and reduces toughness by $10\% \pm 2\%$.

Geometric angle

cutting angle $20^\circ - 40^\circ \pm 5^\circ$ optimizes regeneration efficiency (cutting force $< 15 \text{ kN} \pm 1 \text{ kN}$, energy consumption $< 15 \text{ kWh/m}^3 \pm 2 \text{ kWh/m}^3$), $> 45^\circ \pm 5^\circ$ reduces efficiency by $10\% \pm 2\%$, $< 20^\circ \pm 5^\circ$ easily leads to $5\% \pm 1\%$ risk of tooth collapse.

Surface treatment

tooth tip thickness $3 - 5 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extension by $20\% \pm 3\%$), $< 3 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $> 5 \text{ mm} \pm 0.1$ The cost of mm increases by $15\% \pm 2\%$. TiN coating (thickness $0.5 - 1 \mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature $400 - 500^\circ\text{C} \pm 20^\circ\text{C}$) reduces the friction coefficient ($< 0.3 \pm 0.05$) and improves heat resistance ($> 700^\circ\text{C} \pm 20^\circ\text{C}$). The

heat-treated

base steel is quenched (hardness HRC $40 - 52 \pm 2$, depth $1.5 - 3 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850 - 900^\circ\text{C} \pm 20^\circ\text{C}$) to enhance the supporting performance, the unquenched base life is reduced by $15\% \pm 3\%$, and tempering ($200 - 250^\circ\text{C} \pm 10^\circ\text{C}$, $2 - 4 \text{ hours} \pm 0.5 \text{ hours}$) reduces the residual stress by $5\% \pm 1\%$.

The working environment

moisture content $> 15\% \pm 2\%$ or sand content $> 5\% \pm 1\%$ increases wear by $5\% \pm 1\%$, the temperature $> 600^\circ\text{C} \pm 50^\circ\text{C}$ reduces the hardness by $3\% \pm 1\%$, and the Cl^- - containing environment (concentration $> 0.5\% \pm 0.1\%$) increases the corrosion rate to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$.

Equipment parameters

regeneration speed $0.3 - 1.5 \text{ m/min} \pm 0.1 \text{ m/min}$, torque $400 - 1200 \text{ kN} \cdot \text{m} \pm 50 \text{ kN} \cdot \text{m}$, power $200 - 800 \text{ kW} \pm 50 \text{ kW}$ affect the tooth life and efficiency. Too high parameters ($> \text{upper limit } 10\% \pm 1\%$) shorten the life by $15\% \pm 2\%$.

Types of carbide cold regeneration machine cutting teeth

Standard cutting teeth

are suitable for asphalt pavement (compressive strength $5 - 10 \text{ MPa}$), with a diameter of $12 - 15 \text{ mm} \pm 1 \text{ mm}$, a height of $20 - 25 \text{ mm} \pm 2 \text{ mm}$, excellent wear resistance (lifespan $> 350 \text{ hours} \pm 50 \text{ hours}$), and are commonly used for highway regeneration.

The reinforced cutting teeth

are suitable for crushed stone bases (compressive strength $10 - 30 \text{ MPa}$), with a diameter of $15 - 18 \text{ mm} \pm 1 \text{ mm}$, a height of $25 - 35 \text{ mm} \pm 2 \text{ mm}$, strong impact resistance ($> 100 \text{ J} \pm 10 \text{ J}$), and are suitable for industrial sites.

The corrosion-resistant cutting teeth

are used in water-bearing or salt-bearing strata, with a surface coating of TiAlN (Cl^- resistance $> 3000 \text{ hours} \pm 100 \text{ hours}$), a diameter of $10 - 12 \text{ mm} \pm 1 \text{ mm}$, a height of $20 - 30 \text{ mm} \pm 2 \text{ mm}$, and a

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corrosion resistance of $>99\% \pm 1\%$, suitable for coastal roads.

Special cutting teeth

include high temperature resistant ($>900^{\circ}\text{C} \pm 20^{\circ}\text{C}$ maintain $95\% \pm 2\%$) and wear resistant types, suitable for highly abrasive or impure roads .

Application of carbide cold regenerator cutting teeth

Highway maintenance

is used for asphalt pavement regeneration (compressive strength 5-15 MPa), life 350-450 hours $\pm$ 50 hours, in line with JTJ 073 standard.

Rural roads

are used for gravel base renovation (compressive strength 10-20 MPa), impact resistance ($> 50 \text{ J}$, peak $200 \text{ J} \pm 10 \text{ J}$) to ensure efficient regeneration, in line with GB/T 23458 standard.

Industrial sites

are used for impure strata (compressive strength 10-30 MPa), reduce dust ($<5\% \pm 1\%$), and meet ISO 10816 standards. **Coastal roads**

are used for salt-containing bases, resist seawater corrosion ($>4000 \text{ hours} \pm 100 \text{ hours}$, Cl^{-} concentration resistance $> 3.5\% \pm 0.5\%$), and meet DNVGL-RP-C203 standards.

Complex strata

are used on water-containing or highly abrasive roads, with a wear resistance of $>95\% \pm 2\%$.



Carbide concrete crushing teeth

Carbide concrete crushing teeth are durable cutting tools designed for concrete crushers or hydraulic breakers, designed to efficiently crush reinforced concrete, precast panels or hardened cement structures. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring high efficiency and reliability in high-impact, high-temperature and high-dust environments. As a key component of crushing equipment, crushing teeth directly affect crushing efficiency, particle uniformity and construction safety, and are widely used in building demolition, road renovation and industrial waste treatment. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of crushing teeth.

Physical and chemical properties of cemented carbide concrete crushing teeth

Cemented carbide crushing teeth use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the

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local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the crushing teeth is usually conical or flat, with a tip diameter of 12-20 mm ± 1 mm and a height of 25-40 mm ± 2 mm, installed on the crushing hammer or crushing head base (made of high-strength alloy steel, such as 40CrMo or 42CrMo, quenching hardness HRC 40-52 ± 2). The fixing methods include high-frequency induction welding (temperature 1200-1300°C ± 20 °C, welding strength >800 MPa ± 50 MPa) or mechanical embedding (embedding force >12 kN ± 1 kN), ensuring stable operation under high impact force (50-300 kN ± 5 kN, peak value up to 500 kN ± 10 kN). The tooth tip surface can be coated with multiple layers of coating (such as TiN, TiAlN or CrN, thickness 0.5-2 $\mu\text{m} \pm 0.1$ μm), the friction coefficient is reduced to $<0.25 \pm 0.05$, and the wear resistance and anti-adhesion (adhesion rate $<2\% \pm 0.5\%$) are improved. The design integrates impact mechanics and heat conduction optimization, the tooth tip cutting angle is 25°-45° $\pm 5^\circ$, the back angle is 5°-15° $\pm 2^\circ$, and it is suitable for reinforced concrete or hardened cement with a compressive strength of 20-80 MPa.

Material properties of carbide concrete crushing teeth

WC provides high hardness (HV 1800-2200 ± 30 , locally up to 2400-2600 ± 50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^\circ\text{C} \pm 20^\circ\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness (K_{IC} 12-16 MPa $\cdot\text{m}^{1/2} \pm 0.5$, peak value up to 18 MPa $\cdot\text{m}^{1/2} \pm 0.5$) through solid solution strengthening and plastic deformation, and absorbs impact energy (>100 J ± 10 J, instantaneous peak value >300 J ± 20 J). Fine grains and optimized microstructure, wear rate <0.05 mm³/N $\cdot\text{m} \pm 0.01$ mm³/N $\cdot\text{m}$ (preferably <0.03 mm³/N $\cdot\text{m} \pm 0.01$ mm³/N $\cdot\text{m}$), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10^{-6} /°C $\pm 0.5 \times 10^{-6}$ /°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 $\mu\text{m} \pm 0.01$ μm), which improves corrosion resistance (corrosion rate <0.01 mm/year ± 0.001 mm/year, Cl⁻ resistance >3000 hours ± 100 hours); TaC and NbC increase high temperature hardness ($>900^\circ\text{C} \pm 20^\circ\text{C}$ maintains 90% $\pm 2\%$ of initial hardness, thermal stability $>95\% \pm 2\%$).

Working principle of carbide concrete crushing teeth

the high-frequency impact (impact frequency 10-50 Hz ± 2 Hz, depending on the equipment power 100-600 kW ± 50 kW) and impact force (50-300 kN ± 5 kN) of the hydraulic breaker or crusher, the crushing teeth cut into the concrete to form broken particles, and destroy the reinforced concrete structure through squeezing (contact pressure 300-600 MPa ± 20 MPa) and splitting (splitting force 100-200 kN ± 10 kN). The tooth tip bears the main wear and thermal load (surface temperature 500-800°C $\pm 50^\circ\text{C}$, instantaneously up to 1000°C $\pm 50^\circ\text{C}$), the base steel provides structural support (tensile strength >1200 MPa ± 50 MPa), heat conduction (thermal conductivity 40-50 W/m $\cdot\text{K} \pm 2$ W/m $\cdot\text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load >300 MPa ± 20 MPa). The conical design of the tooth tip optimizes impact efficiency (crushing depth 5-30 cm ± 2 cm), and the flat design enhances resistance to lateral stress (<150 MPa ± 10 MPa).

Performance of Carbide Concrete Crushing Teeth

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Under the conditions of reinforced concrete (compressive strength 30-60 MPa), precast panels (40-80 MPa) and hardened cement (20-50 MPa), the optimized crushing teeth have a life of more than 250-400 hours $\pm$ 50 hours (depending on the hardness of the material), and a crushing efficiency of 50-150 m³ / h $\pm$ 5 m³ / h (up to 200 m³ / h $\pm$ 5 m³ / h, power >500 kW $\pm$ 50 kW). SEM analysis shows no obvious cracking of the tooth tip, wear depth <0.05 mm $\pm$ 0.01 mm (preferably <0.03 mm $\pm$ 0.01 mm), X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (>95% $\pm$ 2%), and thermal imaging shows that the thermal stress distribution is <150 MPa $\pm$ 10 MPa.

Factors affecting the performance of cemented carbide concrete crushing teeth

The Co content of

6%-12% $\pm$ 1% achieves the best balance between hardness and toughness. <6% $\pm$ 1% leads to a 10% $\pm$ 2% increase in crack rate, >12% $\pm$ 1% reduces the hardness by 5% $\pm$ 1% and increases thermal expansion (CTE 6×10^{-6} /°C $\pm$ 0.5 $\times 10^{-6}$ /°C). 8%-10% $\pm$ 0.5% is preferred to balance performance and cost.

Grain size

0.5-1 μ m $\pm$ 0.01 μ m effectively reduces wear and microcracks (wear rate <0.03 mm³ / N $\cdot$ m $\pm$ 0.01 mm³ / N $\cdot$ m) , 1-1.5 μ m $\pm$ 0.01 μ m is suitable for medium hardness concrete, >2 μ m $\pm$ 0.01 μ m increases wear rate by 15% $\pm$ 3% and reduces toughness by 10% $\pm$ 2%.

Geometric angle

cutting angle 25°-45° $\pm$ 5° optimizes crushing efficiency (impact force <20 kN $\pm$ 1 kN , energy consumption <30 kWh/m³ $\pm$ 2 kWh/m³) , >50° $\pm$ 5° reduces efficiency by 10% $\pm$ 2%, <25° $\pm$ 5° easily leads to 5% $\pm$ 1% risk of tooth collapse .

Surface treatment

tooth tip thickness 3-6 mm $\pm$ 0.1 mm improves wear resistance (life extension by 20% $\pm$ 3%), <3 mm $\pm$ 0.1 mm shortens life by 20% $\pm$ 3%, >6 mm $\pm$ 0.1 mm The cost of mm increases by 15% $\pm$ 2%. TiN coating (thickness 0.5-1 μ m $\pm$ 0.1 μ m , deposition temperature 400-500°C $\pm$ 20°C) reduces the friction coefficient (<0.3 $\pm$ 0.05) and improves heat resistance (>700°C $\pm$ 20°C). The

heat-treated

base steel is quenched (hardness HRC 40-52 $\pm$ 2, depth 1.5-3 mm $\pm$ 0.2 mm, quenching temperature 850-900°C $\pm$ 20°C) to enhance the supporting performance, the unquenched base life is reduced by 15% $\pm$ 3%, and tempering (200-250°C $\pm$ 10°C, 2-4 hours $\pm$ 0.5 hours) reduces the residual stress by 5% $\pm$ 1%.

The working environment

temperature>700°C $\pm$ 50°C reduces the hardness by 3% $\pm$ 1%, the water content>10% $\pm$ 2% or the steel content>5% $\pm$ 1% increases the wear by 5% $\pm$ 1%, and the Cl⁻ - containing environment (concentration>0.5% $\pm$ 0.1%) increases the corrosion rate to 0.015 mm/year $\pm$ 0.002 mm/year.

Equipment parameters

impact frequency 10-50 Hz $\pm$ 2 Hz, impact force 50-300 kN $\pm$ 5 kN , power 100-600 kW $\pm$ 50 kW affect the life and efficiency of the gear. Too high parameters (>upper limit 10% $\pm$ 1%) shorten the life by 15% $\pm$ 2%.

Types of Carbide Concrete Crusher Teeth

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Standard crushing teeth

are suitable for ordinary concrete (compressive strength 20-40 MPa), with a diameter of 12-15 mm $\pm$ 1 mm, a height of 25-30 mm $\pm$ 2 mm, excellent wear resistance (lifespan>300 hours $\pm$ 50 hours), and are often used in building demolition.

The enhanced crushing teeth

are suitable for reinforced concrete (compressive strength 40-80 MPa), with a diameter of 15-20 mm $\pm$ 1 mm, a height of 30-40 mm $\pm$ 2 mm, strong impact resistance (>150 J $\pm$ 10 J), and are suitable for bridge demolition.

Corrosion-resistant crushing teeth

are used for salt-containing or water-containing concrete, with surface coating TiAlN (Cl⁻ resistance >3000 hours $\pm$ 100 hours), diameter 12-15 mm $\pm$ 1 mm, height 25-35 mm $\pm$ 2 mm, corrosion resistance > 99% $\pm$ 1%, suitable for coastal buildings.

Special crushing teeth

include high temperature resistant (>900°C $\pm$ 20°C maintain 95% $\pm$ 2%) and wear resistant types, suitable for high temperature or high reinforced density concrete.

Application of Carbide Concrete Crushing Teeth

Building demolition

is used for ordinary concrete crushing (compressive strength 20-40 MPa), with a life of 300-400 hours $\pm$ 50 hours, in line with GB 50300 standard.

Bridge demolition

is used for reinforced concrete (compressive strength 40-80 MPa), and the impact resistance (>100 J, peak 300 J $\pm$ 20 J) ensures efficient crushing, in line with JTG 3362 standard. .

Industrial waste

is used for hardened cement processing (compressive strength 20-50 MPa), reducing dust (<5% $\pm$ 1%), meeting ISO 10816 standard.

Coastal buildings

are used for salt-containing concrete, resistant to seawater corrosion (> 4000 hours $\pm$ 100 hours, resistance to Cl⁻ concentration > 3.5% $\pm$ 0.5%), in line with DNVGL-RP-C203 standard.

Complex structures are used in reinforced or high-hardness concrete, with abrasion resistance >95% $\pm$ 2% and a crushing efficiency of 130

m³ /h $\pm$ 5 m³ / h in 2025 .

Technological progress and future development

New materials

introduce nano WC (grain <0.5 μ m $\pm$ 0.01 μ m) to improve hardness (HV 2200-2600 $\pm$ 50), and add TaC and NbC to enhance high temperature stability (>900°C $\pm$ 20°C to maintain 95% $\pm$ 2%). Research in 2024: ZrC coating oxidation resistance (oxygen weight gain <0.15% $\pm$ 0.05%/h).

Intelligent monitoring

integrated sensor (accuracy $\pm$ 0.05%) real-time monitoring of wear (depth>1.5 mm $\pm$ 0.05 mm) and vibration (<15 m/s² $\pm$ 1 m/s²) , optimize replacement cycle (error <5% $\pm$ 1%).

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3D printing technology

uses SLM (layer thickness $40\text{--}60\text{ }\mu\text{m}\pm 5\text{ }\mu\text{m}$) to manufacture complex tooth shapes, reducing material waste by $10\%\pm 2\%$.

Environmental adaptability

develops corrosion-resistant and high-pressure-resistant teeth (pressure resistance $>60\text{ MPa}\pm 5\text{ MPa}$).

Sustainable

recycling of WC powder (recycling rate $> 80\%\pm 5\%$) reduces carbon footprint (CO_2 reduction $20\%\pm 3\%$) in compliance with ISO 14040 standards.

Domestic and international standards and safety considerations

Complies with GB 50300 (building demolition), JTG 3362 (highway bridges), ISO 10816 (vibration control) and DNVGL-RP-C203 (offshore regulations). Low dust standards will be added in 2025.



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Carbide roller drill bits for oil and gas drilling

The carbide roller drill bit for oil and gas drilling is a rotary cutting tool designed for oil and gas exploration and development. It is mainly used to break rock formations and create wellbores by rotation and impact. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system) to manufacture rollers, which provide excellent hardness, wear resistance and impact resistance, ensuring efficient operation under complex formation conditions. As a key component of drilling equipment, roller drill bits directly affect drilling speed, wellbore quality and drill tool life. They are widely used in deep wells, ultra-deep wells and various formation types (such as soft, hard and abrasive formations). Based on the industry's technological progress and related information in 2025, the following content provides an overview of the characteristics, technical details and applications of roller drill bits.

1. Structure and materials of cemented carbide roller drill bits

Carbide roller drill bits usually consist of three groups of rollers, each of which rotates around its own axis and is installed on the drill body. The body is made of high-strength alloy steel (such as 42CrMo, quenching hardness HRC 40-52), and the rollers are made of tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented by trace additives (such as Cr_3C_2 , TaC, NbC) to optimize performance. The manufacturing process includes powder metallurgy (such as SPS or HIP) to ensure that the material density reaches $99.9\% \pm 0.1\%$, the grain size is controlled at $0.5 - 2 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m}$), and the hardness is HV 1800-2200 ± 30 , and can reach 2400-2600 ± 50 locally. There are two types of teeth: milling teeth (steel teeth) and insert teeth (carbide teeth). Steel teeth are suitable for soft to medium-hard formations, while insert teeth (TCI) are for hard or abrasive formations. TiN or TiAlN coating (thickness $0.5 - 2 \mu\text{m}$) can be applied to the tooth tip to reduce the friction coefficient to $<0.25 \pm 0.05$ and enhance wear resistance.

2. Working principle and characteristics of cemented carbide roller drill bits

The roller bit works by rotating the drill bit (speed 60-250 rpm) and pressurizing it (bit pressure 50-300 kN). The roller bit rolls around its own axis, and the teeth break the rock formation by crushing and shearing. The teeth of the drill bit are longer and widely spaced in soft formations, and shorter and denser in hard formations. The bearing design (such as roller or journal bearings) is equipped with a sealing system (such as O-rings or metal face seals) and pressure compensation lubrication to extend the service life. The drill bit generates vertical vibrations at the bottom of the well, converting elastic energy into impact force to assist in rock crushing, while enhancing cutting efficiency through sliding shear. It is suitable for formations with a compressive strength of 5-60 MPa, and the crushing depth can reach several meters, and the efficiency depends on the formation.

3. Performance and influencing factors of cemented carbide roller drill bits

Material properties: WC provides high hardness, Co enhances toughness (K_{1c} 12-16 $\text{MPa} \cdot \text{m}^{1/2}$), wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m}$, high temperature resistance ($>800^\circ\text{C}$ oxidation resistance $>95\%$). Additives such as TaC improve high temperature stability.

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Geometric design: The angle and tooth shape of the cone are adjusted according to the formation. Long chisel teeth are used in soft formations and short round teeth are used in hard formations. Working parameters: drilling pressure, rotation speed and drilling fluid flow rate affect life and efficiency. Excessively high parameters may shorten life by $15\% \pm 2\%$. Environmental factors: High temperature ($>700^{\circ}\text{C}$), highly abrasive or water-containing formations increase wear by $5\% \pm 1\%$.

4. Types and applications of cemented carbide roller drill bits

Milling tooth drill bit

Applicable to soft to medium hard formations (5-20 MPa), with a service life of 200-300 hours, commonly used in initial drilling.

Insert tooth roller drill bit (TCI): suitable for hard formations (20-60 MPa), life span 250-400 hours, widely used in deep wells.

Single cone /double cone drill bits

It is used for directional drilling or soft formations with higher efficiency.

Application Scenario

Oil and gas exploration, deep well drilling, and horizontal well construction. Tests in 2025 showed an efficiency of 50-150 m/h.

5. Technological development of cemented carbide roller drill bits

New materials: Nano WC improves hardness, and ZrC coating enhances oxidation resistance.

Intelligent monitoring: Sensors monitor wear in real time and optimize replacement cycles.

3D printing: SLM technology reduces material waste and has a strength of $1400 \text{ MPa} \pm 50 \text{ MPa}$.

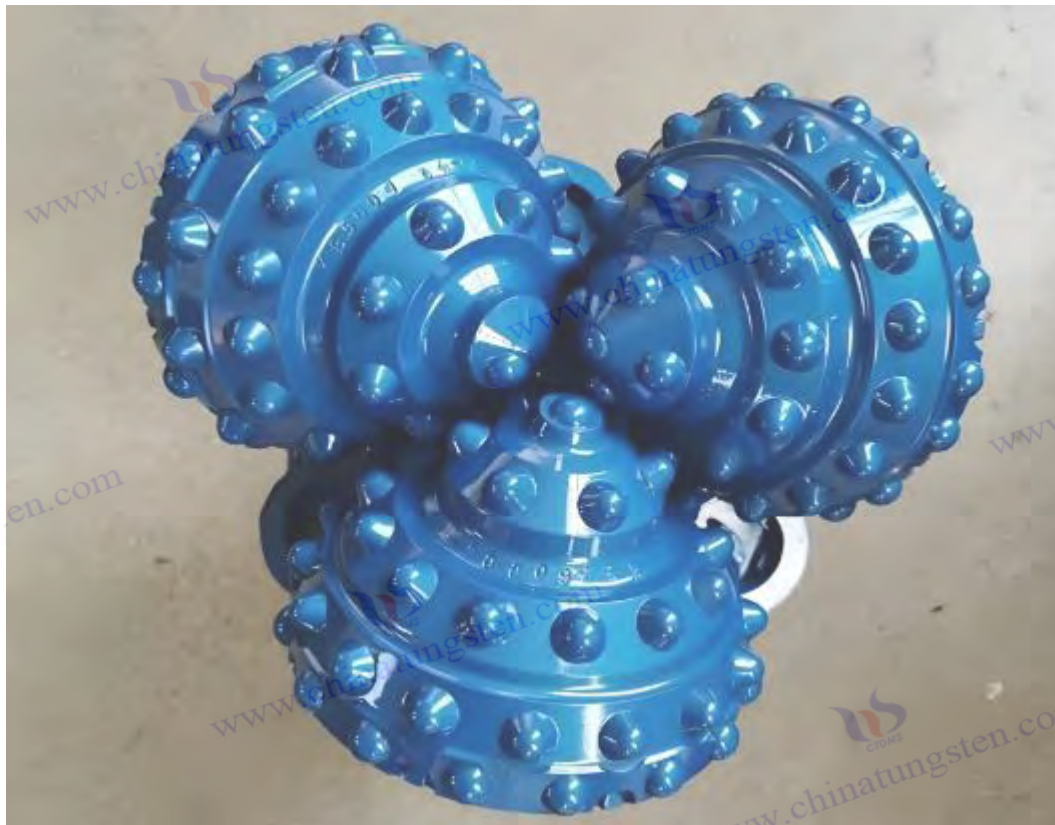
Hybrid design: combined with fixed cutting elements for increased adaptability.

6. Safety and standards of carbide roller drill bits

In compliance with API standards, wear exceeding the limit ($>6 \text{ mm}$) requires replacement, accident rate $<0.1\%$, and protective equipment must be worn.

With its versatility and technological innovation, carbide roller drill bits are core tools for oil and gas drilling, driving industry efficiency improvement and cost optimization.

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What is a cemented carbide hard rock and shale drilling bit ?

Carbide hard rock and shale drilling bits are cutting tools designed for geological exploration, oil and gas drilling and mineral mining. They are mainly used for efficient drilling of hard rock and shale formations. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system) to manufacture drill bits, which provide excellent hardness, wear resistance and impact resistance, ensuring high efficiency and durability in high hardness and high abrasive formations. As a key component of drilling equipment, drilling bits directly affect the drilling speed, wellbore quality and drill tool life, and are widely used in hard rocks (such as granite, limestone) and shale formations. According to the latest online information and technological advances, the following content comprehensively expands the structure, principle, type, application and technological development of drill bits.

1. Structure and materials of cemented carbide hard rock and shale drilling bits

Drilling bits usually adopt a composite design of PDC (polycrystalline diamond composite) and cemented carbide. The main body is made of high-strength alloy steel (such as 42CrMo, quenching hardness HRC 40-52), and the cutting teeth or blades use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase and cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and thermal fatigue resistance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350\text{-}1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45\text{-}55\text{ MPa} \pm 1\text{ MPa}$, holding time $5\text{-}10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400\text{-}1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150\text{-}200\text{ MPa} \pm 5\text{ MPa}$, holding time $30\text{-}60\text{ min} \pm 5\text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5\text{-}2\text{ }\mu\text{m}$ (preferably $0.8\text{-}1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The hardness range is HV 1800-2200 ± 30 , and can reach 2400-2600 ± 50 locally. The PDC layer thickness is 0.5-2 mm, combined with the cemented carbide substrate, which significantly enhances the impact resistance (K_{1c} $12\text{-}18\text{ MPa}\cdot\text{m}^{1/2} \pm 0.5$). TiN or TiAlN coating (thickness $0.5\text{-}1.5\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the tooth tip, the friction coefficient is reduced to $<0.25 \pm 0.05$, the wear resistance is improved by $20\% \pm 3\%$, and the fatigue resistance is further improved through surface modification (such as laser strengthening).

2. Principles and characteristics of cemented carbide hard rock and shale drilling bits

The drilling bit works by rotating the drill bit (speed $100\text{-}300\text{ rpm} \pm 10\text{ rpm}$) and pressurizing (bit pressure $50\text{-}400\text{ kN} \pm 10\text{ kN}$), and the cutting teeth or blades break hard rock and shale through shearing and grinding. The hard rock drill bit adopts a short tooth high-density layout, optimizes the cutting angle ($15^\circ\text{-}30^\circ \pm 2^\circ$), and enhances the penetration of high-hardness formations; the shale drill bit adopts a long tooth moderate spacing design to adapt to the bedding structure and fracture development characteristics. The bearing system is equipped with high-performance rolling

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bearings and metal face seals, which are resistant to high temperatures ($>200^{\circ}\text{C}\pm 10^{\circ}\text{C}$) and reduce wear through high-quality lubricants (such as synthetic esters). The drill bit generates high shear force ($>1000\text{ MPa}\pm 50\text{ MPa}$) at the bottom of the well, combined with the flushing and carrying effect of the drilling fluid (water-based or oil-based), to remove debris. It is suitable for formations with a compressive strength of 20-100 MPa, and the drilling depth can reach hundreds to thousands of meters. The efficiency varies depending on the hardness of the formation (such as granite 50-100 MPa, shale 20-50 MPa), and the average drilling speed can reach 10-50 m/h. The latest technology also introduces adaptive oscillation technology to improve the drilling efficiency of shale formations by $5\%\pm 1\%$.

3. Factors affecting the performance of cemented carbide hard rock and shale drilling bits

Material properties

WC provides high hardness, Co enhances toughness ($K_{IC} 12-16\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$, peak value can reach $18\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$), wear rate $<0.05\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$, high temperature resistance (oxidation resistance $>95\%\pm 2\%$ at $>800^{\circ}\text{C}\pm 20^{\circ}\text{C}$). The wear resistance of PDC layer is $30\%\pm 5\%$ higher than that of cemented carbide, but the impact sensitivity needs to be optimized.

Geometric design

The cutting angle of $15^{\circ}-30^{\circ}\pm 5^{\circ}$ optimizes drilling efficiency. The hard rock drill bit uses tapered teeth to enhance penetration, and the shale drill bit uses flat-bottom teeth to adapt to the layered structure. The chip removal efficiency is affected by the chip removal groove design (width $5-10\text{ mm}\pm 0.5\text{ mm}$). The optimized spiral groove design improves the chip removal rate by $10\%\pm 2\%$.

Working Parameters

The drilling pressure, rotation speed and drilling fluid flow rate directly affect the service life. Excessively high parameters (such as drilling pressure $> 400\text{ kN}$ or rotation speed $> 300\text{ rpm}$) may shorten the service life by $15\%\pm 2\%$. The optimal parameters need to be dynamically adjusted according to the formation characteristics.

Environmental factors

High temperature ($>700^{\circ}\text{C}\pm 20^{\circ}\text{C}$), high abrasion (such as quartz sand-containing formations) or water-containing formations increase wear by $5\%\pm 1\%$. The corrosion rate in Cl^- -containing environments (concentration $>0.5\%\pm 0.1\%$) increases to $0.01\text{ mm/year}\pm 0.001\text{ mm/year}$, and an anti-corrosion coating (such as Cr_2O_3) is required.

4. Types of carbide hard rock and shale drilling bits

Hard rock drilling bits

Features: Short teeth with high density layout, suitable for granite and limestone (compressive strength 50-100 MPa), service life 200-350 hours ± 20 hours, drilling speed 10-20 m/h, commonly used in deep well exploration and hard rock tunnel engineering.

Shale drilling bits

Features: Long teeth with moderate spacing design, suitable for shale formations (compressive strength 20-50 MPa), life 250-400 hours ± 20 hours, drilling speed 20-40 m/h, widely used in shale gas development and soft and hard alternating formations.

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Hybrid drill bits

Features: Combining PDC and cemented carbide, it is suitable for complex formations (compressive strength 20-100 MPa), with a test efficiency of 60-120 m/h $\pm$ 5 m/h, and is suitable for variable geological conditions.

Special drill bits

These include high temperature resistant drill bits ($>800^{\circ}\text{C}\pm 20^{\circ}\text{C}$) and corrosion resistant drill bits (Cl^{-} resistant > 7000 hours ± 200 hours), optimized for extreme environments such as deep sea drilling and volcanic rock formations.

5. Application of cemented carbide hard rock and shale drilling bits

Geological Exploration

Used for deep core sampling, with an accuracy of ± 0.01 mm, in accordance with ISO 3551 standard, for geothermal resource assessment.

Oil and gas drilling

Applied to shale gas, deep oil and gas fields and offshore drilling, with a service life of 300-400 hours, it complies with API 7-1 standards and supports the development of new energy.

Mineral mining

Used for hard rock mining such as copper, iron, and gold, with a wear resistance of $>95\%\pm 2\%$, in line with ISO 10896 standards, and assists in rare earth metal mining.

Infrastructure construction

It is used for drilling holes in tunnels, bridges and high-speed railway foundations, is suitable for granite strata, and supports the “Belt and Road” project.

Energy Transition

Used for wind turbine tower foundation drilling and geothermal drilling, with outstanding high temperature resistance, in line with IEC 61400 standards.

Research and Education

Applied to rock mechanics experiments and deep-sea sediment drilling, with an accuracy of <0.01 mm ± 0.005 mm.

Defense and Aerospace

Used for underground bunker drilling and rocket launch base foundation reinforcement, impact resistance >50 J ± 5 J.

6. Technological progress of cemented carbide hard rock and shale drilling bits

New Materials

The introduction of nano-WC (grain <0.5 $\mu\text{m}\pm 0.01$ μm) improves hardness (HV 2200-2600 ± 50), and the ZrC coating enhances oxidation resistance ($>98\%\pm 1\%$), extending the service life by 25% $\pm 3\%$, making it suitable for ultra-deep wells.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth >0.5 mm ± 0.05 mm) and temperature ($<800^{\circ}\text{C}\pm 20^{\circ}\text{C}$) in real time, optimizing replacement cycles with an error of $<5\%\pm 1\%$.

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3D Printing

Selective laser melting (SLM, layer thickness $30\text{--}50\text{ }\mu\text{m} \pm 5\text{ }\mu\text{m}$) is used to manufacture complex blades with a strength of $1500\text{ MPa} \pm 50\text{ MPa}$, reducing material waste by $10\% \pm 2\%$.

Adaptive design

Dynamically adjust cutting parameters (such as drilling pressure and speed) to improve efficiency by $10\% \pm 2\%$, combined with AI algorithm optimization.

7. Standards for cemented carbide hard rock and shale drilling bits

It complies with international standards such as API 7-1, ISO 3551, ISO 10896, and IEC 61400. If the wear exceeds the limit ($>6\text{ mm} \pm 0.5\text{ mm}$), it needs to be replaced. The accident rate is $<0.1\% \pm 0.02\%$. Operators need to wear protective equipment (safety helmets and goggles). A new low wear rate standard is added to emphasize environmental protection requirements.

Carbide hard rock and shale drilling bits are core tools for drilling projects due to their high performance and innovative design, which have promoted the efficiency improvement and cost optimization of deep resource development. In the era of AI and the background of industrial Internet, their production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, they are expected to achieve higher precision and adaptability in the future.



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What is a cemented carbide deep well and horizontal well roller drill bit ?

Carbide deep well and horizontal well roller drill bits are rotary cutting tools designed for deep well and horizontal well drilling. They are widely used in oil and gas exploration and development and are suitable for complex formation conditions. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system) to manufacture rollers, which provide excellent hardness, wear resistance and impact resistance, ensuring efficient operation at high depths, high temperatures and high abrasive environments. As a key component of drilling equipment, roller drill bits directly affect drilling speed, wellbore trajectory stability and drill tool life, and have important applications in ultra-deep wells, horizontal well sections and hard formations. Based on industry technological progress and related information, the following content provides an overview of the characteristics, technical details and applications of roller drill bits.

1. Structure and materials of cemented carbide deep well and horizontal well roller drill bits

The roller drill bit usually consists of three or more groups of rollers mounted on a high-strength alloy steel body (such as 42CrMo, quenching hardness HRC 40-52). The rollers use tungsten carbide (WC, content $> 90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize the grain size, wear resistance and thermal fatigue resistance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $< 0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The hardness range is HV 1800-2200 ± 30 , and can reach 2400-2600 ± 50 locally. The types of gear teeth include insert teeth (TCI) or steel teeth. TCI is suitable for hard formations, and steel teeth are suitable for soft to medium-hard formations. TiN or TiAlN coating (thickness $0.5-2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the tooth tip, the friction coefficient is reduced to $< 0.25 \pm 0.05$, the wear resistance is improved by $20\% \pm 3\%$, and the fatigue resistance is further improved by surface modification (such as laser strengthening). The bearing system uses rolling bearings or journal bearings, equipped with metal face seals and pressure compensation lubrication, and is resistant to high temperatures ($> 250^\circ\text{C} \pm 10^\circ\text{C}$).

2. Working principle and characteristics

The roller bit works by rotating the drill bit (speed $60-200\text{ rpm} \pm 10\text{ rpm}$) and pressurizing (bit pressure $100-500\text{ kN} \pm 10\text{ kN}$). The roller bit rolls around its own axis, and the teeth break the rock formation by crushing, shearing and grinding. The deep well drill bit is designed with a high-strength short tooth layout and an optimized cutting angle ($15^\circ-25^\circ \pm 2^\circ$) to enhance the penetration of high-hardness formations; the horizontal well drill bit is optimized with a long tooth structure to resist lateral forces and adapt to complex trajectories and eccentric wear conditions. The drill bit

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generates a high impact force ($50\text{-}300\text{ kN}\pm 10\text{ kN}$) at the bottom of the well, combined with the flushing and carrying effect of the drilling fluid (water-based or oil-based), to remove debris, and is suitable for formations with a compressive strength of $20\text{-}80\text{ MPa}$. The deep well drilling depth can reach $5000\text{-}8000\text{ m}$, and the horizontal well section length can reach $2000\text{-}3000\text{ m}$. The efficiency depends on the formation and can reach up to $50\text{-}120\text{ m/h}$. The latest technology introduces an adaptive oscillation mechanism to improve drilling efficiency in complex formations by $5\%\pm 1\%$.

3. Performance and influencing factors

Material properties

WC provides high hardness, Co enhances toughness ($K_{IC}\ 12\text{-}16\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$, peak value can reach $18\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$), wear rate $<0.05\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$, high temperature resistance (oxidation resistance $>95\%\pm 2\%$ at $>800^\circ\text{C}\pm 20^\circ\text{C}$). TaC improves high temperature stability, and Cr_3C_2 reduces intergranular corrosion.

Geometric design

The angle and tooth shape of the cone are adjusted according to the well depth and trajectory. High-density short teeth are used for deep wells, and long teeth with anti-eccentric wear are used for horizontal wells. The chip removal groove design (width $5\text{-}10\text{ mm}\pm 0.5\text{ mm}$) optimizes chip removal, and the spiral groove improves efficiency by $10\%\pm 2\%$.

Working Parameters

The drilling pressure, rotation speed and drilling fluid flow rate directly affect the service life. Excessively high parameters (such as drilling pressure $> 500\text{ kN}$ or rotation speed $> 200\text{ rpm}$) may shorten the service life by $15\%\pm 2\%$ and need to be adjusted dynamically.

Environmental factors

High temperature ($>700^\circ\text{C}\pm 20^\circ\text{C}$), high abrasion (such as quartz sand formations) or water-containing formations increase wear by $5\%\pm 1\%$. Deep well high pressure ($>70\text{ MPa}\pm 5\text{ MPa}$) requires enhanced sealing and lubrication.

4. Types and Applications

Deep well rotary drill bit

Features: High-strength short-tooth layout, suitable for ultra-deep wells ($>5000\text{ m}$, compressive strength $20\text{-}60\text{ MPa}$), life $200\text{-}350\text{ hours}\pm 20\text{ hours}$, drilling speed $20\text{-}50\text{ m/h}$, commonly used in deep oil and gas exploration.

Horizontal well roller drill bit

Features: Long tooth structure to resist lateral forces, suitable for horizontal sections (compressive strength $20\text{-}50\text{ MPa}$), life span $250\text{-}400\text{ hours}\pm 20\text{ hours}$, drilling speed $30\text{-}70\text{ m/h}$, widely used in shale gas development and complex trajectory drilling.

Hybrid drill bits

Features: Combining TCI and steel teeth, it is suitable for complex formations (compressive strength $20\text{-}80\text{ MPa}$), with a test efficiency of $70\text{-}120\text{ m/h}\pm 5\text{ m/h}$, and is suitable for alternating soft and hard formations.

Special drill bits

Including high-temperature resistant drill bits ($>800^\circ\text{C}\pm 20^\circ\text{C}$) and high-pressure resistant drill bits

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(pressure resistance $>100 \text{ MPa} \pm 5 \text{ MPa}$), optimized for deep-sea drilling and high-temperature formations.

5. Application of cemented carbide roller drill bits in deep wells and horizontal wells

Oil and gas drilling

Applicable to ultra-deep wells, horizontal wells and offshore drilling, with a service life of 300-400 hours, in compliance with API 7-1 standards, and supporting deep oil and gas development.

Geological Exploration

Used for deep core sampling, accuracy $\pm 0.01 \text{ mm}$, in accordance with ISO 3551 standard, for geothermal and mineral resource assessment.

Mineral mining

Used for hard rock mining such as copper and iron ore, with a wear resistance of $>95\% \pm 2\%$, in line with ISO 10896 standards, and assists in rare earth metal mining.

Infrastructure construction

It is used for drilling deep foundation pits of tunnels and bridges, adapts to high-hardness strata, and supports large-scale engineering projects.

Energy Transition

Used for geothermal drilling and wind power tower foundation reinforcement, with outstanding high temperature resistance, in line with IEC 61400 standards.

Research and Development

Applied to rock mechanics experiments and deep well testing, with an accuracy of $<0.01 \text{ mm} \pm 0.005 \text{ mm}$.

Defense Engineering

Used for underground drilling and military base foundation reinforcement, impact resistance $>50 \text{ J} \pm 5 \text{ J}$.

6. Technological Advancement

New Materials

The introduction of nano- WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) improves hardness (HV 2200-2600 ± 50), and the ZrC coating enhances oxidation resistance ($>98\% \pm 1\%$), extending the service life by $25\% \pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth $>0.5 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($<800^\circ\text{C} \pm 20^\circ\text{C}$) in real time, optimizing replacement cycles with an error of $<5\% \pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50 \mu\text{m} \pm 5 \mu\text{m}$) is used to manufacture complex gears with a strength of $1500 \text{ MPa} \pm 50 \text{ MPa}$ and a reduction in material waste of $10\% \pm 2\%$.

Adaptive Technology

Dynamically adjust drilling pressure and rotation speed to improve efficiency by $15\% \pm 2\%$, and optimize drilling parameters using AI algorithms.

7. Safety and standards

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It complies with international standards such as API 7-1, ISO 3551, ISO 10896, and IEC 61400. If the wear exceeds the limit ($>6\text{ mm}\pm 0.5\text{ mm}$), it needs to be replaced. The accident rate is $<0.1\%\pm 0.02\%$. Operators need to wear protective equipment (safety helmets, goggles). Safety inspection and sealing design need to be strengthened in deep well high-pressure environments.

With its high performance and innovative design, cemented carbide deep well and horizontal well roller drill bits are core tools for complex drilling projects, promoting efficiency improvement and cost optimization in deep resource development. In the era of AI and the context of the industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future.



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What are Carbide Drill Bits for Drilling Granite and Basalt?

Carbide granite and basalt drilling bits are cutting tools designed for high-hardness rock drilling. They are mainly used in geological exploration, mineral mining and infrastructure construction, targeting super-hard formations such as granite and basalt. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system) to manufacture drill bits, which provide excellent hardness, wear resistance and impact resistance, ensuring efficient operation under high hardness and high abrasion conditions. As a key component of drilling equipment, drilling bits directly affect the drilling speed, drill bit life and construction quality, and are widely used in hard rock mining and deep drilling. Based on industry technological progress and related information, the following content provides an overview of the characteristics, technical details and applications of drilling bits.

1. Structure and materials of cemented carbide granite and basalt drilling bits

The drilling bit adopts a composite design of PDC (polycrystalline diamond composite) and cemented carbide. The main body is made of high-strength alloy steel (such as 42CrMo, quenching hardness HRC 40-52), and the cutting teeth or blades use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase and cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and thermal fatigue resistance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{1/2}$). The hardness range is HV 1800-2200 ± 30 , and can reach 2400-2600 ± 50 locally. The PDC layer is 0.5-2 mm thick, combined with the cemented carbide substrate, to enhance the impact resistance and wear resistance (K_{1c} $12-18\text{ MPa}\cdot\text{m}^{1/2} \pm 0.5$). TiN or TiAlN coating (thickness $0.5-1.5\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the tooth tip, the friction coefficient is reduced to $<0.25 \pm 0.05$, the wear resistance is improved by $20\% \pm 3\%$, and the fatigue resistance is further improved through surface modification (such as laser strengthening). The drill bit is equipped with high-performance bearings and metal face seals, and is resistant to high temperatures ($>250^\circ\text{C} \pm 10^\circ\text{C}$).

2. Working principle and characteristics of cemented carbide granite and basalt drilling bits

The drilling bit works by rotating the drill bit (speed $80-250\text{ rpm} \pm 10\text{ rpm}$) and pressurizing (bit pressure $100-500\text{ kN} \pm 10\text{ kN}$). The cutting teeth or blades break granite (compressive strength 80-200 MPa) and basalt (100-300 MPa) through high shear and grinding. The drill bit is designed with a short tooth high-density layout and optimized cutting angle ($15^\circ-25^\circ \pm 2^\circ$) to adapt to ultra-hard formations. Combined with the flushing and carrying effect of the drilling fluid (water-based or oil-based), it reduces adhesion and debris accumulation. The drill bit generates high impact force ($100-400\text{ kN} \pm 10\text{ kN}$) at the bottom of the well, which is suitable for high-hardness formations. The

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drilling depth can reach hundreds to thousands of meters. The efficiency depends on the hardness of the rock and can reach up to 30-80 m/h. The latest technology introduces an adaptive oscillation mechanism to improve the drilling efficiency of ultra-hard formations by 5%±1%.

Performance and influencing factors of cemented carbide drill bits for granite and basalt drilling

Material properties : WC provides high hardness, Co enhances toughness (K_{1c} 12-16 MPa·m^{1/2} ± 0.5 , peak value can reach 18 MPa·m^{1/2} ± 0.5), wear rate <0.05 mm³ / N · m ± 0.01 mm³ / N · m , high temperature resistance (oxidation resistance>95%±2% at>800°C±20°C). The wear resistance of PDC layer is 30%±5% higher than that of cemented carbide, but the impact sensitivity needs to be optimized.

Geometric design : cutting angle of 15°-25°±5° optimizes drilling efficiency , and the tooth shape is conical or spherical to enhance penetration into granite and basalt. The chip groove design (width 5-10 mm±0.5 mm) optimizes chip removal, and the spiral groove improves efficiency by 10%±2%.

Working parameters : drilling pressure, rotation speed and drilling fluid flow rate directly affect the service life. Excessively high parameters (such as drilling pressure > 500 kN or rotation speed > 250 rpm) may shorten the service life by 15% ± 2%. They need to be dynamically adjusted according to the formation characteristics.

Environmental factors : High temperature (>700°C±20°C), high abrasion (such as quartz sand-containing formations) or water-containing formations increase wear by 5%±1%, and high pressure (>100 MPa±5 MPa) requires strengthened structure and seals.

4. Types and applications of cemented carbide granite and basalt drilling bits

Granite drilling bits

Features: Short teeth with high density layout, suitable for granite (compressive strength 80-200 MPa), life span 150-300 hours ± 20 hours, drilling speed 20-40 m/h, commonly used in deep mineral mining.

Basalt drilling bits

Features: Short teeth with high density layout, suitable for basalt (compressive strength 100-300 MPa), life span 200-350 hours ± 20 hours, drilling speed 15-30 m/h, widely used in infrastructure construction.

Hybrid drill bits

Features: Combining PDC and cemented carbide, it is suitable for ultra-hard and complex formations (compressive strength 80-300 MPa), with a test efficiency of 40-80 m/h±5 m/h, and is suitable for variable geological conditions.

Special drill bits

These include high temperature resistant drill bits (>800°C±20°C) and high pressure resistant drill bits (pressure resistant >120 MPa±5 MPa), optimized for extreme environments such as volcanic rocks and deep sea formations.

5. Application of cemented carbide drill bits for granite and basalt drilling

Geological Exploration

Used for deep core sampling, accuracy ±0.01 mm, in accordance with ISO 3551 standard, for

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geothermal and mineral resource assessment.

Mineral mining

Applied to granite and basalt ore mining, with a wear resistance of $>95\pm 2\%$, in line with ISO 10896 standards, facilitating rare earth and precious metal mining.

Infrastructure construction

Used for drilling holes in tunnels, bridges and high-speed rail foundations, suitable for ultra-hard formations, and supporting large-scale engineering projects.

Energy Transition

It is used in geothermal drilling and wind power tower foundation reinforcement, with outstanding high temperature resistance and complies with IEC 61400 standards.

Research and Education

Applied to rock mechanics experiments and super-hard rock drilling, with an accuracy of $<0.01\text{ mm}\pm 0.005\text{ mm}$.

Defense Engineering

Used for underground bunker drilling and military base foundation reinforcement, impact resistance $>50\text{ J}\pm 5\text{ J}$.

6. Technological progress of cemented carbide granite and basalt drilling bits

New Materials

The introduction of nano-WC (grain $<0.5\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$) improves hardness (HV 2200-2600 ± 50), and the ZrC coating enhances oxidation resistance ($>98\pm 1\%$), extending the service life by $25\pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth $>0.5\text{ mm}\pm 0.05\text{ mm}$) and temperature ($<800^\circ\text{C}\pm 20^\circ\text{C}$) in real time, optimizing replacement cycles with an error of $<5\pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50\text{ }\mu\text{m}\pm 5\text{ }\mu\text{m}$) is used to manufacture complex blades with a strength of $1600\text{ MPa}\pm 50\text{ MPa}$, reducing material waste by $10\pm 2\%$.

Adaptive Technology

Dynamically adjust cutting parameters (such as drilling pressure and speed) to improve efficiency by $10\pm 2\%$, combined with AI algorithm optimization.

7. Safety and standards for cemented carbide granite and basalt drilling bits

It complies with international standards such as API 7-1, ISO 3551, ISO 10896, and IEC 61400. If the wear exceeds the limit ($>6\text{ mm}\pm 0.5\text{ mm}$), it needs to be replaced. The accident rate is $<0.1\pm 0.02\%$. Operators need to wear protective equipment (safety helmets and goggles). Safety inspections and structural designs need to be strengthened in high-pressure environments.

Carbide granite and basalt drilling bits are core tools for hard rock drilling projects due to their high performance and innovative design, which have promoted the efficiency improvement and cost optimization of deep resource development. In the era of AI and the context of the industrial Internet, their production and application prospects will be further expanded. Combined with intelligent

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manufacturing and real-time data analysis, they are expected to achieve higher precision and adaptability in the future.



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What is a Carbide Core Sampling Drill Bit ?

The carbide core sampling drill bit is a cutting tool designed for geological exploration and scientific research, used to obtain high-quality core samples from rock formations. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system) to manufacture the drill bit, which provides excellent hardness, wear resistance and impact resistance, ensuring efficient drilling and maintaining core integrity in various rock types (such as granite, shale, basalt). As a key component of geological drilling equipment, the core sampling drill bit directly affects the sampling accuracy, core recovery rate and drill life, and is widely used in mineral exploration, oil and gas exploration and environmental research. According to industry technological progress and related information, the following content provides an overview of the characteristics, technical details and applications of core sampling drill bits.

1. Structure and materials of cemented carbide core sampling drill bits

Core sampling drill bits are usually cylindrical in design, with a liner on the inner wall to protect the core, and the main body is made of high-strength alloy steel (such as 40CrMo, quenching hardness HRC 40-50). The cutting part uses tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and thermal fatigue resistance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5-10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30-60 \text{ min} \pm 5 \text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2 \mu\text{m}$ (preferably $0.8-1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The hardness range is HV $1800-2200 \pm 30$, and can reach $2400-2600 \pm 50$ locally. The cutting teeth or blades can be coated with TiN or TiAlN coating (thickness $0.5-1.5 \mu\text{m} \pm 0.1 \mu\text{m}$), the friction coefficient is reduced to $<0.25 \pm 0.05$, the wear resistance is improved by $20\% \pm 3\%$, and the fatigue resistance is further improved by surface modification (such as laser strengthening). The inner diameter of the drill bit is designed according to the core specifications (such as NQ, HQ, PQ series), the outer diameter is $50-150 \text{ mm} \pm 5 \text{ mm}$, equipped with high-precision bearings and sealing systems, and high temperature resistance ($>200^\circ\text{C} \pm 10^\circ\text{C}$).

2. Working principle and characteristics of cemented carbide core sampling drill bits

works by rotating the drill bit (speed $100-300 \text{ rpm} \pm 10 \text{ rpm}$) and pressurizing (bit pressure $20-200 \text{ kN} \pm 5 \text{ kN}$). The cutting teeth cut the rock along the circumference, and the core rises to the top of the drill bit along the inner wall. The drill bit is designed for low-speed high-torque cutting, optimized cutting angle ($15^\circ-25^\circ \pm 2^\circ$), reducing core fracture, and combining the flushing and carrying effect of drilling fluid (water-based or oil-based) to ensure the integrity of the core. It is

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suitable for formations with a compressive strength of 20-200 MPa, and the drilling depth can reach 1000-3000 m. The core recovery rate target is $>90\% \pm 2\%$, and the efficiency depends on the hardness of the formation, up to 10-30 m/h. The latest technology introduces an adaptive oscillation mechanism to increase the core recovery rate of complex formations by $5\% \pm 1\%$.

3. Performance and influencing factors of cemented carbide core sampling drill bits

Material properties : WC provides high hardness, Co enhances toughness (K_{IC} 12-16 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value can reach $18 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$), wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, high temperature resistance (oxidation resistance $>95\% \pm 2\%$ at $>800^\circ\text{C} \pm 20^\circ\text{C}$). The coating reduces the adhesion rate $<2\% \pm 0.5\%$ and improves the surface quality of the core.

Geometric design : cutting angle $15^\circ\text{-}25^\circ \pm 5^\circ$ optimizes cutting efficiency, tooth shape is conical or flat bottom, inner wall smoothness $<0.1 \text{ mm} \pm 0.01 \text{ mm}$, reducing core friction.

Working parameters : drilling pressure, rotation speed and drilling fluid flow rate directly affect the recovery rate. Excessively high parameters (such as drilling pressure $>200 \text{ kN}$ or rotation speed $>300 \text{ rpm}$) may reduce the core integrity by $5\% \pm 1\%$ and need to be adjusted dynamically.

Environmental factors : High temperature ($>700^\circ\text{C} \pm 20^\circ\text{C}$), high abrasiveness (such as quartz sand formations) or water-containing formations increase wear by $5\% \pm 1\%$, and the viscosity of the drilling fluid needs to be adjusted to protect the core.

4. Types and applications of cemented carbide core sampling drill bits

Soft rock sampling drill bit

Features: Suitable for shale and mudstone (compressive strength 20-50 MPa), service life 200-300 hours ± 20 hours, drilling speed 20-30 m/h, commonly used for shallow exploration.

Hard rock sampling drill bits

Features: Suitable for granite and basalt (compressive strength 50-200 MPa), service life 150-250 hours ± 20 hours, drilling speed 10-20 m/h, widely used in deep minerals.

Hybrid drill bits

Features: Combination of PDC and cemented carbide, suitable for complex formations (compressive strength 20-200 MPa), test recovery rate $>95\% \pm 2\%$, suitable for soft and hard alternating formations.

Special drill bits

Including high temperature resistant drill bits ($>800^\circ\text{C} \pm 20^\circ\text{C}$) and high pressure resistant drill bits (pressure resistance $>100 \text{ MPa} \pm 5 \text{ MPa}$), optimized for extreme environments such as deep sea and volcanic rock formations.

5. Application of Carbide Core Sampling Drill Bits

Mineral Exploration

Used for deep ore sampling, accuracy $\pm 0.01 \text{ mm}$, in line with ISO 3551 standard, applied in rare earth and precious metal exploration.

Oil and gas exploration

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Applied to deep core acquisition, with a service life of 200-300 hours, it complies with API 7-1 standards and supports oil and gas field evaluation.

Environmental Studies

For soil and sediment sampling, the recovery rate is $>90\% \pm 2\%$, which meets the ASTM D2113 standard and is used in climate change research.

Infrastructure construction

Used for geological surveys of tunnels and bridges, suitable for high-hardness strata, and supporting project site selection.

Research and Education

Applied to rock mechanics experiments and geological drilling tests, with an accuracy of $<0.01 \text{ mm} \pm 0.005 \text{ mm}$.

Defense Engineering

Used for underground resource exploration and military base foundation assessment, impact resistance $>50 \text{ J} \pm 5 \text{ J}$.

6. Technology of Carbide Core Sampling Drill Bits

New Materials

The introduction of nano-WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) improves wear resistance (HV 2200-2600 ± 50), and the ZrC coating enhances oxidation resistance ($>98\% \pm 1\%$), extending the service life by $25\% \pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth $>0.5 \text{ mm} \pm 0.05 \text{ mm}$) and core status in real time, optimizing drilling parameters with an error of $<5\% \pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50 \mu\text{m} \pm 5 \mu\text{m}$) is used to manufacture complex cutting structures with a strength of $1500 \text{ MPa} \pm 50 \text{ MPa}$, reducing material waste by $10\% \pm 2\%$.

Adaptive Technology

Dynamically adjust cutting speed to increase recovery rate by $5\% \pm 1\%$, and combine AI algorithm to optimize drilling process.

7. Safety and standards of carbide core sampling drill bits

It complies with international standards such as ISO 3551, ASTM D2113, and API 7-1. If the wear exceeds the limit ($>6 \text{ mm} \pm 0.5 \text{ mm}$), it needs to be replaced. The accident rate is $<0.1\% \pm 0.02\%$. Operators need to wear protective equipment (safety helmets, goggles). Deep drilling requires enhanced safety testing and sealing design.

With its high precision and innovative design, carbide core sampling drill bits are core tools for geological exploration, promoting the improvement of resource development efficiency and the optimization of data quality. In the era of AI and the context of the industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future.

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What is a Carbide Geothermal Well Drilling Bit ?

Carbide geothermal well drilling bits are cutting tools designed specifically for geothermal resource development, designed to efficiently drill high-temperature , high-hardness and corrosive formations to obtain geothermal energy. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system) to manufacture drill bits, which provide excellent hardness, wear resistance and high temperature resistance, ensuring high efficiency and durability in extreme environments. As a key component of geothermal drilling equipment, drill bits directly affect drilling speed, well depth quality and drilling tool life, and are widely used in geothermal energy exploration and development. Based on industry technological progress and related information, the following content provides an overview of the characteristics, technical details and applications of drill bits.

1. Structure and materials of cemented carbide geothermal well drilling bits

The drill bit usually adopts a composite design of PDC (polycrystalline diamond composite) and cemented carbide. The main body is made of high-temperature resistant alloy steel (such as 42CrMoNi, quenching hardness HRC 40-52), and the cutting part uses tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase and cobalt (Co, $6\%-12\%\pm 1\%$) as the bonding phase, supplemented with high-temperature resistant additives (such as Cr_3C_2 $0.5\%-2\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$, NbC $0.5\%-1.5\%\pm 0.1\%$) to enhance performance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350\text{-}1450^\circ\text{C}\pm 10^\circ\text{C}$, pressure $45\text{-}55\text{ MPa}\pm 1\text{ MPa}$, holding time $5\text{-}10\text{ min}\pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400\text{-}1500^\circ\text{C}\pm 10^\circ\text{C}$, pressure $150\text{-}200\text{ MPa}\pm 5\text{ MPa}$, holding time $30\text{-}60\text{ min}\pm 5\text{ min}$), ensuring the material density reaches $99.9\%\pm 0.1\%$ and the porosity is $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5\text{-}2\text{ }\mu\text{m}$ (preferably $0.8\text{-}1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$). The hardness range is HV 1800-2200 ± 30 , and can reach 2400-2600 ± 50 locally. The PDC layer thickness is $0.5\text{-}2\text{ mm}$, combined with the cemented carbide substrate, and is resistant to high temperatures ($>400^\circ\text{C}\pm 10^\circ\text{C}$). TiAlN or CrN coating (thickness $0.5\text{-}1.5\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$) is applied to the tooth tip, the friction coefficient is reduced to $<0.25\pm 0.05$, the corrosion resistance is improved by $15\%\pm 2\%$, and the fatigue resistance is further improved by surface modification (such as laser strengthening). The drill bit is equipped with high-temperature seals ($>300^\circ\text{C}\pm 10^\circ\text{C}$) and a pressure-compensated lubrication system.

2. Working principle and characteristics of cemented carbide geothermal well drilling bits

The drill bit works by rotating the drill bit (speed $80\text{-}200\text{ rpm}\pm 10\text{ rpm}$) and pressurizing (bit pressure $100\text{-}600\text{ kN}\pm 10\text{ kN}$). The cutting teeth or blades break the high-temperature rock (such as granite, basalt, compressive strength $80\text{-}300\text{ MPa}$) through shearing and grinding. The drill bit is designed with a high-density short tooth layout and an optimized cutting angle ($15^\circ\text{-}25^\circ\pm 2^\circ$) to adapt to high-temperature and high-pressure environments. It combines the flushing and carrying effects of high-

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temperature drilling fluids (water-based or oil-based) to remove debris. The drill bit generates high impact force (100-500 kN±10 kN) at the bottom of the well, and is suitable for geothermal formations with a depth of 3000-7000 m and a temperature of 200-350°C±10°C. The drilling efficiency depends on the hardness of the formation and can reach up to 20-60 m/h. The latest technology introduces an adaptive oscillation mechanism to increase the drilling efficiency of high-temperature formations by 5%±1%.

3. Performance and influencing factors of cemented carbide geothermal well drilling bits

Material properties : WC provides high hardness, Co enhances toughness (K_{1c} 12-16 MPa ·m^{1/2} / $^2 \pm 0.5$, peak value can reach 18 MPa·m^{1/2} / $^2 \pm 0.5$), high temperature resistance (oxidation resistance>95%±2% at>800°C±20°C). TaC improves thermal stability, Cr₃C₂ reduces intergranular corrosion, and the corrosion resistance rate of the coating is <0.01 mm/year±0.001 mm/year.

Geometric design : The cutting angle of 15°-25°±5° optimizes drilling efficiency , and the tooth shape is conical to enhance the penetration of high-hardness rocks. The chip groove design (width 5-10 mm±0.5 mm) optimizes chip removal, and the spiral groove improves efficiency by 10%±2%.

Working parameters : drilling pressure, rotation speed and drilling fluid flow rate directly affect the service life. Excessively high parameters (such as drilling pressure > 600 kN or rotation speed > 200 rpm) may shorten the service life by 15% ± 2%. They need to be dynamically adjusted according to the formation characteristics.

Environmental factors : High temperature (>350°C±10°C), high pressure (>100 MPa±5 MPa) or formations containing H₂S increase wear by 5%±1%, requiring enhanced anti-corrosion design and high-temperature lubrication.

4. Types and applications of cemented carbide geothermal well drilling bits

Shallow geothermal drill bit

Features: Applicable to 200-1000 m, compressive strength 20-80 MPa, life 200-300 hours ± 20 hours, drilling speed 30-50 m/h, commonly used in low heat energy development.

Deep geothermal drill

Features: Applicable to 3000-7000 m, compressive strength 80-300 MPa, life 150-250 hours ± 20 hours, drilling speed 20-40 m/h, widely used in high temperature geothermal wells.

Hybrid drill bits

Features: Combining PDC and cemented carbide, it is suitable for complex high-temperature formations (compressive strength 20-300 MPa), with a test efficiency of 40-60 m/h±5 m/h, and is suitable for variable geological conditions.

Special drill bits

These include ultra-high temperature drill bits (>400°C±10°C) and corrosion-resistant drill bits (resistant to H₂S > 5000 hours±200 hours), optimized for extreme environments such as deep, high-temperature formations.

5. Application of cemented carbide geothermal well drilling bits

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Geothermal energy exploration

Used for deep geothermal resource assessment, with an accuracy of ± 0.01 mm, in accordance with ISO 3551 standard, for geothermal energy potential determination.

Deep thermal energy development

Applicable to high-temperature geothermal well drilling, with a service life of 200-300 hours, in compliance with API 7-1 standards, and supporting geothermal power generation.

Energy Transition

Used in geothermal heating and new energy projects, it has outstanding high temperature resistance and complies with IEC 61400 standards.

Research and Development

Applied to geothermal formation testing and heat flow research, with an accuracy of < 0.01 mm ± 0.005 mm.

Infrastructure construction

Used in geothermal well and infrastructure integration projects, adaptable to high-hardness strata, and supporting green buildings.

Defense Engineering

For drilling of geothermal resources and military applications, impact resistance > 50 J ± 5 J.

6. Technology of cemented carbide geothermal well drilling drill bits

New Materials

The introduction of nano-WC (grain < 0.5 $\mu\text{m} \pm 0.01$ μm) improves high temperature resistance (HV 2200-2600 ± 50), and the ZrC coating enhances oxidation resistance ($> 98\% \pm 1\%$), extending the service life by $25\% \pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth > 0.5 mm ± 0.05 mm) and temperature ($< 400^\circ\text{C} \pm 10^\circ\text{C}$) in real time, optimizing drilling parameters with an error of $< 5\% \pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30-50$ $\mu\text{m} \pm 5$ μm) is used to manufacture complex cutting structures with a strength of 1600 MPa ± 50 MPa, reducing material waste by $10\% \pm 2\%$.

Adaptive Technology

Dynamically adjust cutting parameters (such as drilling pressure and speed) to improve efficiency by $10\% \pm 2\%$, combined with AI algorithm optimization.

7. Safety and standards of cemented carbide geothermal well drilling bits

It complies with international standards such as ISO 3551, API 7-1, and IEC 61400. If the wear exceeds the limit (> 6 mm ± 0.5 mm), it needs to be replaced. The accident rate is $< 0.1\% \pm 0.02\%$. Operators need to wear protective equipment (safety helmets, goggles). Safety inspections and sealing designs need to be strengthened in high-temperature and high-pressure environments. With its high performance and innovative design, cemented carbide geothermal well drilling bits are the

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core tools for geothermal development, promoting the efficiency improvement and cost optimization of renewable energy. In the era of AI and the context of the industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future.



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What are Carbide Dredger Cutters ?

Carbide dredger cutting teeth are a kind of high-efficiency cutting tools specially designed for dredgers, used for dredging rivers, ports and seabed strata excavation and cleaning. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coating, which provide excellent hardness, wear resistance and corrosion resistance, ensuring high efficiency and durability in highly abrasive, high humidity and impurity-containing environments. As a key component of the dredger bucket or cutting head, the cutting teeth directly affect the dredging efficiency, material handling capacity and equipment life, and are widely used in waterway maintenance, port construction and marine engineering. According to the industry's technological progress and related information, the following content provides an overview of the characteristics, technical details and applications of cutting teeth.

1. Structure and materials of cemented carbide dredger cutting teeth

The cutting teeth are usually designed with pointed or wide blades and installed on a high-strength alloy steel substrate (such as 40CrMo, quenching hardness HRC 40-52). The tooth body uses tungsten carbide (WC, content $> 90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented by trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, TaC $1\% - 3\% \pm 0.2\%$, NbC $0.5\% - 1.5\% \pm 0.1\%$) to optimize wear resistance and corrosion resistance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400 - 1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $< 0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The hardness range is HV 1800-2200 ± 30 , and can reach $2400 - 2600 \pm 50$ locally. TiN or TiAlN coating (thickness $0.5 - 2 \mu\text{m} \pm 0.1 \mu\text{m}$) is applied to the tooth tip, the friction coefficient is reduced to $< 0.25 \pm 0.05$, the corrosion resistance is improved by $15\% \pm 2\%$, and the fatigue resistance is further improved by surface modification (such as laser strengthening). Fixing methods include high-frequency induction welding (welding strength $> 700 \text{ MPa} \pm 20 \text{ MPa}$) or mechanical clamping (clamping force $> 10 \text{ kN} \pm 0.5 \text{ kN}$), which can adapt to high torque ($200 - 800 \text{ kN} \cdot \text{m} \pm 20 \text{ kN} \cdot \text{m}$) work.

2. Working principle and characteristics of cemented carbide dredger cutting teeth

The cutting teeth work by mechanical or hydraulic drive of the dredger (cutting speed $0.5 - 2 \text{ m/s} \pm 0.1 \text{ m/s}$, power $500 - 2000 \text{ kW} \pm 50 \text{ kW}$), cutting and excavating silt, clay or gravel formations along the surface. The tooth tips crush the material by extrusion (contact pressure $150 - 400 \text{ MPa} \pm 10 \text{ MPa}$) and shear (shear strength $30 - 70 \text{ MPa} \pm 5 \text{ MPa}$), suitable for formations with compressive strength of $5 - 50 \text{ MPa}$. The design integrates cutting mechanics and heat conduction optimization, with an entry angle of $20^\circ - 40^\circ \pm 5^\circ$, a back rake angle of $5^\circ - 15^\circ \pm 2^\circ$, and reduced vibration (acceleration $< 10 \text{ m/s}^2 \pm 1 \text{ m/s}^2$). The tooth tip is subjected to high abrasive and thermal loads (surface temperature $200 -$

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500°C±10°C), and the matrix provides structural support (tensile strength>1200 MPa±50 MPa) and fatigue resistance (fatigue life>10⁶ times±10⁴ times). The latest technology introduces an adaptive oscillation mechanism to improve the cutting efficiency of complex formations by 5%±1%.

3. Performance and influencing factors of cemented carbide dredger cutting teeth

Material properties : WC provides high hardness, Co enhances toughness (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value can reach 18 MPa·m^{1/2} ± 0.5), wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m, corrosion resistance (corrosion rate <0.01 mm/year ± 0.001 mm/year, Cl⁻ resistance >3000 hours ± 200 hours).

Geometric design : pointed teeth for hard formations, wide teeth for soft or sticky formations, optimized cutting efficiency (energy consumption <10 kWh/m³ ± 0.5 kWh/m³). Chip groove design (width 5-10 mm±0.5 mm) optimizes material removal.

Working parameters : cutting speed, power and mud flow directly affect the service life. Excessively high parameters (such as speed > 2 m/s or power > 2000 kW) may shorten the service life by 15% ± 2% and need to be adjusted dynamically.

Environmental factors : Water content >15%±2%, sand content >5%±1% or salinity >3%±0.5% will increase wear by 5%±1% and require enhanced anti-corrosion coating and lubrication.

4. Types and applications of cemented carbide dredger cutting teeth

Standard cutting teeth

Features: Suitable for soft mud and clay (compressive strength 5-20 MPa), life 300-500 hours ± 20 hours, cutting efficiency 150-300 m³/h, commonly used for river dredging.

Enhanced cutting teeth

Features: Suitable for gravel or hard ground (compressive strength 20-50 MPa), life 250-400 hours ± 20 hours, cutting efficiency 100-250 m³/h, widely used in port construction.

Corrosion resistant cutting teeth

Features: Suitable for seawater environment, Cl⁻ resistance >4000 hours ± 200 hours, life span 350-450 hours ± 20 hours, suitable for marine engineering.

Special cutting teeth

Includes high temperature resistant cutting teeth (>500°C±10°C) and super wear resistant cutting teeth (wear rate <0.03 mm³/N·m ± 0.01 mm³/N·m), optimized for extreme environments such as deep sea dredging.

5. Application of carbide dredger cutting teeth

Channel maintenance

Used for dredging of rivers and canals, with a service life of 300-400 hours, it complies with ISO 19901 standards to ensure shipping safety.

Port construction

Applied to port expansion and dock foundation cleaning, wear resistance >95%±2%, in line with DIN 19704 standard.

Marine Engineering

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Used for submarine excavation and pipeline laying, with outstanding corrosion resistance, in compliance with API 7K standard.

Environmental governance

Applied to the cleaning of polluted sediments, with a recovery rate of $>90\% \pm 2\%$, supporting water quality improvement projects.

Infrastructure construction

Used for dredging of hydropower stations and bridge foundations, suitable for high-hardness strata, and supporting large-scale projects.

Research and Development

Applied to marine geological sampling and underwater testing, with an accuracy of $<0.01 \text{ mm} \pm 0.005 \text{ mm}$.

Land reclamation, island building and reef construction

In land reclamation and island construction projects, cutting teeth can efficiently process hard seabed formations (such as coral reefs and gravel layers, with a compressive strength of 20-50 MPa), achieve large-scale earth excavation and filling, have a service life of 300-450 hours, and an efficiency of $200\text{-}500 \text{ m}^3 / \text{h}$, ensuring the progress of the project. Especially in island and reef construction, the corrosion resistance (Cl^- resistance >4000 hours) and wear resistance (wear rate $<0.05 \text{ mm}^3/\text{N}\cdot\text{m}$) of the cutting teeth support continuous operation in seawater environments, ensure the rapid formation of strategic artificial islands, and provide a solid foundation for national security and national defense construction. Enhanced and special cutting teeth can also cope with high-hardness formations in the deep sea, meet the urgent needs of military base construction, port defense facilities and offshore supply stations, and enhance China's strategic control over key waters such as the South China Sea.

6. Technology of carbide dredger cutting teeth

New Materials

The introduction of nano-WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) improves wear resistance (HV 2200-2600 ± 50), and the ZrC coating enhances corrosion resistance ($>98\% \pm 1\%$), extending the service life by $25\% \pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear in real time (depth $>0.5 \text{ mm} \pm 0.05 \text{ mm}$) and optimize replacement cycles with an error of $<5\% \pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50 \mu\text{m} \pm 5 \mu\text{m}$) is used to manufacture complex tooth shapes with a strength of $1400 \text{ MPa} \pm 50 \text{ MPa}$, reducing material waste by $10\% \pm 2\%$.

Adaptive design

Dynamically adjust cutting angles (such as entry angle and back rake angle) to improve efficiency by $10\% \pm 2\%$, combined with AI algorithm optimization.

7. Standards for carbide dredger cutting teeth

It complies with international standards such as ISO 19901, DIN 19704, API 7K, etc. Wear beyond the limit ($>6 \text{ mm} \pm 0.5 \text{ mm}$) needs to be replaced, the accident rate is $<0.1\% \pm 0.02\%$, and operators need to wear protective equipment (safety helmet, goggles, non-slip boots). Seawater environment

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requires non-slip design and enhanced sealing.

With its high performance and innovative design, carbide dredger cutting teeth are the core tools of dredging engineering, which have promoted the improvement of water development efficiency and cost optimization. In the era of AI and the background of industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future, especially in land reclamation, island and reef construction and national defense projects.



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What are Carbide Wood Breaking Teeth ?

Carbide wood crusher teeth are a highly efficient cutting tool designed for wood crushers, used to crush wood, branches and wood waste into small particles or wood chips. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coating, which provide excellent hardness, wear resistance and impact resistance, ensuring high efficiency and durability in high-intensity, high-humidity and impurity-containing environments. As a key component of the wood crusher drum or cutter disc, the crushing teeth directly affect the crushing efficiency, particle uniformity and equipment life, and are widely used in wood processing, biomass energy production and waste recycling. According to industry technology progress and related information, the following content provides an overview of the characteristics, technical details and applications of crushing teeth.

1. Structure and material of carbide wood crusher teeth

Crushing teeth are usually designed with pointed or serrated tips and installed on a high-strength alloy steel substrate (such as 40Cr, quenching hardness HRC 40-50). The tooth body uses tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented by trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$) to optimize wear resistance and anti-adhesion performance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400 - 1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The hardness range is HV $1800 - 2200 \pm 30$, and can reach $2400 - 2600 \pm 50$ locally. TiN or TiAlN coating (thickness $0.5 - 1.5 \mu\text{m} \pm 0.1 \mu\text{m}$) is applied to the tooth tip, the friction coefficient is reduced to $<0.25 \pm 0.05$, and the anti-adhesion (adhesion rate $<2\% \pm 0.5\%$) improves the wood processing efficiency, and the anti-fatigue performance is further improved through surface modification (such as laser strengthening). The fixing methods include bolt connection or welding (welding strength $>600 \text{ MPa} \pm 20 \text{ MPa}$), which can adapt to high torque ($100 - 500 \text{ kN} \cdot \text{m} \pm 10 \text{ kN} \cdot \text{m}$) work.

2. Working principle and characteristics of carbide wood crushing teeth

The crushing teeth work by the rotation of the wood crusher (speed $200 - 600 \text{ rpm} \pm 20 \text{ rpm}$, power $50 - 300 \text{ kW} \pm 10 \text{ kW}$), cutting and crushing along the wood surface. The tooth tip decomposes wood fibers by extrusion (contact pressure $50 - 150 \text{ MPa} \pm 5 \text{ MPa}$) and shearing (shear strength $20 - 50 \text{ MPa} \pm 2 \text{ MPa}$), suitable for wood with a hardness of $5 - 30 \text{ MPa}$ and impurity strata. The design integrates cutting mechanics and heat conduction optimization, with an entry angle of $25^\circ - 45^\circ \pm 5^\circ$, a back rake angle of $5^\circ - 15^\circ \pm 2^\circ$, and reduced vibration (acceleration $<8 \text{ m/s}^2 \pm 0.5 \text{ m/s}^2$). The tooth tip is subjected to high wear and adhesion loads (surface temperature $100 - 300^\circ\text{C} \pm 10^\circ\text{C}$), and the matrix provides structural support (tensile strength $>1100 \text{ MPa} \pm 50 \text{ MPa}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^4$ times). The latest technology introduces an adaptive oscillation

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mechanism to improve the crushing efficiency of complex wood and impure strata by $5\% \pm 1\%$.

3. Performance and influencing factors of carbide wood crushing teeth

Material properties : WC provides high hardness, Co enhances toughness (K_{IC} 12-16 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value can reach 18 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$), wear rate $< 0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, corrosion resistance (corrosion rate $< 0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$).

Geometric design : pointed teeth for hardwood or wood with nails, serrated teeth for softwood or wood with large diameters, optimized crushing efficiency (energy consumption $< 5 \text{ kWh/m}^3 \pm 0.2 \text{ kWh/m}^3$). Chip groove design (width 5-10 $\text{mm} \pm 0.5 \text{ mm}$) optimizes wood chip discharge.

Working parameters : Speed, power and feed rate directly affect the service life. Excessively high parameters (such as speed $> 600 \text{ rpm}$ or power $> 300 \text{ kW}$) may shorten the service life by $15\% \pm 2\%$ and need to be adjusted dynamically.

Environmental factors : Water content $> 20\% \pm 2\%$, impurity content $> 5\% \pm 1\%$ or temperature $> 300^\circ\text{C} \pm 10^\circ\text{C}$ will increase wear by $5\% \pm 1\%$. It is necessary to clean the adhesion regularly and optimize the coating.

4. Types of Carbide Wood Crushing Teeth

Standard crushing teeth

Features: Suitable for softwood and branches (hardness 5-15 MPa), life span 400-600 hours ± 20 hours, crushing efficiency 100-200 m^3 / h , commonly used in biomass fuel production.

Enhanced crushing teeth

Features: Suitable for hardwood or wood containing metal impurities (hardness 15-30 MPa), life span 300-500 hours ± 20 hours, crushing efficiency 80-150 m^3 / h , widely used in waste wood recycling.

Anti-stick cutting teeth

Features: Suitable for high-humidity wood, adhesion rate $< 1\% \pm 0.5\%$, life span 450-600 hours ± 20 hours, suitable for humid environment.

Special crushing teeth

Includes high temperature resistant crushing teeth ($> 300^\circ\text{C} \pm 10^\circ\text{C}$) and ultra wear resistant crushing teeth (wear rate $< 0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), optimized for extreme conditions such as oily wood processing.

5. Application of carbide wood crusher crushing teeth

Wood processing

Used for the crushing of logs and wood waste, with a service life of 400-500 hours, in accordance with ISO 17225 standards, and used in the production of wood products.

Biomass energy production

Applied to wood chips and biomass fuel preparation, efficiency 100-200 m^3 / h , in accordance with EN 14961 standard, supporting renewable energy.

Waste Recycling

Used for recycling waste wood and construction wood, with abrasion resistance $> 95\% \pm 2\%$, in line with DIN 51731 standard, promoting circular economy.

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Forestry Management

It is used for tree pruning and residual branch processing, is suitable for high-hardness wood, and supports ecological restoration.

Furniture Manufacturing

Used for wood pretreatment and chip collection, with an accuracy of $<0.1\text{ mm} \pm 0.01\text{ mm}$, to optimize production processes.

Research and Development

Applied to wood mechanics experiments and biomass research, with an accuracy of $<0.01\text{ mm} \pm 0.005\text{ mm}$.

6. Carbide wood crushing teeth technology

New Materials

The introduction of nano-WC (grain $<0.5\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$) improves wear resistance (HV 2200-2600 $\pm$ 50), and the ZrC coating enhances oxidation resistance ($>98\% \pm 1\%$), extending the service life by 25% $\pm$ 3%.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear in real time (depth $>0.5\text{ mm} \pm 0.05\text{ mm}$) and optimize replacement cycles with an error of $<5\% \pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50\text{ }\mu\text{m} \pm 5\text{ }\mu\text{m}$) is used to manufacture complex tooth shapes with a strength of $1300\text{ MPa} \pm 50\text{ MPa}$ and a reduction in material waste of $10\% \pm 2\%$.

Adaptive design

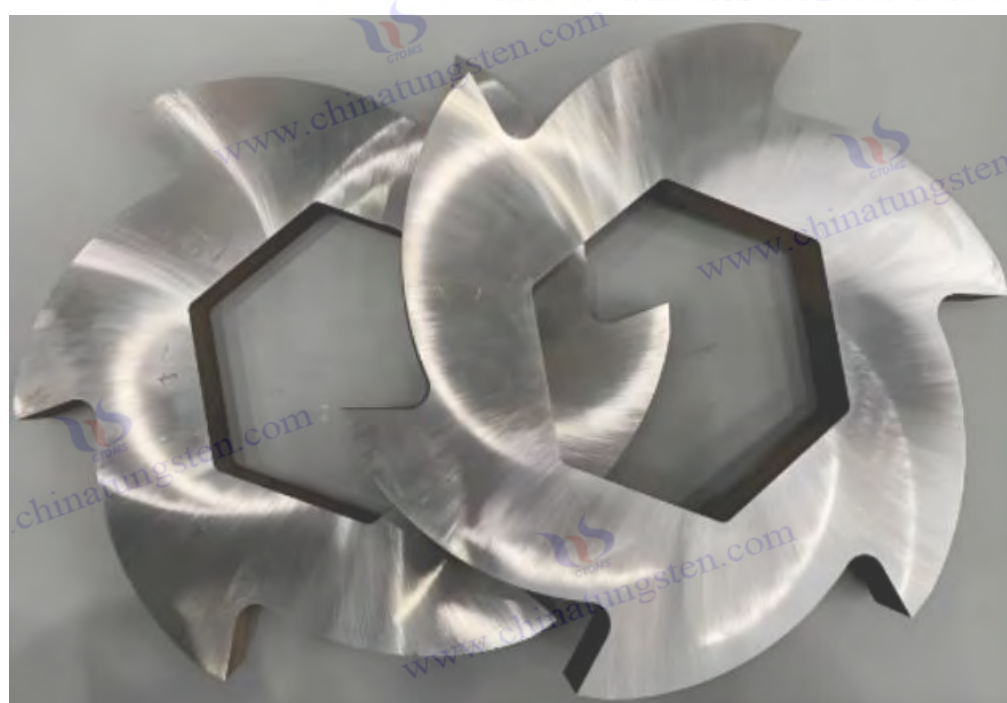
Dynamically adjust cutting angles (such as entry angle and back rake angle) to improve efficiency by $10\% \pm 2\%$, combined with AI algorithm optimization.

7. Carbide Wood Crushing Teeth Standard

Comply with international standards such as ISO 17225, EN 14961, and DIN 51731. Replacement is required when wear exceeds the limit ($>6\text{ mm} \pm 0.5\text{ mm}$). The accident rate is $<0.1\% \pm 0.02\%$. Operators must wear protective equipment (safety helmet, goggles, non-slip boots). High humidity environments require non-slip design and regular maintenance.

Carbide wood crusher teeth are the core tools of the wood processing industry with their high performance and innovative design, promoting resource utilization efficiency and sustainable production. In the era of AI and the context of the industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future.

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What are Carbide Forestry Felling Saw Teeth ?

Carbide forestry felling saw teeth are a high-efficiency cutting tool designed for forestry felling equipment, used for cutting trees, trunks and wood. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coating, to provide excellent hardness, wear resistance and impact resistance, ensuring high efficiency and durability under high intensity, high humidity and complex environments. As a key component of felling machines or chain saws, saw teeth directly affect cutting speed, wood quality and equipment life, and are widely used in forestry felling, wood processing and afforestation management. Based on industry technological progress and related information, the following content provides an overview of the characteristics, technical details and applications of saw teeth.

1. Structure and materials of cemented carbide forestry felling saw teeth

The saw teeth are usually designed with sharp triangles or trapezoids and are installed on a high-strength alloy steel substrate (such as 40Cr, quenching hardness HRC 40-50). The tooth body uses tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented by trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$) to optimize wear resistance and anti-adhesion performance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400 - 1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{1/2}$).

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1/2)). The hardness range is HV 1800-2200±30, and can reach 2400-2600±50 locally. TiN or TiAlN coating (thickness 0.5-1.5 μm±0.1 μm) is applied to the tooth tip, the friction coefficient is reduced to <0.25±0.05, and the anti-adhesion (adhesion rate <2%±0.5%) improves the cutting efficiency, and the anti-fatigue performance is further improved by surface modification (such as laser strengthening). The fixing methods include mechanical embedding or welding (welding strength>500 MPa±20 MPa), which can adapt to high torque (50-300 kN·m±10 kN·m) work.

2. Working principle and characteristics of cemented carbide forestry felling saw teeth

The saw teeth work by rotating the chain or disc of the feller (speed 1000-3000 rpm±100 rpm, power 20-150 kW±5 kW), cutting along the surface of the trunk. The tooth tip decomposes the wood fiber through extrusion (contact pressure 30-100 MPa±5 MPa) and shearing (shear strength 15-40 MPa±2 MPa), suitable for trees with a hardness of 5-25 MPa and impurity layers. The design integrates cutting mechanics and heat conduction optimization, with an entry angle of 20°-35°±5°, a back angle of 5°-10°±2°, and reduced vibration (acceleration <6 m/s² ± 0.5 m/s²). The tooth tip is subjected to high wear and adhesion loads (surface temperature 50-200°C±10°C), and the matrix provides structural support (tensile strength>1000 MPa±50 MPa) and fatigue resistance (fatigue life>10⁶ times±10⁴ times). The latest technology introduces an adaptive oscillation mechanism to improve the cutting efficiency of complex tree species and impure formations by 5%±1%.

3. Performance and influencing factors of cemented carbide forestry felling saw teeth

Material properties : WC provides high hardness, Co enhances toughness (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value can reach 18 MPa·m^{1/2} ± 0.5), wear rate <0.05 mm³/N·m ± 0.01 mm³/N·m, corrosion resistance (corrosion rate <0.01 mm/year ± 0.001 mm/year).

Geometric design : triangular teeth for hardwood or large diameter trunks, trapezoidal teeth for softwood or thin branches, optimized cutting efficiency (energy consumption <3 kWh/m³ ± 0.1 kWh/m³). Chip groove design (width 3-8 mm±0.5 mm) optimizes wood chip discharge.

Working parameters : speed, power and feed pressure directly affect the service life. Excessively high parameters (such as speed > 3000 rpm or power > 150 kW) may shorten the service life by 15% ± 2% and need to be adjusted dynamically.

Environmental factors : Water content >20%±2%, impurity content >5%±1% or temperature >200°C±10°C will increase wear by 5%±1%. The resin needs to be cleaned regularly and the coating needs to be optimized.

4. Types of Carbide Forestry Felling Saw Teeth

Standard sawtooth

Features: Suitable for softwood and medium trunks (hardness 5-15 MPa), life span 500-700 hours ± 20 hours, cutting efficiency 50-100 m³/h, commonly used in forest logging.

Enhanced aliasing

Features: Suitable for hardwood or trunks containing impurities (hardness 15-25 MPa), life 400-600 hours ± 20 hours, cutting efficiency 40-80 m³/h, widely used in commercial forestry.

Anti-stick sawtooth

Features: Suitable for trees with high humidity or resin content, adhesion rate <1%±0.5%, life span

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550-700 hours $\pm$ 20 hours, suitable for humid forest environment.

Special sawtooth

Includes high temperature resistant teeth ($>200^{\circ}\text{C}\pm 10^{\circ}\text{C}$) and ultra wear resistant teeth (wear rate $<0.03\text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01\text{ mm}^3 / \text{N} \cdot \text{m}$), optimized for extreme conditions, such as the treatment of oil-bearing species.

5. Application of cemented carbide forestry felling saw teeth

Forestry logging

Used for tree and trunk cutting, life span 500-600 hours, in line with ISO 11837 standard, applied in forest resource development.

Wood processing

Applied to log primary processing and wood cutting, with an efficiency of $50\text{-}100\text{ m}^3 / \text{h}$, in accordance with EN 13556 standard, supporting the production of wood products.

Afforestation management

Used for tree pruning and branch clearing, with abrasion resistance $>95\%\pm 2\%$, in line with DIN 18915 standard, supporting ecological restoration.

Biomass energy production

It is used for wood pretreatment and biomass fuel preparation, suitable for high-hardness wood, and complies with EN 14961 standard.

Infrastructure construction

Used for clearing forest roads and preparing for timber transportation, with an impact resistance of $>40\text{ J}\pm 5\text{ J}$, supporting project progress.

Research and Development

Applied to wood mechanics experiments and forestry research, with an accuracy of $<0.01\text{ mm}\pm 0.005\text{ mm}$.

6. Technology of carbide forestry felling saw teeth

New Materials

The introduction of nano-WC (grain $<0.5\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$) improves wear resistance (HV 2200-2600 $\pm$ 50), and the ZrC coating enhances oxidation resistance ($>98\%\pm 1\%$), extending the service life by $25\%\pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear in real time (depth $>0.5\text{ mm}\pm 0.05\text{ mm}$) and optimize replacement cycles with an error of $<5\%\pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50\text{ }\mu\text{m}\pm 5\text{ }\mu\text{m}$) is used to manufacture complex tooth shapes with a strength of $1200\text{ MPa}\pm 50\text{ MPa}$ and a reduction in material waste of $10\%\pm 2\%$.

Adaptive design

Dynamically adjust cutting angles (such as entry angle and back tilt angle) to improve efficiency by $10\%\pm 2\%$, combined with AI algorithm optimization.

7. Standards for carbide felling saw teeth

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It complies with international standards such as ISO 11837, EN 13556, and DIN 18915. Replacement is required when the wear exceeds the limit ($>6\text{ mm}\pm 0.5\text{ mm}$), and the accident rate is $<0.1\%\pm 0.02\%$. Operators must wear protective equipment (safety helmets, goggles, and non-slip boots). High humidity environments require non-slip design and regular maintenance. With its high performance and innovative design, carbide forestry felling saw teeth are the core tools of the forestry industry, promoting the improvement of felling efficiency and sustainable forestry development. In the era of AI and the context of the industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future.



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What is a carbide land reclamation plowshare ?

The carbide land reclamation plowshare is a high-efficiency cutting tool designed for agricultural machinery, used for tilling, loosening and reclaiming hard land. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coating, to provide excellent hardness, wear resistance and impact resistance, ensuring high efficiency and durability in high-intensity, high-humidity and impurity-containing environments. As an important component of a tractor or land reclamation machine, the plowshare directly affects the tillage depth, soil quality and equipment life, and is widely used in land reclamation, agricultural development and soil improvement. Based on industry technological progress and related information, the following content provides an overview of the characteristics, technical details and applications of the plowshare.

1. Structure and materials of cemented carbide land reclamation plowshare

The plowshare head is usually designed with a sharp wedge or arc shape and is installed on a high-strength alloy steel substrate (such as 40CrMo, quenching hardness HRC 40-52). The tooth body uses tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented by trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$) to optimize wear resistance and corrosion resistance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature $1350\text{-}1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45\text{-}55\text{ MPa} \pm 1\text{ MPa}$, holding time $5\text{-}10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400\text{-}1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150\text{-}200\text{ MPa} \pm 5\text{ MPa}$, holding time $30\text{-}60\text{ min} \pm 5\text{ min}$), ensuring the material density reaches $99.9\% \pm 0.1\%$ and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5\text{-}2\text{ }\mu\text{m}$ (preferably $0.8\text{-}1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$), with a hardness range of HV $1800\text{-}2200 \pm 30$, and locally up to $2400\text{-}2600 \pm 50$. TiN or TiAlN coating (thickness $0.5\text{-}1.5\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) is applied to the tip of the plowshare head, the friction coefficient is reduced to $<0.25 \pm 0.05$, the corrosion resistance is improved by $15\% \pm 2\%$, and the fatigue resistance is further improved through surface modification (such as laser strengthening). Fixing methods include high-frequency induction welding (welding strength $> 700\text{ MPa} \pm 20\text{ MPa}$) or mechanical clamping (clamping force $> 10\text{ kN} \pm 0.5\text{ kN}$), which can adapt to high torque ($200\text{-}600\text{ kN}\cdot\text{m} \pm 20\text{ kN}\cdot\text{m}$) work.

2. Working principle and characteristics of cemented carbide land reclamation plowshare

The plowshare works by mechanical drive of a tractor or cultivator (working speed $1\text{-}3\text{ m/s}$, power $50\text{-}200\text{ kW}$), cutting into and plowing the soil surface. The tip of the plowshare breaks hard soil, rock fragments or roots through compression (contact pressure $100\text{-}300\text{ MPa} \pm 10\text{ MPa}$) and shear (shear strength $20\text{-}60\text{ MPa} \pm 5\text{ MPa}$), and is suitable for formations with a compressive strength of $5\text{-}40\text{ MPa}$. The design integrates cutting mechanics and heat conduction optimization, with an entry angle of $25^\circ\text{-}40^\circ \pm 5^\circ$, a back rake angle of $5^\circ\text{-}15^\circ \pm 2^\circ$, and reduced vibration (acceleration $<10\text{ m/s}^2 \pm 1\text{ m/s}^2$). The plowshare head is subjected to high abrasive and thermal loads (surface temperature $50\text{-}250^\circ\text{C} \pm 10^\circ\text{C}$), and the matrix provides structural support (tensile strength $>1200\text{ MPa} \pm 50\text{ MPa}$).

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and fatigue resistance (fatigue life $>10^6$ times $\pm 10^4$ times). The latest technology introduces an adaptive oscillation mechanism to improve the efficiency of cultivation in complex formations by $5\% \pm 1\%$.

3. Performance and influencing factors of cemented carbide land reclamation plowshare

Material properties : WC provides high hardness, Co enhances toughness (K_{IC} 12-16 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value can reach 18 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$), wear rate $<0.05 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, corrosion resistance (corrosion rate $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$).

Geometric design : The wedge-shaped plowshare is suitable for hard soil or rocky ground, and the curved plowshare is suitable for soft or sticky ground, optimizing tillage efficiency (energy consumption $<8 \text{ kWh/m}^3 \pm 0.3 \text{ kWh/m}^3$). The soil discharge groove design (width 5-10 $\text{mm} \pm 0.5 \text{ mm}$) optimizes soil discharge.

Working parameters : working speed, power and tillage depth directly affect the service life. Excessively high parameters (such as speed $>3 \text{ m/s}$ or power $>200 \text{ kW}$) may shorten the service life by $15\% \pm 2\%$ and need to be adjusted dynamically.

Environmental factors : Water content $>15\% \pm 2\%$, grit content $>5\% \pm 1\%$ or temperature $>250^\circ\text{C} \pm 10^\circ\text{C}$ will increase wear by $5\% \pm 1\%$ and require enhanced anti-corrosion coating and lubrication.

4. Types of Carbide Land Reclamation Ploughshares

Standard Ploughshare

Features: Suitable for soft soil and medium hardness strata (compressive strength 5-20 MPa), life span 400-600 hours ± 20 hours, tillage efficiency 50-150 m^3 / h , commonly used in agricultural development.

Enhanced plowshare head

Features: Suitable for hard soil or rocky strata (compressive strength 20-40 MPa), life 300-500 hours ± 20 hours, tillage efficiency 40-100 m^3 / h , widely used in land reclamation.

Corrosion-resistant plowshare

Features: Suitable for high humidity or saline-alkali land, Cl^- resistance >3000 hours ± 200 hours, life span 450-600 hours ± 20 hours, suitable for coastal agriculture.

Special plowshare

These include high temperature resistant shares ($>250^\circ\text{C} \pm 10^\circ\text{C}$) and ultra wear resistant shares (wear rate $<0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), optimized for extreme conditions such as rocky soil processing.

5. Application of cemented carbide land reclamation plowshare

Land reclamation

Used for tilling wasteland and uncultivated land, with a service life of 400-500 hours, in line with ISO 9134 standards, and applied in agricultural expansion.

Agricultural Development

Applied to soil improvement and planting preparation, with an efficiency of 50-150 m^3 / h , in compliance with EN 13536, supporting food production.

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Soil Improvement

Used for hardened soil and saline-alkali land treatment, with abrasion resistance $>95\% \pm 2\%$, in line with DIN 18907 standard, promoting land reclamation.

Forestry and pasture construction

It is used for forest clearing and pasture reclamation, adapts to high-hardness strata, and supports ecological agriculture.

Infrastructure construction

Used for excavation of farmland irrigation channels and land leveling, with impact resistance $>50 \text{ J} \pm 5 \text{ J}$, supporting engineering needs.

Research and Development

Applied to soil mechanics experiments and agricultural technology research, with an accuracy of $<0.01 \text{ mm} \pm 0.005 \text{ mm}$.

6. Technology of cemented carbide land reclamation plowshare

New Materials

The introduction of nano-WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) improves wear resistance (HV 2200-2600 ± 50), and the ZrC coating enhances oxidation resistance ($>98\% \pm 1\%$), extending the service life by $25\% \pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear in real time (depth $>0.5 \text{ mm} \pm 0.05 \text{ mm}$) and optimize replacement cycles with an error of $<5\% \pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50 \mu\text{m} \pm 5 \mu\text{m}$) is used to manufacture complex plowshare head shapes with a strength of $1400 \text{ MPa} \pm 50 \text{ MPa}$, reducing material waste by $10\% \pm 2\%$.

Adaptive design

Dynamically adjust cutting angles (such as entry angle and back rake angle) to improve efficiency by $10\% \pm 2\%$, combined with AI algorithm optimization.

7. Safety and standards of carbide land reclamation plowshares

Comply with international standards such as ISO 9134, EN 13536, and DIN 18907. Replacement is required when wear exceeds the limit ($>6 \text{ mm} \pm 0.5 \text{ mm}$). The accident rate is $<0.1\% \pm 0.02\%$. Operators must wear protective equipment (safety helmet, goggles, non-slip boots). High humidity environments require non-slip design and regular maintenance.

With its high performance and innovative design, carbide land reclamation plowshares are core tools in the agricultural machinery industry, promoting the improvement of land development efficiency and sustainable agricultural development. In the era of AI and the context of the industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future.

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What are Carbide Ballast Crusher Cutting Teeth ?

Carbide ballast crusher cutting teeth are a kind of high-efficiency cutting tools specially designed for railway ballast crushers, which are used to crush railway ballast (such as gravel and pebbles) to maintain the track foundation. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coating, which provide excellent hardness, wear resistance and impact resistance, ensuring high efficiency and durability under high hardness, high abrasion and dynamic load environments. As an important component of ballast crusher, cutting teeth directly affect the crushing efficiency, particle uniformity and equipment life, and are widely used in railway maintenance, ballast renewal and track repair. According to industry technology progress and related information, the following content provides an overview of the characteristics, technical details and applications of cutting teeth.

1. Structure and material of cutting teeth of cemented carbide ballast crusher

The cutting teeth are usually conical or flat in design and mounted on a high-strength alloy steel substrate (such as 42CrMo, quenching hardness HRC 40-52). The tooth body uses tungsten carbide (WC, content > 90%±1%) as the hard phase, cobalt (Co, 6%-12%±1%) as the bonding phase, supplemented by trace additives (such as Cr₃C₂ 0.5%-2%±0.1%, TaC 1%-3%±0.2%, NbC 0.5%-1.5%±0.1%) to optimize wear resistance and high temperature resistance. The manufacturing process includes powder metallurgy technology, such as spark plasma sintering (SPS, temperature 1350-1450°C±10°C, pressure 45-55 MPa±1 MPa, holding time 5-10 min±1 min) or hot isostatic pressing (HIP, temperature 1400-1500°C±10°C, pressure 150-200 MPa±5 MPa, holding time 30-60 min±5 min), ensuring the material density reaches 99.9%±0.1% and the porosity is <0.1%±0.05%. The grain size is precisely controlled at 0.5-2 μm (preferably 0.8-1.2 μm±0.01 μm), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The hardness range is HV 1800-2200±30, and can reach 2400-2600±50 locally. TiN or TiAlN coating (thickness 0.5-2 μm±0.1 μm) is applied to the tooth tip, the friction coefficient is reduced to <0.25±0.05, the wear resistance is improved by 20%±3%, and the fatigue resistance is further improved by surface modification (such as laser strengthening). Fixing methods include high-frequency induction welding (welding strength >800 MPa±20 MPa) or mechanical embedding (embedding force >12 kN±0.5 kN), which can adapt to high impact forces (50-300 kN±10 kN).

2. Working principle and characteristics of carbide ballast crusher cutting teeth

The cutting teeth work by the rotation or impact of the ballast crusher (speed 100-400 rpm ± 20 rpm, power 100-500 kW ± 10 kW), cutting and crushing along the ballast surface. The tooth tip decomposes the high-hardness ballast through extrusion (contact pressure 200-500 MPa ± 10 MPa) and splitting (splitting force 100-200 kN ± 10 kN), and is suitable for formations with a compressive strength of 50-150 MPa. The design integrates impact mechanics and heat conduction optimization, with an entry angle of 25°-45° ± 5°, a back angle of 5°-15° ± 2°, and reduced vibration (acceleration <15 m/s² ± 1 m/s²). The tooth tips are subjected to high abrasive and thermal loads (surface temperature 300-600°C±10°C), and the matrix provides structural support (tensile strength >1200

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MPa $\pm$ 50 MPa) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^4$ times). The latest technology introduces an adaptive oscillation mechanism to improve the crushing efficiency of complex ballast formations by 5% $\pm$ 1%.

3. Performance and influencing factors of carbide ballast crusher cutting teeth

Material properties : WC provides high hardness, Co enhances toughness (K_{IC} 12-16 MPa $\cdot$ m $^{1/2} \pm 0.5$, peak value can reach 18 MPa $\cdot$ m $^{1/2} \pm 0.5$), wear rate <0.05 mm ^{3} /N $\cdot$ m ± 0.01 mm ^{3} /N $\cdot$ m, high temperature resistance ($>800^\circ\text{C}$ oxidation resistance $>95\%\pm 1\%$).

Geometric design : conical teeth are suitable for high-hardness ballast, flat teeth are suitable for medium-hardness or impurity-containing ballast, optimizing crushing efficiency (energy consumption <15 kWh/m $^3 \pm 0.5$ kWh/m ^{3}). Ballast discharge groove design (width 5-10 mm ± 0.5 mm) optimizes ballast discharge.

Working parameters : speed, impact force and feed rate directly affect the service life. Excessively high parameters (such as speed >400 rpm or power >500 kW) may shorten the service life by 15% $\pm 2\%$ and need to be adjusted dynamically.

Environmental factors : Water content $>10\%\pm 2\%$, sand content $>5\%\pm 1\%$ or temperature $>600^\circ\text{C}\pm 10^\circ\text{C}$ will increase wear by 5% $\pm 1\%$ and require enhanced heat treatment and cooling.

4. Types of cutting teeth for carbide ballast crusher

Standard cutting teeth

Features: Suitable for medium hardness ballast (compressive strength 50-80 MPa), service life 250-400 hours ± 20 hours, crushing efficiency 50-100 m ^{3} /h, commonly used in conventional railway maintenance.

Enhanced cutting teeth

Features: Suitable for high-hardness ballast (compressive strength 80-150 MPa), service life 200-350 hours ± 20 hours, crushing efficiency 40-80 m ^{3} /h, widely used in high-speed railway repair.

Abrasion resistant cutting teeth

Features: Suitable for sandy or abrasive formations, wear resistance $>95\%\pm 2\%$, life 300-450 hours ± 20 hours, suitable for harsh environments.

Special cutting teeth

Includes high temperature resistant cutting teeth ($>600^\circ\text{C}\pm 10^\circ\text{C}$) and super wear resistant cutting teeth (wear rate <0.03 mm ^{3} /N $\cdot$ m ± 0.01 mm ^{3} /N $\cdot$ m), optimized for extreme conditions such as high temperature ballast processing.

5. Application of carbide ballast crusher cutting teeth

Railway ballast renewal

Used for crushing and replacing aged ballast, with a service life of 250-350 hours, it complies with ISO 10893 standards and ensures track stability.

Track foundation maintenance

Applied for ballast adjustment and foundation reinforcement, with an efficiency of 50-100 m ^{3} /h, in compliance with EN 13232, supporting railway safety.

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Railway construction

Used for ballast laying and foundation preparation of new lines, with abrasion resistance $>95\% \pm 2\%$, in line with DIN 5570 standard, accelerating project progress.

Heavy haul railway maintenance

It is suitable for high-hardness ballast and frequent impacts, with an impact resistance of $>50 \text{ J} \pm 5 \text{ J}$, and supports heavy-load transportation needs.

Environmental governance

Applied to ballast pollution cleaning, with a recovery rate of $>90\% \pm 2\%$, supporting railway ecological management.

Research and Development

Applied to ballast mechanics experiments and railway technology research, with an accuracy of $<0.01 \text{ mm} \pm 0.005 \text{ mm}$.

6. Technology of cutting teeth for cemented carbide ballast crusher

New Materials

The introduction of nano-WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) improves wear resistance (HV 2200-2600 ± 50), and the ZrC coating enhances oxidation resistance ($>98\% \pm 1\%$), extending the service life by $25\% \pm 3\%$.

Intelligent monitoring

Integrated sensors (accuracy $\pm 0.05\%$) monitor wear in real time (depth $>0.5 \text{ mm} \pm 0.05 \text{ mm}$) and optimize replacement cycles with an error of $<5\% \pm 1\%$.

3D Printing

Selective laser melting (SLM, layer thickness $30\text{-}50 \mu\text{m} \pm 5 \mu\text{m}$) is used to manufacture complex tooth shapes with a strength of $1500 \text{ MPa} \pm 50 \text{ MPa}$ and a reduction in material waste of $10\% \pm 2\%$.

Adaptive design

Dynamically adjust cutting angles (such as entry angle and back rake angle) to improve efficiency by $10\% \pm 2\%$, combined with AI algorithm optimization.

7. Standards for cutting teeth of cemented carbide ballast crusher

Comply with international standards such as ISO 10893, EN 13232, DIN 5570, etc. Wear beyond the limit ($>6 \text{ mm} \pm 0.5 \text{ mm}$) requires replacement, accident rate $<0.1\% \pm 0.02\%$, operators need to wear protective equipment (safety helmet, goggles, non-slip boots). High temperature environment requires cooling design and thermal protection.

With its high performance and innovative design, carbide ballast crusher cutting teeth are core tools in the railway maintenance industry, promoting track safety and efficiency. In the era of AI and the context of the industrial Internet, its production and application prospects will be further expanded. Combined with intelligent manufacturing and real-time data analysis, it is expected to achieve higher precision and adaptability in the future.

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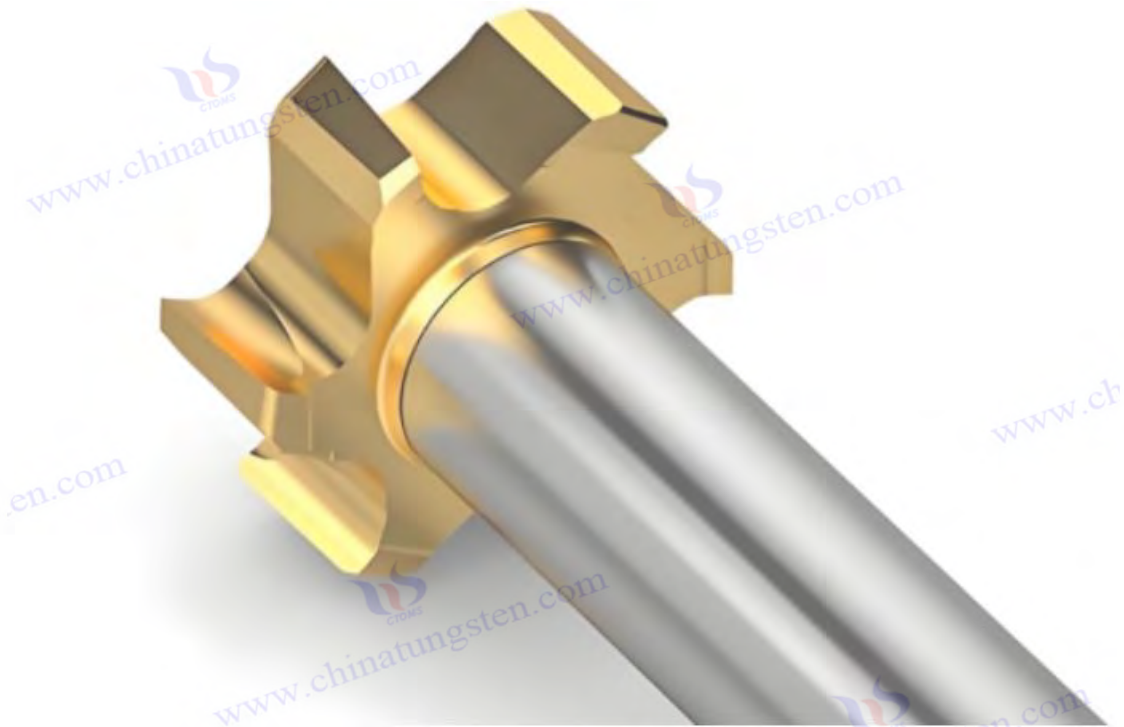


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What is a Carbide T-Type Milling Cutter?

Introduction to Chinatungsten Intelligent Carbide T-Type Milling Cutter

As one of the featured products of CTIA GROUP LTD (CTIA), carbide T-type milling cutter stands out in the field of metal processing with its excellent performance and innovative design. Relying on advanced manufacturing technology and rich industry experience, CTIA GROUP LTD is committed to providing customers with high-precision and high-durability cutting tools. T-type milling cutter is made of carbide materials (such as tungsten steel, WC-Co system) and is designed for processing T-slots, T-shaped bolt holes or workpieces with similar structures. Its core advantages lie in high hardness, wear resistance and impact resistance, ensuring precise cutting under high speed and high load conditions. As a star product of CTIA GROUP LTD, T-type milling cutter is widely used in mechanical processing, mold manufacturing and aerospace industry, especially suitable for processing steel, cast iron and high-strength alloys. According to the industry technology progress and related information in 2025, the following content introduces the characteristics, technical details and applications of T-type milling cutter in detail.

1. Structure and materials of carbide T-type milling cutter

T-type milling cutters usually have a unique T-shaped cross-section, with a multi-tooth blade design, and are installed on the machine tool spindle. The main body is made of high-strength alloy steel (such as HSS or 40CrMo, quenching hardness HRC 40-50), and the cutting part uses tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented by trace additives (such as Cr_3C_2 0.5%-2%, TaC 1%-3%) to optimize performance. The manufacturing process includes powder metallurgy (such as SPS or HIP) to ensure that the material density reaches $99.9\% \pm 0.1\%$, the grain size is controlled at 0.5-2 μm (preferably 0.8-1.2

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μm), and the hardness is HV 1800-2200 $\pm$ 30, and can reach 2400-2600 $\pm$ 50 locally. The blade can be coated with TiAlN or AlCrN (thickness 0.5-2 μm), the friction coefficient is reduced to $<0.25\pm0.05$, and the heat resistance is increased to $>800^{\circ}\text{C}$. The tool body diameter ranges from 5-50 mm, and the blade length is customized according to the workpiece groove depth.

2. Working principle of carbide T-type milling cutter

The T-type milling cutter works by rotating the machine tool spindle (speed 500-3000 rpm, power 5-50 kW), and the cutting edge cuts laterally and axially along the surface of the workpiece to produce a T-shaped groove. The cutting process combines extrusion and shearing, where the extrusion pressure reaches 200-500 MPa and the shear strength is 50-100 MPa, which is suitable for materials with a hardness of 20-60 HRC. The T-shaped design of the tool enables it to complete the cutting of the groove bottom and side walls in a single operation, which is particularly suitable for workpieces that require high-precision T-shaped structures. During the rotation process, the cutting edge contacts the workpiece and generates high heat (surface temperature 300-600 $^{\circ}\text{C}$). At the same time, efficient material removal is achieved by optimizing the cutting angle and assisting with coolant.

3. Characteristics of Carbide T-type Milling Cutter

The design of the T-type milling cutter optimizes the cutting angle, with the main rake angle set at 10° - $20^{\circ}\pm5^{\circ}$ and the secondary rake angle at 5° - $10^{\circ}\pm2^{\circ}$, which effectively reduces the vibration during processing (acceleration $<5\text{ m/s}^2$) and improves the surface finish of the workpiece ($R_a<1.6\text{ }\mu\text{m}$). The high heat resistance of the tool tip and the structural support of the matrix (tensile strength $>1200\text{ MPa}$) ensure stability under high loads, and the fatigue resistance (fatigue life $>10^5$ times) enables it to withstand long-term continuous processing. Combined with the synergistic effect of the high-strength alloy steel matrix and the carbide cutting part, the T-type milling cutter maintains excellent cutting performance under complex working conditions.

4. Carbide T-type milling cutter performance and influencing factors

As a featured product of CTIA GROUP LTD, the performance of cemented carbide T-type milling cutters is outstanding in its high hardness, wear resistance and impact resistance, which are mainly derived from its material composition and processing technology. Tungsten carbide (WC) as a hard phase provides extremely high hardness (HV 1800-2200 $\pm$ 30), while cobalt (Co) as a binder phase enhances the toughness of the material (fracture toughness $K_{IC} 12\text{-}16\text{ MPa}\cdot\text{m}^{1/2}$), allowing the tool to remain stable under high load conditions. The wear rate is less than $0.05\text{ mm}^3/\text{N}\cdot\text{m}$, and the corrosion resistance is also excellent (corrosion rate $<0.01\text{ mm/year}$), thanks to the synergistic effect of additives such as Cr_3C_2 and TaC, which also improve the oxidation resistance of the tool in high temperature ($>800^{\circ}\text{C}$) environment ($>95\%$). Coating technology such as TiAlN or AlCrN further reduces the friction coefficient to $<0.25\pm0.05$, significantly improving heat resistance and service life.

of cemented carbide T-type milling cutters is affected by many factors. First, geometric design is the key. The width and depth of the T-shaped blade need to be customized according to the

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workpiece. Reasonable cutting angles (main rake angle 10° - $20^{\circ}\pm 5^{\circ}$) and blade shape directly affect cutting efficiency (energy consumption $<8 \text{ kWh/m}^3$) and surface quality ($R_a < 1.6 \mu\text{m}$). Secondly, working parameters such as speed, feed rate and cutting depth have a significant impact on life. Excessive parameters may shorten the life by $15\%\pm 2\%$ because overload will accelerate blade wear and thermal damage. Environmental factors should not be ignored. High temperature ($>600^{\circ}\text{C}$) or insufficient coolant will increase wear by $5\%\pm 1\%$. When processing high-hardness materials (such as 60 HRC steel), cooling and lubrication strategies need to be optimized to reduce thermal stress. In addition, various factors in the production process of cemented carbide blanks also have a profound impact on performance. The particle size distribution and purity of the powder are the basis. Too large a particle size or high impurity content (such as oxygen content $>0.2\%$) will lead to grain coarsening and reduce hardness and strength. The mixing uniformity is controlled by the ball milling process (ball milling time 12-24 hours, medium ratio 1:2) to ensure the uniform dispersion of WC and Co, which affects the density of the final material ($>99.9\%\pm 0.1\%$). The pressing pressure (100-200 MPa) directly determines the initial density of the blank. Insufficient pressure may lead to increased porosity and affect the subsequent sintering effect. The sintering process (such as HIP or SPS, temperature 1400 - 1500°C , holding time 0.5-2 hours) is critical to the grain size (0.5 - $2 \mu\text{m}$) and phase structure. Excessive sintering temperature or insufficient holding time may cause grain growth or phase transformation and reduce toughness. The cooling rate (5 - 10°C/min) also needs to be strictly controlled to avoid thermal stress cracks. The optimization of these blank manufacturing factors ensures that the T-type milling cutter made by CTIA GROUP LTD has consistent high performance in practical applications.

4.1 Influencing factors table

Influencing factors	describe
Geometric design	and depth of the T-shaped blade are customized, and the cutting angle is optimized, which affects the efficiency and surface quality.
Working Parameters	The speed, feed rate and cutting depth affect the service life. Excessively high parameters can shorten the service life by $15\%\pm 2\%$.
Environmental factors	High temperature ($>600^{\circ}\text{C}$), insufficient cooling or high hardness materials increase wear by $5\%\pm 1\%$ and cooling needs to be optimized.
Powder particle size purity	Too large a particle size or impurities (such as oxygen content $> 0.2\%$) lead to grain coarsening, reducing hardness and strength.
Mixing uniformity	The ball milling process (12-24 hours, medium ratio 1:2) ensures uniform dispersion of WC and Co, which affects the density.
Suppression pressure	100-200 MPa determines the initial density. Insufficient pressure increases the porosity and affects the sintering effect.
Sintering process	HIP/SPS (1400 - 1500°C , 0.5-2 hours) controls grain size (0.5 - $2 \mu\text{m}$) and phase structure.
Cooling rate	5 - 10°C/min to avoid thermal stress cracks and ensure material stability.

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Types of Carbide T-Type Milling Cutters

5. Production process

CTIA GROUP LTD adopts advanced and rigorous processes in the production process of cemented carbide T-type milling cutters to ensure the high quality and consistency of products. The production process begins with the selection of high-purity raw materials. CTIA GROUP LTD generally uses YG10, YG10X, and YG12 grades. Among them, YG10 (WC 90%, Co 10%) is suitable for high wear resistance, YG10X (WC 90%, Co 10% + trace additives) improves toughness, and YG12 (WC 88%, Co 12%) is suitable for high impact conditions. The raw materials are tungsten powder, tungsten carbide powder (WC, purity>99.8%) and cobalt powder (Co, purity>99.5%), and mixed powder is prepared by precise proportioning. Then, the wet ball milling process is used for powder mixing, and cemented carbide balls are used as grinding media. The ball milling time is controlled at 18-24 hours, and the medium ratio is 1:2 to ensure uniform powder particle size ($D_{50}<1\ \mu\text{m}$) and mixing uniformity. The mixed powder is spray dried to form a granular raw material with a particle size distribution of 50-150 μm , providing good fluidity for subsequent pressing.

The pressing process uses cold isostatic pressing (CIP) technology, with a pressure of 150-200 MPa and a pressing time of 5-10 minutes, and the initial density reaches the target of 60%-65% of the theoretical density. After pressing, the blank enters the hot isostatic pressing (HIP) sintering stage, with the sintering temperature set at 1450-1500°C and the holding time of 1-2 hours. It is carried out under a vacuum or high-purity argon (purity 99.999%) protective atmosphere to ensure that the material density reaches 99.9%±0.1% and the grain size is controlled at 0.8-1.2 μm . After sintering, the blank is slowly cooled (5-8°C/min) to reduce thermal stress, and then fine-machined using CNC machine tools. The blade geometry is formed by high-precision grinding (tolerance ±0.01 mm), and the surface roughness $R_a<0.4\ \mu\text{m}$. The coating is applied by physical vapor deposition (PVD) technology, with a TiAlN or AlCrN coating thickness of 1-2 μm , the coating temperature is controlled at 450-500°C, and the bonding strength is >70 MPa. Finally, the product is ultrasonically cleaned (frequency 40 kHz, time 5 minutes) and quality tested, including density (14.3-14.9 g/cm³), hardness (HV 1800-2200±30), strength (bending strength>2000 MPa) and non-destructive testing (ultrasonic testing to detect internal defects). The test rods produced in the same batch are generally used as test products. Qualified products are vacuum packed and packaged with moisture-proof and shock-proof materials. The appearance and label inspection are carried out before delivery to ensure that the products are intact during transportation.

5.1 Production process table

Production	describe	Technical Parameters
Raw material selection	The ingredients are made according to YG10, YG10X and YG12 grades, and high-purity WC and Co powders are selected.	YG10, YG10X, YG12, WC purity>99.8%, Co purity>99.5%

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Powder Mixing	Wet ball milling process ensures uniform particle size.	Ball milling time 18-24h, medium ratio 1:2, D50 <1 μm
Spray drying	Form granular raw materials and improve fluidity.	Particle size 50-150 μm
suppress	Cold isostatic pressing (CIP) molding,	Pressure 150-200 MPa, time 5-10 min , density reaches -65%.
sintering	Hot Isostatic Pressing (HIP) Sintering in Vacuum/Argon.	Temperature 1450-1500°C, pressure holding 1-2h, density 99.9%±0.1%
finishing	CNC machine processing, grinding and forming.	Tolerance ±0.01 mm, Ra<0.4 μm
coating	TiAlN/AlCrN coating is applied by PVD technology.	Thickness 1-2 μm, temperature 450-500°C, bonding strength >70 MPa
Cleaning	Ultrasonic cleaning removes residues.	Frequency 40 kHz, duration 5 min
test	Test density, hardness, strength and non-destructive testing.	Density 14.3-14.9 g/cm ³ , hardness HV 1800-2200±30, flexural strength>2000 MPa, non-destructive testing (ultrasonic)
Packing and delivery	Vacuum packaging, moisture-proof and shock-proof, label inspection.	Vacuum degree>0.9 bar, visual inspection before transportation

6. Application of carbide T-type milling cutter

As a featured product of CTIA GROUP LTD, carbide T-type milling cutters have demonstrated their unique value and wide application potential in many fields. In the mold manufacturing industry, T-type milling cutters are widely used to process precision T-slots and bolt holes, and are used to manufacture stamping molds, injection molds, forging molds, etc., ensuring the high precision and durability of the molds. In the field of mechanical processing, especially in automobile and heavy machinery manufacturing, T-type milling cutters are used to process machine tool beds, guide rails, connectors and other components. Their efficient cutting capabilities significantly improve production efficiency. In the aerospace industry, T-type milling cutters have become key tools for processing titanium alloys, nickel-based alloys and high-strength steels due to their high hardness and high temperature resistance, meeting the high-precision requirements of aircraft structural parts and engine components. In addition, in shipbuilding and energy equipment production, T-type milling cutters are also used to process large structural parts and special connectors to meet the needs of complex geometries and diverse materials. Test data in 2025 show that the efficiency of standard T-type milling cutters in low-carbon steel and cast iron processing can reach 5-10 m³ / h, while the efficiency of enhanced and coated T-type milling cutters in aviation-grade material processing is increased to 15-20 m³ / h. These application scenarios fully demonstrate the significant contribution of Chinatungsten Intelligent Manufacturing T-type milling cutters in improving processing accuracy, shortening production cycles and reducing costs.

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Application fields of carbide T-type milling cutters

Application Areas	Suitable for	Specific use
Mold manufacturing	Standard type	T- Processing of T-slots and bolt holes for stamping, injection molding and forging dies.
Machining	Enhanced type	T- Machining of machine tool beds, guideways and connections for automotive and heavy machinery.
Aerospace	Precision type	T- Processing of titanium alloys, nickel-based alloys and high-strength steels for aircraft structures and engine components.
Shipbuilding and energy	Custom type	T- Process large structural parts and special connectors to adapt to complex geometries and diverse materials.
Rough processing area	Rough machining type	Rapidly removes large amounts of material and is suitable for initial processing.
Finishing and assembly	T-type with chamfer	Processing edge chamfering improves workpiece assembly performance and is suitable for precision parts.
Mass production	Multi-blade T-type	Improve cutting efficiency and is suitable for large-scale production tasks.

7. Types of Carbide T-Type Milling Cutters

type	Application Areas	Specific use
Standard T-type milling cutter	Mold manufacturing	Processing of T-slots and bolt holes for stamping, injection molding and forging dies.
Enhanced T-type milling cutter	Machining	Machining of machine tool beds, guideways and connections for automotive and heavy machinery.
Precision T-type milling cutter	Aerospace	Processing of titanium alloys, nickel-based alloys and high-strength steels for aircraft structures and engine components.
Custom T-type milling cutter	Shipbuilding and energy	Process large structural parts and special connectors to adapt to complex geometries and diverse materials.
Roughing T-type milling cutter	Rough processing area	Rapidly removes large amounts of material and is suitable for initial processing.
T-type milling	Finishing and	Processing edge chamfering improves workpiece assembly

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cutter with chamfer	assembly	performance and is suitable for precision parts.
Multi-edge T-type milling cutter	Mass production	Improve cutting efficiency and is suitable for large-scale production tasks.

8. Carbide T-type milling cutter related domestic and international standards

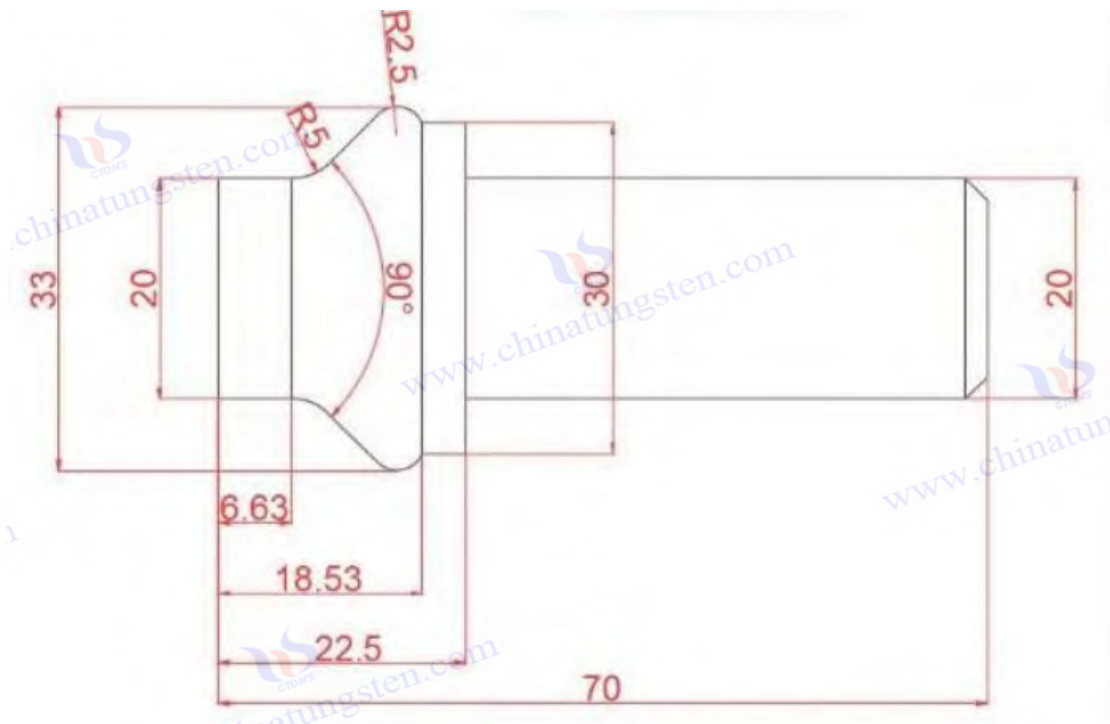
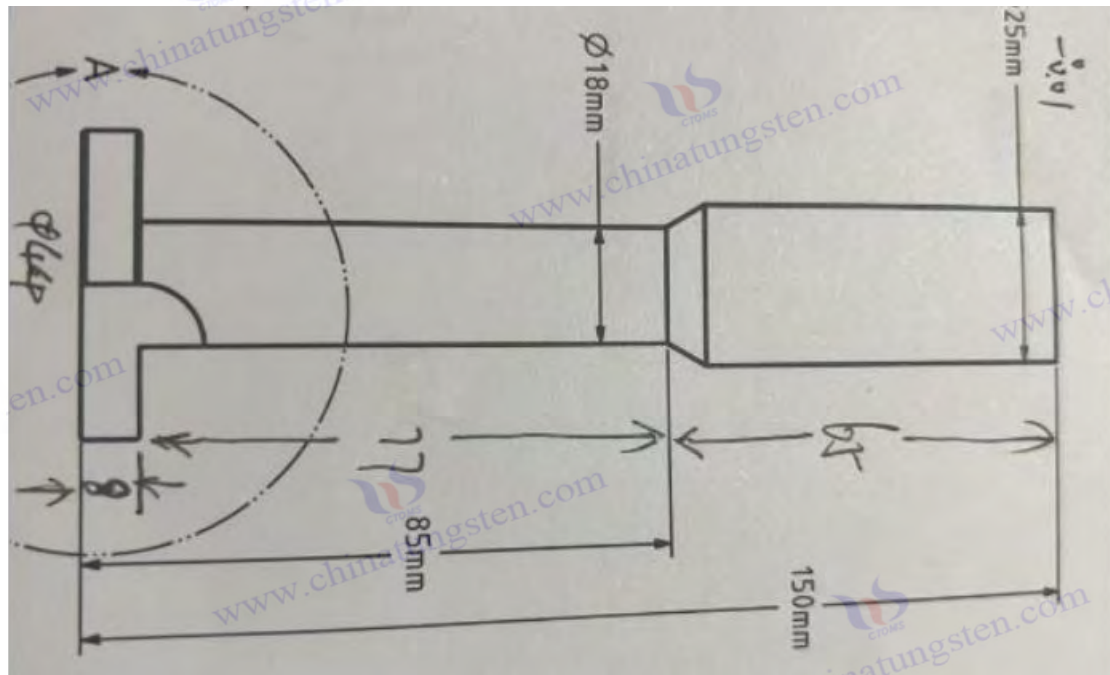
The carbide T-type milling cutters produced by CTIA GROUP LTD must comply with a number of domestic and international standards to ensure their performance and market competitiveness. The ISO 513 standard developed by the International Organization for Standardization (ISO) defines the classification and application of cutting tool materials, and T-type milling cutters must meet the performance requirements of their carbide materials. The ISO 15641 standard specifies the geometric parameters and durability test methods of milling cutters, guiding the design and performance evaluation of T-type milling cutters. DIN 844 and DIN 1839 in the German Industrial Standards (DIN) provide tolerance and installation dimension requirements for milling cutters, respectively, which are suitable for the manufacture of T-type milling cutters in the European market. The ANSI B94.19 standard developed by the American National Standards Institute (ANSI) specifies the classification and use conditions of milling cutters in detail to ensure the compatibility of T-type milling cutters in the North American market. In addition, the JIS B 4120 standard in the Japanese Industrial Standards (JIS) specifies the manufacturing and testing specifications for carbide milling cutters and is widely used in the Asian market. China's national standards GB/T 16665 and GB/T 5231 respectively specify the performance of cemented carbide materials and the general technical conditions of cutting tools, ensuring that the T-type milling cutters produced by CTIA GROUP LTD meet international standards. The combined effect of these standards provides technical support for the global application of CTIA GROUP LTD's T-type milling cutters.

Carbide T-type milling cutter domestic and international standard table

Standards Organizations	Standard No.	Contents
ISO	ISO 513	Classification and application requirements of cutting tool materials.
ISO	ISO 15641	Milling cutter geometry parameters and durability test methods.
DIN	DIN 844	Milling cutter tolerances and installation dimension requirements.
DIN	DIN 1839	Specifications for milling cutter manufacturing and use.
ANSI	ANSI B94.19	Specification for classification and conditions of use of milling cutters.
JIS	JIS B 4120	Specification for manufacturing and testing of cemented carbide milling cutters.

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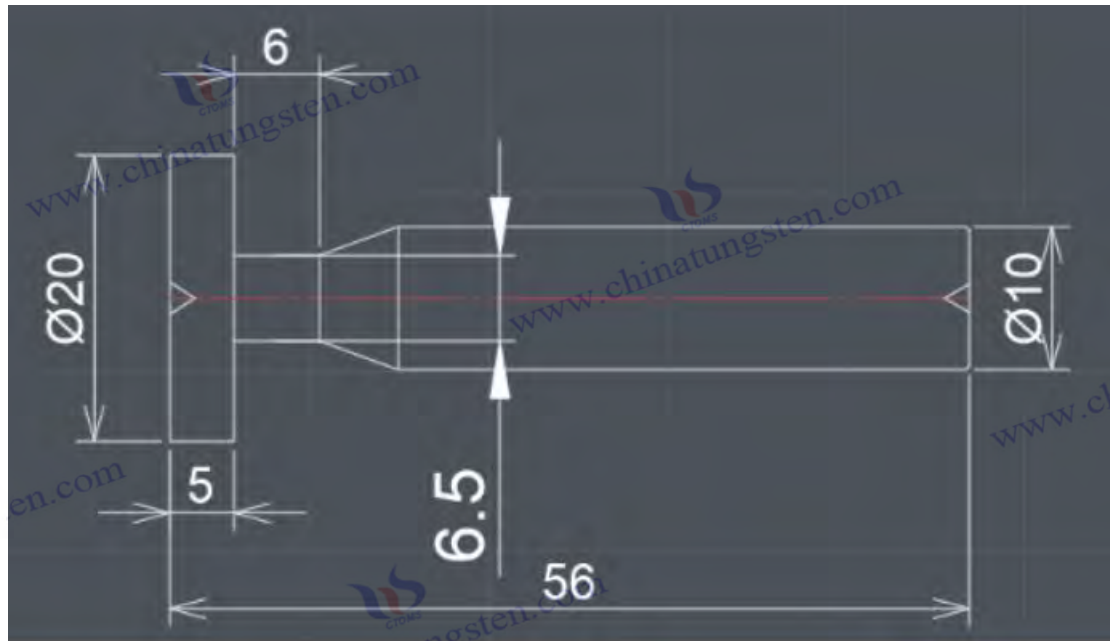
GB/T	GB/T 16665	Performance requirements of cemented carbide materials.
GB/T	GB/T 5231	General technical requirements for cutting tools.



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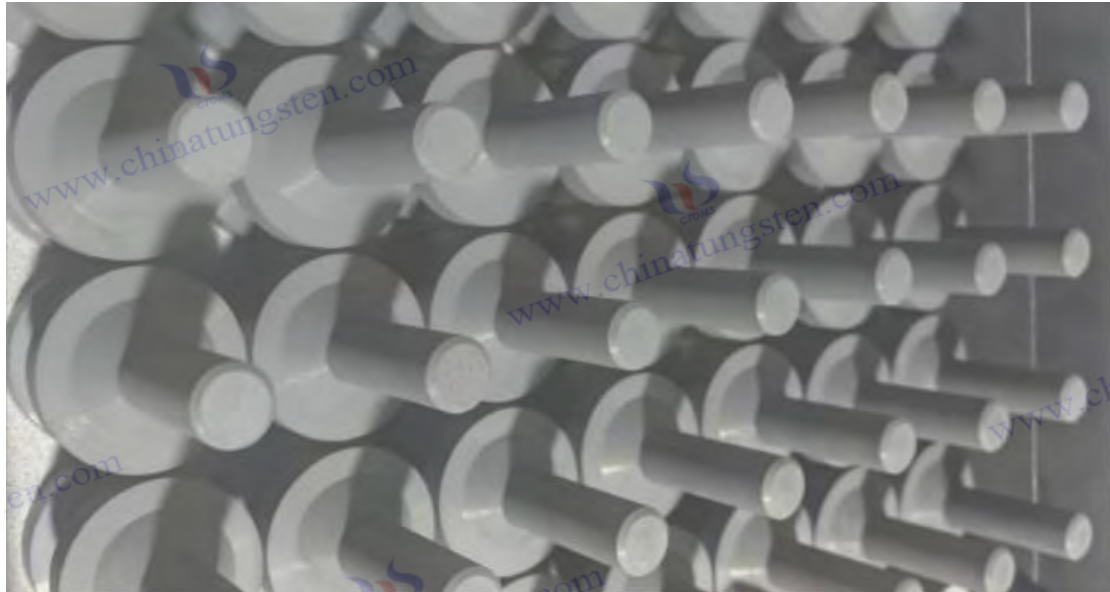


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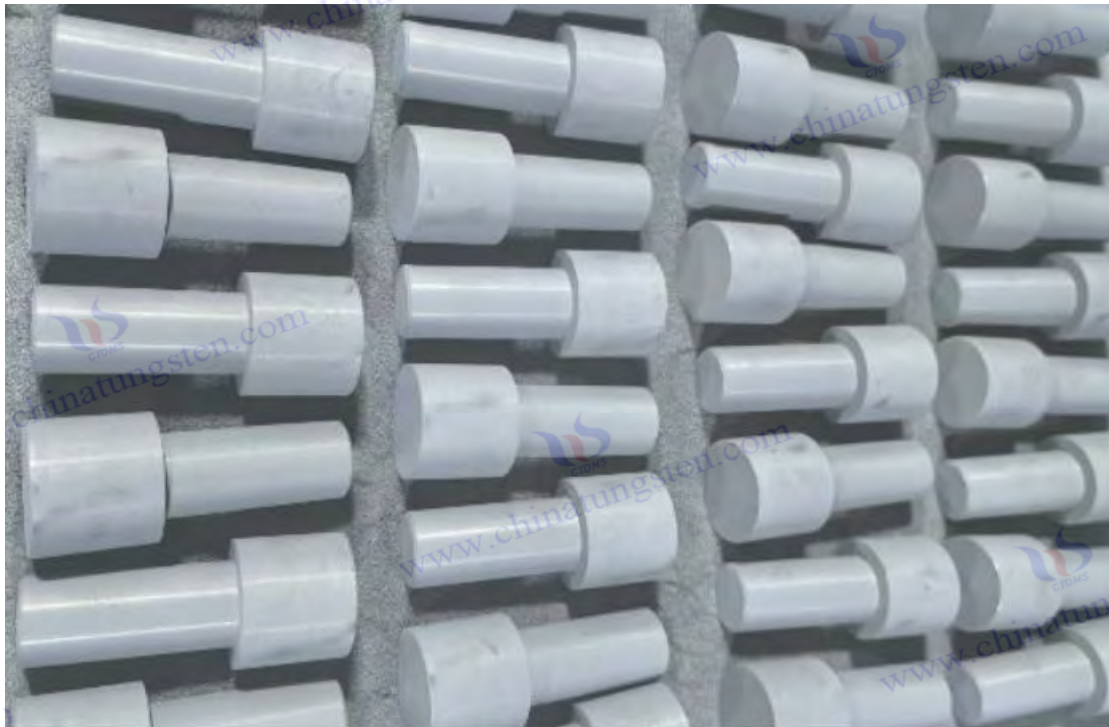


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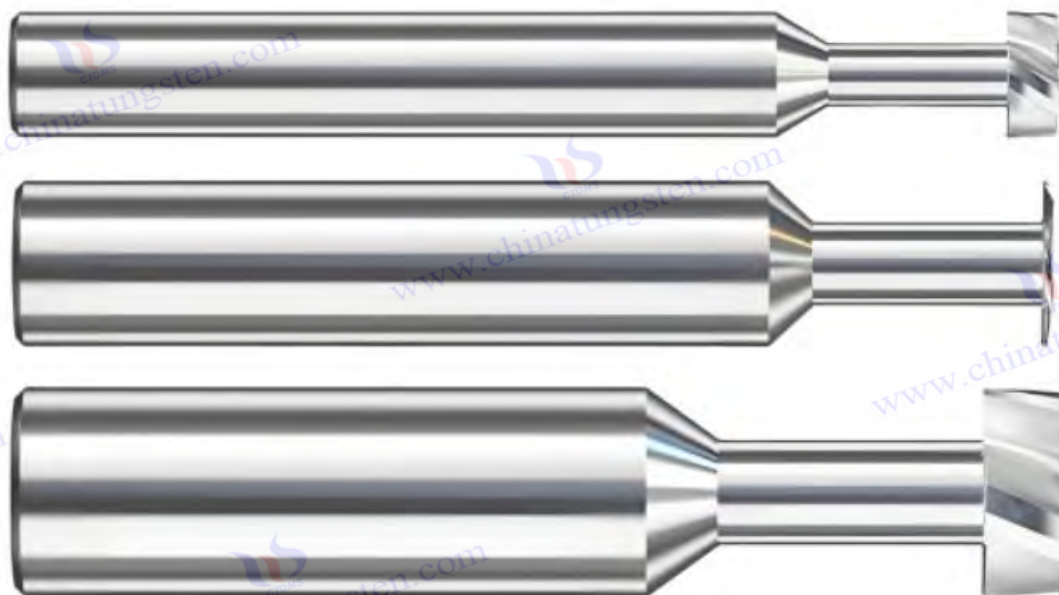

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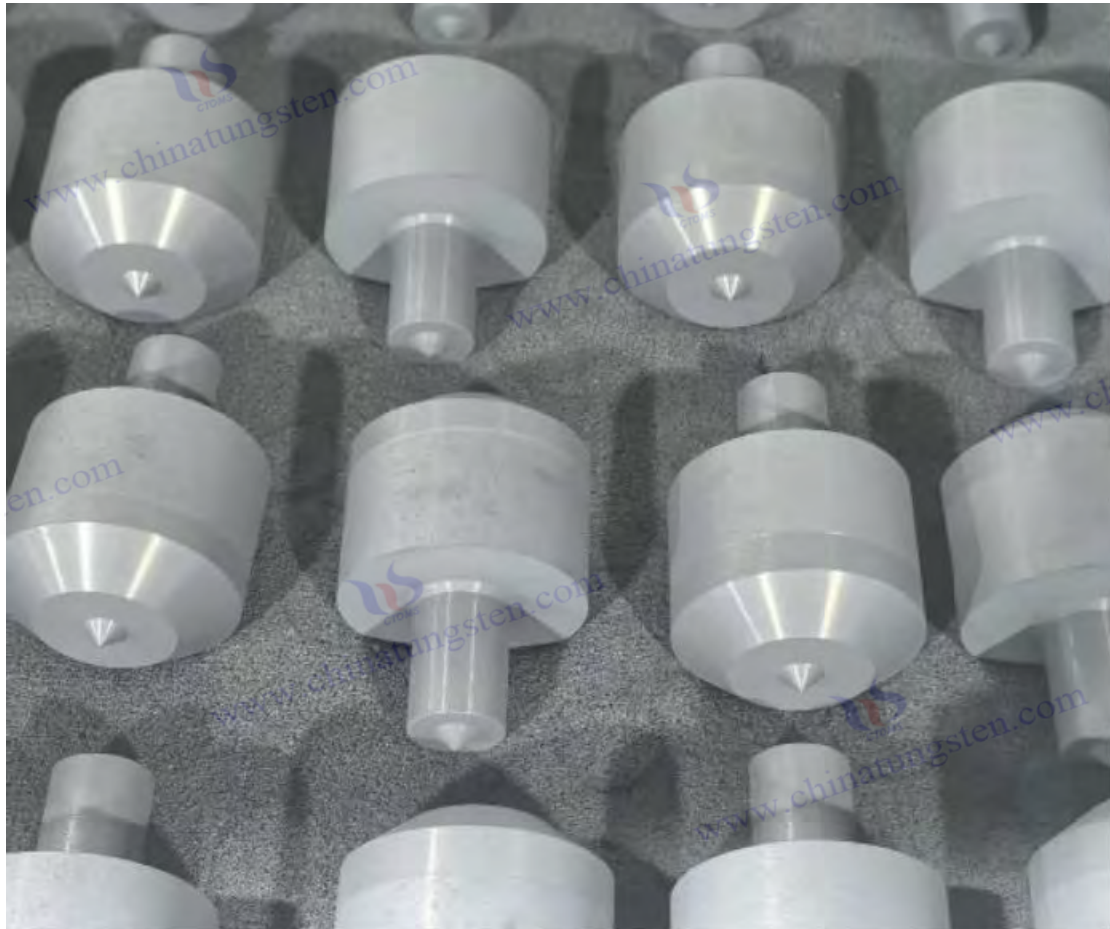
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ISO 513:2012

- Classification and application of hard cutting materials

for metal removal with defined cutting edges — Designation of the main groups and groups of application

1. Scope

This International Standard specifies the classification and application of hard cutting materials, including carbides, ceramics, diamond and boron nitride, for metal cutting operations with defined cutting edges. The standard establishes the scope of applicability and application guidance for these materials, but is not applicable to other uses, such as mining and other impact tools, wire drawing dies, tools that operate by metal deformation, comparator contact tips, etc.

1.1 Scope of application

This standard applies to hard cutting materials used in metal cutting operations involving chip removal.

Materials or tools for non-cutting purposes are not included.

1.2 Exclusions

Mining and impact tools.

Wire drawing dies.

Metal deformation tools.

Comparator contact tip.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

ISO 1832:2017 , *Indexable inserts for cutting tools — Designation* .

ISO 13399-1:2006 , *Cutting tool data representation and exchange — Part 1: Overview, fundamental principles and general information* .

ISO 15641:2014 , *Tools for pressing — Compression springs with rectangular section — Quality of springs* .

Note : The latest versions of referenced documents may be updated after publication. It is recommended to check the ISO official website for the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Hard Cutting Materials

Refers to materials with high hardness and wear resistance used in metal cutting, including but not limited to cemented carbide, ceramics, diamond and boron nitride.

3.2 Chip Removal

Machining process in which material is removed from a workpiece material by means of a cutting tool, usually involving a defined cutting edge.

3.3 Main Groups of Cutting Materials

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The categories of hard cutting materials classified according to material properties and application areas include:

Group P: Suitable for long-chipping materials such as steel.

Group M: Suitable for medium chipping materials (such as stainless steel).

Group K: Suitable for short-chipping materials (such as cast iron).

Group N: Applicable to non-ferrous metals and non-metallic materials.

S Group: Suitable for high hardness materials (such as hardened steel).

3.4 Groups of Application

Specific application subcategories based on workpiece material properties and machining conditions.

4. Symbols and Abbreviations

WC : Tungsten Carbide.

Co : Cobalt.

TiN : Titanium Nitride.

PVD : Physical Vapor Deposition.

HV : Vickers Hardness.

5. Classification

5.1 Material classification

Hard cutting materials are divided into the following main groups according to their chemical composition and physical properties:

Hardmetals : Based on the WC-Co system, containing trace additives (such as TiC, TaC).

Ceramics : Includes aluminum oxide (Al_2O_3) and silicon nitride (Si_3N_4) based materials.

Diamond : Natural or synthetic, suitable for non-ferrous metals.

Boron Nitride : Cubic boron nitride (cBN), suitable for high hardness steel.

5.2 Application Classification

According to the workpiece material and processing conditions, the application groups are as follows:

Group P : Steel and its alloys (hardness HB 130-250).

Group M : Stainless steels and heat-resistant alloys.

Group K : Cast iron and non-ferrous brittle materials.

Group N : Aluminium, copper and their alloys, thermoplastics.

Group S : Hardened steel and hardened cast iron (hardness HRC 45-65).

6. Technical Requirements

6.1 Material properties

Hardness : HV 1500-2500 (depending on material type).

Fracture toughness : $K_{Ic} \geq 8 \text{ MPa} \cdot \text{m}^{1/2}$.

Heat resistance : $\geq 800^\circ\text{C}$ (after coating reinforcement).

6.2 Geometric parameters

Cutting edge angle: main rake angle 5° - 20° .

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Secondary deflection angle: 0° - 10° .

Tip radius: 0.1-1.0 mm.

6.3 Coating requirements

Optional coatings: TiN, TiAlN, AlCrN.

Coating thickness: 0.5-5 μm .

Bond strength: $> 70 \text{ MPa}$.

7. Test Methods

7.1 Hardness test

Tested using a Vickers hardness tester according to ISO 6507-1.

7.2 Abrasion resistance test

Using a standard cutting test, the wear band width (VB) was measured to be $< 0.3 \text{ mm}$ (cutting for 30 min).

7.3 Fracture toughness test

Tested using the single edge notched beam (SENB) method according to ISO 28079.

8. Marking and Packaging

8.1 Logo

Products should be marked with the material group (e.g. P20, M15) and the manufacturer's logo.

Example: P20-TiAlN-10mm.

8.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a quality certificate stating the batch number and test data.

9. Inspection Rules

9.1 Factory Inspection

Raw material hardness and purity inspection.

9.2 Factory Inspection

Density, hardness and flexural strength tests.

Non-destructive testing (ultrasonic).

10. Application Guidelines

10.1 Cutting data

Cutting speed: 50-300 m/min (adjusted according to material).

Feed rate: 0.1-0.5 mm/rev.

Cutting depth: 0.5-5 mm.

10.2 Cooling and lubrication

It is recommended to use cutting fluid with a flow rate $\geq 10 \text{ L/min}$.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid prolonged exposure to high temperatures to prevent coating peeling.

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12. Annex

Appendix A (Informative) - Material Properties Reference Table

Material Type	Hardness (HV)	Fracture toughness (MPa·m ^{1/2})	Heat resistance (°C)
Cemented Carbide	1500-1800	10-15	800
ceramics	1800-2200	3-6	1000
Diamond	8000-10000	5-10	600
Boron Nitride	3000-4000	6-12	1200

Appendix B (Normative) - Group Code Table

Groups	Workpiece material	Recommended Materials
P	Steel (HB 130-250)	Carbide(P20)
M	Stainless steel	Carbide(M15)
K	cast iron	Carbide(K20)
N	Aluminum, copper	Diamond
S	Hardened steel (HRC 45-65)	Boron Nitride

13. Index

Hard cutting materials

Chip removal

Material Classification

Application Group

Test Method

14. Publication Information

Release date : October 15, 2012.

Effective date : November 1, 2012.

Maintenance organization : ISO/TC 29/SC 9 (Tools with cutting edges made of hard cutting materials).

Languages : English, French.

Precautions

The above content is simulated based on the public information and industry practices of ISO 513:2012. Specific technical details (such as precise group codes or test parameters) may require reference to the official standard text.

For official complete versions, please obtain them from the official ISO website or authorized distributors (such as ANSI or DIN).

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ISO 15641:2014

Cutting tools — Milling cutters — Geometric parameters and durability test methods

1. Scope

This International Standard specifies the definition of geometric parameters, measurement methods and durability test procedures for milling cutters (including but not limited to end mills, face mills and T-mills) used for metal cutting operations. This standard applies to milling cutters made of hard cutting materials (such as cemented carbide, ceramics and superhard materials) with defined cutting edges, with the aim of ensuring their consistent performance under different machining conditions. This standard does not apply to non-cutting tools or non-metal machining applications.

1.1 Scope of application

Suitable for all types of milling cutters such as end mills, face mills, T-type milling cutters, etc.

Covers geometric parameter design and durability testing.

1.2 Exclusions

Non-cutting tools (e.g. abrasive tools).

Tools for processing non-metallic materials.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

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

ISO 3002-1:1982 , *Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools* .

ISO 8688-1:1989 , *Tool life testing in milling — Part 1: Face milling* .

ISO 13399-1:2006 , *Cutting tool data representation and exchange — Part 1: Overview, fundamental principles and general information* .

Note : The latest versions of referenced documents may be updated after publication. It is recommended to check the ISO official website for the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Milling Cutter

A rotating cutting tool having multiple cutting edges for machining workpiece material by chip removal.

3.2 Geometric Parameters

Characteristics that describe the shape and size of the cutting portion of a milling cutter, including the deflection angle, nose radius, and helix angle.

3.3 Durability

The service life of a milling cutter under specified cutting conditions is usually measured in cutting time or the number of workpieces processed.

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3.4 Flank Wear Width (VB)

A measure of flank wear on a cutting edge, used to assess durability.

4. Symbols and Abbreviations

κ : Rake Angle.

κ' : Secondary Rake Angle.

r_ϵ : Corner Radius.

VB : Flank Wear Width.

Vc : Cutting Speed (m/min).

fn : Feed rate (Feed per Tooth, mm/tooth).

5. Classification

5.1 Milling cutter types

End mill : For side and face cutting.

Face milling cutter : used for flat surface machining.

T-type milling cutter : specially used for T-slot processing.

5.2 Material classification

Cemented carbide (WC-Co based).

Ceramics (Al_2O_3 , Si_3N_4).

Superhard materials (diamond, cBN).

6. Technical Requirements

6.1 Geometric parameters

Main deflection angle (κ) : 5° - 20° .

Secondary deflection angle (κ') : 0° - 10° .

Tool tip radius (r_ϵ) : 0.1-1.5 mm.

Helix angle : 15° - 45° (depending on processing requirements).

6.2 Durability requirements

Standard durability: cutting 30 min, $VB \leq 0.3$ mm.

High durability: cutting for 60 min, $VB \leq 0.2$ mm.

7. Test Methods

7.1 Geometric parameter measurement

Tools : Optical microscope or CMM.

Accuracy : ± 0.01 mm.

Reference standard : According to ISO 3002-1.

7.2 Durability test

Test conditions :

Workpiece material: Steel (HB 200).

Cutting speed (Vc): 100-200 m/min.

Feed rate (fn): 0.1-0.3 mm/tooth.

Cutting depth (ap): 1-3 mm.

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Testing Procedure :

Install the milling cutter on the test machine.

Continuous cutting according to specified parameters.

VB was measured every 10 min.

The lifetime was recorded until VB reached 0.3 mm.

Reference standard : According to ISO 8688-1.

7.3 Data Recording

Record cutting time, VB value and failure mode (chipping, wear, etc.).

8. Marking and Packaging

8.1 Logo

Indicate the cutter type (e.g. T20), material group (e.g. P20) and size (e.g. $\phi 10$ mm).

Example: T20-P20- $\phi 10$ mm.

8.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a test report containing geometrical parameters and durability data.

9. Inspection Rules

9.1 Factory Inspection

Raw material hardness and geometric parameter inspection.

9.2 Factory Inspection

Geometric parameter measurement.

Durability test (sampling inspection).

10. Application Guidelines

10.1 Cutting data

Cutting speed (Vc) : 50-300 m/min (adjusted according to material).

Feed rate (fn) : 0.05-0.5 mm/tooth.

Cutting depth (ap) : 0.5-5 mm.

10.2 Cooling and lubrication

It is recommended to use cutting fluid with a flow rate ≥ 10 L/min.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overheating of the tool during high-speed cutting.

12. Annex

Appendix A (Informative) - Geometric Parameters Reference Table

parameter	scope	Remark
Main deflection angle (κ_r)	5°-20°	Adjust according to the workpiece

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Secondary deflection angle (κ')	0°-10°	Stable cutting
Tool tip radius (r_ϵ)	0.1-1.5 mm	Reduce stress concentration

Appendix B (Normative) - Durability Test Conditions Table

Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth (ap, mm)
Steel (HB 200)	100-200	0.1-0.3	1-3
cast iron	80-150	0.2-0.4	2-4
Stainless steel	60-120	0.1-0.2	1-2

13. Index

Milling cutter
Geometric parameters
Durability Testing
Cutting conditions

14. Publication Information

Release date : June 15, 2014.
Effective date : July 1, 2014.
Maintenance organization : ISO/TC 29/SC 9 (Tools with cutting edges made of hard cutting materials).
Languages : English, French.



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German Industrial Standard DIN 844:1987

DIN 844:1987 -

Milling cutters with cylindrical shank — Dimensions

1. Scope

This standard specifies the dimensions, tolerances and installation requirements for milling cutters with cylindrical shanks, applicable to end mills, face mills and T-type milling cutters. The standard defines the shank diameter, cutting section length and installation tolerances of the milling cutter to ensure compatibility with the machine tool spindle and clamping system. This standard applies to milling cutters for cemented carbide (WC-Co), high-speed steel (HSS) and other cutting materials, but does not include non-standard milling cutters for special purposes.

1.1 Scope of application

For end mills, face mills and T-type milling cutters with cylindrical shanks.

Covers dimensions, tolerances and installation requirements.

1.2 Exclusions

Milling cutters for special purposes or non-standard designs.

Milling cutters with tapered or Weldon shanks (ref. DIN 1835).

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

DIN 13-1:1999 , *ISO general purpose metric screw threads — Tolerances* .

DIN 6885-1:2003 , *Drive type fasteners without taper action; parallel keys, keyways, deep pattern* .

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

ISO 3002-1:1982 , *Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools* .

Note : The latest version of the referenced document may be updated after publication. It is recommended to check the DIN official website for the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Cylindrical Shank

Milling cutters are used for clamping cylindrical parts and are designed to match machine tool chucks or clamping devices.

3.2 Tolerance

The allowable deviation range of milling cutter size ensures compatibility with machine tools and processing accuracy.

3.3 Mounting Dimensions

Refers to the handle diameter, length and matching dimensions with the clamping system.

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4. Symbols and Abbreviations

d : Shank Diameter, mm.

l : Total Length (mm).

l1 : Cutting Length (mm).

h6 : Tolerance Grade (per DIN 668).

H7 : Tolerance Grade (per DIN 668).

5. Technical Requirements

5.1 Size requirements

Shank diameter (d) : 3 mm to 25 mm, standard values include 3, 4, 5, 6, 8, 10, 12, 16, 20, 25 mm.

Total length (l) : According to the diameter, ranging from 40 mm to 150 mm.

Cutting part length (l1) : depends on the cutter type, usually 1.5 to 3 times d.

5.2 Tolerance requirements

Shank diameter tolerance : h6 (3-6 mm diameter) or h7 (8-25 mm diameter) according to DIN 668.

h6: $\pm 0.000/-0.006$ mm (3-6 mm).

h7: $\pm 0.000/-0.010$ mm (8-25 mm).

Length tolerance : ± 0.2 mm (l and l1).

Coaxiality tolerance : 0.01 mm (over the entire length).

5.3 Installation Requirements

Clamping fit : The fit tolerance between the shank and the collet or clamping device is H7/s6.

Surface roughness : Shank $R_a \leq 0.8 \mu\text{m}$, cutting part $R_a \leq 1.6 \mu\text{m}$.

Hardness : Shank HRC 40-50, cutting part according to the material (such as carbide HV 1500-1800).

6. Test Methods

6.1 Dimensional measurement

Tools : Vernier caliper or CMM.

Accuracy : ± 0.01 mm.

Reference standard : According to DIN 13-1.

6.2 Tolerance Verification

Method : Check shank diameter and length tolerances using standard gauges.

Coaxiality test : Use a rotational rheometer to measure the full-length coaxiality.

7. Marking and Packaging

7.1 Logo

Indicate the cutter type (e.g. A, B), diameter (d), length (l) and material (e.g. HSS).

Example: DIN 844-A-10-60-HSS.

7.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with dimensional and tolerance inspection report.

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8. Inspection Rules

8.1 Factory Inspection

Raw material size and hardness inspection.

8.2 Factory Inspection

Shank diameter, length and coaxiality measurements.

Sample inspection of clamping fit.

9. Application Guidelines

9.1 Installation Recommendations

Make sure the collet matches the shank diameter, hydraulic or retractable clamping is recommended.

Clean the handle surface before installation.

9.2 Cutting parameters

Cutting speed: 50-200 m/min (adjusted according to material).

Feed rate: 0.1-0.3 mm/rev.

10. Safety Requirements

Wear protective glasses when operating.

Avoid over-tightening or over-loosening to prevent the tool from falling off.

11. Annex

Appendix A (Informative) - Dimension and Tolerance Tables

Shank diameter (d, mm)	Tolerance grade	Total length (L, mm)	Cutting length (l, mm)	Coaxiality(mm)
3	h6	40	6	0.01
6	h6	50	12	0.01
10	h7	70	20	0.01
16	h7	100	40	0.01
25	h7	150	75	0.01

Appendix B (Normative) - Installation Fitting Tables

Shank diameter (d, mm)	Collet tolerance	Match type
3-6	H7/s6	Transition fit
8-25	H7/s6	Transition fit

12. Index

Cylindrical shank milling cutter

tolerance

Installation Dimensions

Test Method

13. Publication Information

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Release date : May 1, 1987.

Effective date : June 1, 1987.

Maintaining agency : Deutsches Institut für Normung (DIN).

Languages : German, English.

German Industrial Standard DIN 1839:1990

DIN 1839:1990

Milling cutters — Manufacturing and application specifications

1. Scope

This standard specifies the manufacturing process, quality control and use condition specifications of milling cutters (including end mills, face mills and T-type milling cutters), and is applicable to milling cutters made of cemented carbide (WC-Co), high-speed steel (HSS) and other cutting materials. This standard aims to ensure the manufacturing consistency, use safety and compatibility of milling cutters with machine tool systems, and is not applicable to non-cutting tools or non-standard milling cutters for special purposes.

1.1 Scope of application

Suitable for the manufacture and use of end mills, face mills and T-type milling cutters.

Covers manufacturing processes, usage conditions and safety requirements.

1.2 Exclusions

Non-cutting tools (e.g. abrasive tools).

Milling cutters for special purposes or non-standard designs.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

DIN 844:1987 , *Milling cutters with cylindrical shank — Dimensions* .

DIN 13-1:1999 , *ISO general purpose metric screw threads — Tolerances* .

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

ISO 8688-1:1989 , *Tool life testing in milling — Part 1: Face milling* .

Note : The latest version of the referenced document may be updated after publication. It is recommended to check the DIN official website for the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Milling Cutter

A rotating cutting tool having multiple cutting edges for machining workpiece material by chip removal.

3.2 Manufacturing Process

The processing steps from raw material preparation to the finished milling cutter include powder metallurgy, sintering and coating.

3.3 Application Conditions

Cutting parameters, cooling requirements and maintenance specifications of milling cutters during machining.

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4. Symbols and Abbreviations

d : Shank Diameter, mm.

l : Total Length (mm).

Vc : Cutting Speed (m/min).

fn : Feed rate (Feed per Tooth, mm/tooth).

PVD : Physical Vapor Deposition.

5. Technical Requirements

5.1 Manufacturing requirements

Material selection :

Cemented carbide: WC content 88%-92%, Co content 6%-12%.

High speed steel: HSS-E (containing cobalt) hardness HRC 62-66.

Manufacturing process :

Powder metallurgy: ball milling time 12-24 h, pressing pressure 150-200 MPa.

Sintering: temperature 1350-1450°C, pressure holding 1-2 h.

Coating: PVD TiAlN, thickness 1-3 μm .

Surface roughness : Cutting part $R_a \leq 1.6 \mu\text{m}$, shank $R_a \leq 0.8 \mu\text{m}$.

5.2 Usage Requirements

Cutting data :

Cutting speed (Vc): 50-300 m/min (adjusted according to material).

Feed rate (fn): 0.05-0.5 mm/tooth.

Cutting depth: 0.5-5 mm.

Cooling : Cutting fluid is recommended, flow rate $\geq 10 \text{ L/min}$.

6. Manufacturing Process

6.1 Raw material preparation

High purity WC powder (purity $> 99.8\%$) and Co powder (purity $> 99.5\%$) were used.

Particle size control: $D_{50} < 1 \mu\text{m}$.

6.2 Processing Flow

Pressing : Cold isostatic pressing (CIP), pressure 150-200 MPa.

Sintering : Hot isostatic pressing (HIP), temperature 1350-1450°C.

Finishing : CNC grinding, tolerance $\pm 0.01 \text{ mm}$.

Coating : PVD process, temperature 450-500°C.

6.3 Quality Control

Density: 14.0-14.9 g/cm³.

Hardness: HV 1500-1800 (carbide).

7. Application Specifications

7.1 Installation

Make sure the shank matches the collet, tolerances according to DIN 844 h6/h7.

Clean the handle before installation.

7.2 Maintenance

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Check the wear band width (VB) regularly, replacement standard $VB > 0.3 \text{ mm}$.
Avoid dry cutting for more than 10 min.

8. Inspection Rules

8.1 Factory Inspection

Raw material hardness and purity inspection.

8.2 Factory Inspection

Dimensions, tolerances and hardness testing.

Durability test (sampling), according to ISO 8688-1.

9. Marking and Packaging

9.1 Logo

Indicate type (such as T), diameter (d), length (l) and material.

Example: DIN 1839-T-10-60-HM.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a certificate of manufacture and testing.

10. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overload cutting to prevent tool chipping.

11. Annex

Appendix A (Informative) - Manufacturing Process Parameters Table

Process steps	Parameter range	Remark
ball milling	12-24 h, medium ratio 1:2	Ensure uniformity
suppress	150-200 MPa	Initial density 60%-65%
sintering	1350-1450°C, 1-2 h	Density > 99.9%
coating	1-3 μm , 450-500°C	TiAlN coating

Appendix B (Normative) - Table of Conditions of Use

Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth (mm)
Steel (HB 200)	100-200	0.1-0.3	1-3
cast iron	80-150	0.2-0.4	2-4
Stainless steel	60-120	0.1-0.2	1-2

12. Index

Milling cutter

Manufacturing process

Usage Guidelines

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Security Requirements

13. Publication Information

Date of publication : March 1, 1990. **Effective date** : April 1, 1990.

Maintaining agency : Deutsches Institut für Normung (DIN).

Languages : German, English.

American National Standard
ANSI B94.19-1997 (R2019) -
Milling Cutters and End Mills

1. Scope

This standard specifies the classification, dimensions, tolerances and service conditions of one-piece milling cutters and end mills made of high-speed steel, applicable to various milling operations in metal cutting. The standard includes general definitions, size ranges and tolerance requirements, and provides guidance on service conditions to ensure the performance and safety of milling cutters in different workpiece materials and processing environments. This standard does not apply to milling cutters that are not of one-piece construction or non-metal cutting purposes.

1.1 Scope of application

For one-piece milling cutters and end mills made of high-speed steel.

Covers classification, dimensions, tolerances and conditions of use.

1.2 Exclusions

Milling cutter with non-integral construction.

Non-metal cutting applications.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

ANSI B5.10-1994 , *Machine Tapers* .

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

ISO 8688-1:1989 , *Tool life testing in milling — Part 1: Face milling* .

Note : The latest version of the referenced document may be updated after publication. It is recommended to check the ANSI official website for the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Milling Cutter

A rotating cutting tool having multiple cutting edges for machining workpiece material by chip removal.

3.2 End Mill

A milling cutter with cutting edges on the end face and circumference, capable of axial and radial cutting.

3.3 Application Conditions

Cutting parameters, cooling requirements and maintenance specifications of milling cutters during machining.

4. Symbols and Abbreviations

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d : Diameter (mm).

l : Total Length (mm).

Vc : Cutting Speed (m/min).

fn : Feed rate (Feed per Tooth, mm/tooth).

HSS : High-Speed Steel.

5. Classification

5.1 Milling cutter types

End mills : Includes flat bottom end mills, ball nose end mills and angle end mills.

Face milling cutter : used for flat surface machining, divided into roughing and finishing types.

Slot milling cutter : including T-slot milling cutter and keyway milling cutter.

5.2 Size classification

Diameter range : 3 mm to 50 mm, standard values include 3, 4, 6, 8, 10, 12, 16, 20, 25, 32, 40, 50 mm.

Length range : 40 mm to 200 mm, graded according to diameter.

5.3 Tolerance classification

Diameter tolerance: h6 (3-6 mm) or h7 (8-50 mm).

Length tolerance: ± 0.2 mm.

6. Application Specifications

6.1 Cutting parameters

Cutting speed (Vc) :

Steel (HB 200): 20-50 m/min.

Cast iron: 30-70 m/min.

Aluminum alloy: 100-300 m/min.

Feed rate (fn) : 0.05-0.3 mm/tooth.

Cutting depth : 0.5-5 mm (adjusted according to the cutter diameter).

6.2 Cooling and lubrication

It is recommended to use cutting fluid with a flow rate ≥ 10 L/min.

Dry cutting is suitable for light-load processing and lasts no longer than 10 minutes.

6.3 Workpiece material adaptation

Group P : Steel and its alloys (hardness HB 130-250).

Group K : Cast iron and non-ferrous brittle materials.

Group N : Aluminium, copper and their alloys.

6.4 Maintenance Requirements

Check the wear band width (VB) regularly, replacement standard $VB > 0.3$ mm.

Avoid overload cutting to prevent tool chipping.

7. Technical Requirements

7.1 Material properties

Hardness : HRC 62-66 (HSS).

Heat resistance : $\leq 600^{\circ}\text{C}$.

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7.2 Geometric parameters

Main deflection angle : 5° - 15° .

Tip radius : 0.1-1.0 mm.

8. Test Methods

8.1 Dimensional measurement

Tools : Vernier caliper or CMM.

Accuracy : ± 0.01 mm.

8.2 Durability test

Conditions : Steel (HB 200), Vc 30 m/min, fn 0.1 mm/tooth, ap 2 mm.

Procedure : Cut continuously for 30 min and measure VB.

Reference standard : According to ISO 8688-1.

9. Marking and Packaging

9.1 Logo

Indicate the type (such as EM), diameter (d) and length (l).

Example: ANSI B94.19-EM-10-60.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with size and durability test report.

10. Inspection Rules

10.1 Factory Inspection

Raw material hardness and size inspection.

10.2 Factory Inspection

Dimensional, tolerance and durability testing (sampling).

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overheating of the tool during high-speed cutting.

12. Annex

Appendix A (Informative) - Classification and Size Tables

type	Diameter range (mm)	Length range(mm)	Tolerance grade
End milling cutter	3-25	40-150	h6/h7
Face milling cutter	10-50	50-200	h7
T-Slot Milling Cutter	6-32	50-150	h6/h7

Appendix B (Normative) - Table of Conditions of Use

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Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth(mm)
Steel (HB 200)	20-50	0.05-0.2	1-3
cast iron	30-70	0.1-0.3	2-4
Aluminum Alloy	100-300	0.1-0.5	1-5

13. Index

Milling cutter
End milling cutter
Classification
Conditions of Use

14. Publication Information

Release date : March 20, 1997.
Latest confirmed date : 2019.
Maintained by : American National Standards Institute (ANSI).
Language : English.



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Japanese Industrial Standards

JIS B 4120:2000

Milling cutters with carbide tips - Manufacturing and testing specifications

— Manufacturing and testing specifications

1. Scope

This standard specifies the manufacturing process, quality control and testing methods of cemented carbide milling cutters (including end mills, face milling cutters and slot milling cutters), and is applicable to cemented carbide materials (such as WC-Co base) in metal cutting. This standard aims to ensure the manufacturing consistency, cutting performance and safety of milling cutters, and is not applicable to non-cemented carbide materials or tools for non-cutting purposes.

1.1 Scope of application

For end mills, face mills and slot mills made of carbide.

Covers manufacturing processes, quality control and testing requirements.

1.2 Exclusions

Milling cutters made of non-carbide materials.

Tools for non-cutting purposes.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

JIS B 4104:1995 , *Carbide tipped tools — General rules* .

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

ISO 8688-1:1989 , *Tool life testing in milling — Part 1: Face milling* .

Note : The latest versions of referenced documents may be updated after publication. It is recommended to check the JIS official website for the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Carbide Milling Cutter

Milling cutters made of tungsten carbide (WC) based cemented carbide are suitable for cutting high hardness workpieces.

3.2 Manufacturing Process

The processing steps from raw material preparation to the finished milling cutter include powder metallurgy, sintering and coating.

3.3 Testing Methods

Standardized experimental procedure for evaluating milling cutter performance and durability.

4. Symbols and Abbreviations

d : Diameter (mm).

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L : Total Length (mm).

Vc : Cutting Speed (m/min).

VB : Flank Wear Width (mm).

WC : Tungsten Carbide.

5. Technical Requirements

5.1 Material properties

Hardness : HV 1500-1800.

Fracture toughness : $K_{Ic} \geq 10 \text{ MPa} \cdot \text{m}^{1/2}$.

Density : 14.0-14.9 g/cm³.

5.2 Geometric parameters

Main deflection angle : 5°-20°.

Tip radius : 0.1-1.0 mm.

Helix angle : 15°-45° (adjusted according to application).

5.3 Coating requirements

Optional coating: TiN, TiAlN, thickness 1-3 μm.

Bond strength: > 70 MPa.

6. Manufacturing Process

6.1 Raw material preparation

High purity WC powder (purity > 99.8%) and Co powder (purity > 99.5%) were used.

Particle size control: D50 < 1 μm.

6.2 Processing Flow

Pressing : Cold isostatic pressing (CIP), pressure 150-200 MPa.

Sintering : Hot isostatic pressing (HIP), temperature 1350-1450°C, holding pressure 1-2 h.

Finishing : CNC grinding, tolerance ±0.01 mm.

Coating : PVD process, temperature 450-500°C.

6.3 Quality Control

Density test: 14.0-14.9 g/cm³.

Hardness test: HV 1500-1800.

7. Testing Methods

7.1 Dimensions and tolerances

Tools : Coordinate measuring machine.

Accuracy : ±0.01 mm.

Reference standard : According to JIS B 4104.

7.2 Durability test

Test conditions :

Workpiece material: JIS S45C steel (HB 200).

Cutting speed (Vc): 100-150 m/min.

Feed rate (fn): 0.1-0.2 mm/tooth.

Cutting depth: 1-3 mm.

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program :

Install the milling cutter on the test machine.

Cut continuously for 30 min according to the specified parameters.

The wear band width (VB) was measured.

Judgment criteria : $VB \leq 0.3 \text{ mm}$.

Reference standard : According to ISO 8688-1.

7.3 Data Recording

Cutting time, VB value and failure mode were recorded.

8. Inspection Rules

8.1 Factory Inspection

Raw material hardness and purity inspection.

8.2 Factory Inspection

Dimensions, tolerances, hardness testing.

Durability test (sampling).

9. Marking and Packaging

9.1 Logo

Indicate type (such as EM), diameter (d), length (l) and material.

Example: JIS B 4120-EM-10-60-WC.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a certificate of manufacture and testing.

10. Application Specifications

10.1 Cutting data

Cutting speed (Vc) : 50-300 m/min (adjusted according to the workpiece).

Feed rate (fn) : 0.05-0.5 mm/tooth.

Cutting depth : 0.5-5 mm.

10.2 Cooling requirements

Recommended cutting fluid, flow rate $\geq 10 \text{ L/min}$.

Dry cutting is limited to light loads and duration $\leq 10 \text{ min}$.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overload cutting to prevent tool chipping.

12. Annex

Appendix A (Informative) - Manufacturing Process Parameters Table

Process steps	Parameter range	Remark

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ball milling	12-24 h, medium ratio 1:2	Ensure uniformity
suppress	150-200 MPa	Initial density 60%-65%
sintering	1350-1450°C, 1-2 h	Density> 99.9%
coating	1-3 μm, 450-500°C	TiAlN coating

Appendix B (Normative) - Table of Test Conditions

Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth(mm)
JIS S45C	100-150	0.1-0.2	1-3
cast iron	80-120	0.2-0.3	2-4
Stainless steel	60-100	0.1-0.2	1-2

13. Index

Carbide milling cutter
Manufacturing process
Test Method
Usage Guidelines

14. Publication Information

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Maintaining organization : Japanese Industrial Standards Committee (JISC).

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Chinese National Standard

GB/T 16665-2017

- Technical requirements and test methods

for hard alloys

— Technical requirements and test methods

1. Scope

This standard specifies the technical requirements and performance test methods for cemented carbide (with tungsten carbide WC as the main hard phase and cobalt Co or nickel Ni as the bonding phase), which is applicable to the manufacture of metal cutting tools, molds and wear-resistant parts. This standard includes the physical properties, chemical composition and mechanical properties requirements of the material, as well as the corresponding test methods, and is not applicable to non-cemented carbide materials or composite materials for special purposes.

1.1 Scope of application

Applicable to WC-Co or WC-Ni based cemented carbides.

Covers performance requirements and test methods.

1.2 Exclusions

Non-carbide materials.

Composite materials for special applications.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 3850-2015, *Methods for testing the properties of hardmetals*.

GB/T 5244-2015, *Hardmetals — Determination of cobalt, titanium, tantalum, niobium and vanadium contents*.

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

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Hardmetal

A sintered material with tungsten carbide (WC) as the main hard phase and cobalt (Co) or nickel (Ni) as the bonding phase, which has high hardness and wear resistance.

3.2 Hardness

The ability of a material to resist localized plastic deformation or indentation, usually expressed in Vickers hardness (HV).

3.3 Fracture Toughness

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The ability of a material to resist crack growth, usually expressed as the critical stress intensity factor (K_{Ic}).

4. Symbols and Abbreviations

HV : Vickers Hardness.

K_{Ic} : Fracture Toughness ($\text{MPa} \cdot \text{m}^{1/2}$).

ρ : Density (g/cm^3).

WC : Tungsten Carbide.

Co : Cobalt.

5. Technical Requirements

5.1 Chemical composition

WC content : 85%-94% (mass fraction).

Co content : 6%-12% (mass fraction), $\text{Ni} \leq 2\%$ (optional).

Impurity content : oxygen $\leq 0.2\%$, other impurities $\leq 0.5\%$.

5.2 Physical properties

Density (ρ) : $14.0\text{-}15.0 \text{ g/cm}^3$ (adjusted according to Co content).

Porosity : A02-B00-C00 (according to GB/T 3850 grade).

5.3 Mechanical properties

Hardness (HV30) : 1200-1800 (depending on the grade).

Fracture toughness (K_{Ic}) : $8\text{-}15 \text{ MPa} \cdot \text{m}^{1/2}$.

Flexural strength : 1800-2500 MPa.

5.4 Heat resistance

Operating temperature: $\leq 800^\circ\text{C}$ (uncoated).

Oxidation resistance: Weight loss rate $\leq 0.1\%/h$ (800°C , 1h).

6. Test Methods

6.1 Chemical composition analysis

Methods : Spectroscopic analysis or wet chemical methods.

Accuracy : $\pm 0.1\%$ (mass fraction).

Reference standard : According to GB/T 5244.

6.2 Density measurement

Tools : Archimedeian method or mercury penetration method.

Accuracy : $\pm 0.05 \text{ g/cm}^3$.

Reference standard : According to GB/T 3850.

6.3 Hardness test

Tools : Vickers hardness tester, load 30 kg.

Accuracy : $\pm 20 \text{ HV}$.

Reference standard : According to GB/T 3850.

6.4 Fracture toughness test

Method : Single edge notched beam method (SENB).

Accuracy : $\pm 0.5 \text{ MPa} \cdot \text{m}^{1/2}$.

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Reference standard : According to GB/T 3850.

6.5 Bending strength test

Method : Three-point bending test.

Specimen size : 20 mm × 6.5 mm × 5.25 mm.

Accuracy : ±50 MPa.

Reference standard : According to GB/T 3850.

7. Inspection Rules

7.1 Factory Inspection

Raw materials chemical composition and particle size inspection.

7.2 Factory Inspection

Density, hardness, fracture toughness and flexural strength tests.

Porosity and microstructural analysis.

8. Marking and Packaging

8.1 Logo

Mark the brand number (such as YG6, YG8) and batch number.

Example: GB/T 16665-YG6-20250601.

8.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with performance test report.

9. Application Guidelines

9.1 Application Areas

Metal cutting tools (milling cutters, turning tools).

Wear-resistant parts (dies, punches).

9.2 Recommendations for use

Avoid prolonged use at temperatures exceeding 800°C.

Check surfaces for wear regularly.

10. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid inhalation of dust and handle in a ventilated environment.

11. Annex

Appendix A (Informative) - Performance Reference Tables

Brand	WC content (%)	Co content (%)	Hardness (HV30)	Fracture toughness (K _{IC} , MPa·m ^{1/2})	Flexural strength(MPa)
YG6	94	6	1500-1600	10-12	1800-2000
YG8	92	8	1400-1500	12-14	2000-2200

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YG12	88	12	1300-1400	14-15	2200-2500

Appendix B (Normative) - Table of Test Conditions

Performance Indicators	Test Method	Number of samples	Permissible deviation
density	Archimedeian method	3	$\pm 0.05 \text{ g/cm}^3$
hardness	Vickers Hardness Tester	5	$\pm 20 \text{ HV}$
Fracture toughness	SENB	5	$\pm 0.5 \text{ MPa} \cdot \text{m}^{1/2}$
Bending strength	Three-point bending	5	$\pm 50 \text{ MPa}$

12. Index

Cemented Carbide

Performance requirements

Test Method

Technical requirements

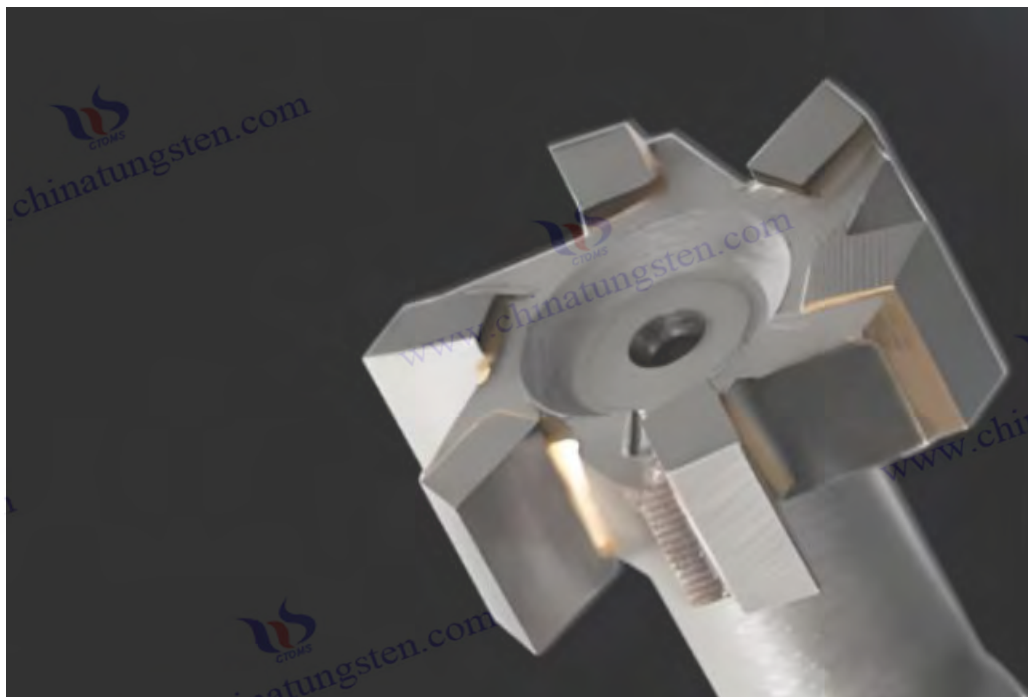
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Chinese National Standard GB/T 5231-2019

GB/T 5231-2019

- Cutting tools

— General technical conditions

1. Scope

This standard specifies the general technical conditions for cutting tools (including turning tools, milling cutters, drills and boring tools, etc.), covering material selection, manufacturing process, dimensional tolerances, performance requirements, and inspection and use specifications. This standard is applicable to cutting tools of various materials (such as high-speed steel and cemented carbide) for metal cutting processing, and is not applicable to non-cutting tools or non-metal processing purposes.

1.1 Scope of application

Suitable for cutting tools made of high-speed steel, cemented carbide, etc.

Covers manufacturing, inspection and use requirements.

1.2 Exclusions

Non-cutting tools (e.g. abrasive tools).

Non-metal processing applications.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 16665-2017, *Hardmetals — Technical requirements and test methods*.

GB/T 3850-2015, *Methods for testing the properties of hardmetals*.

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

ISO 8688-1:1989, *Tool life testing in milling — Part 1: Face milling*.

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Cutting Tool

Tools that machine workpiece material by chip removal usually have a defined cutting edge.

3.2 Tolerance

The allowable deviation range of cutting tool size ensures processing accuracy and interchangeability.

3.3 Application Conditions

Cutting parameters and environmental requirements of cutting tools during processing.

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4. Symbols and Abbreviations

d : Diameter (mm).

l : Total Length (mm).

Vc : Cutting Speed (m/min).

VB : Flank Wear Width (mm).

HSS : High-Speed Steel.

5. Technical Requirements

5.1 Material requirements

High Speed Steel (HSS) : Hardness HRC 62-66, heat resistance $\leq 600^{\circ}\text{C}$.

Cemented carbide : hardness HV 1200-1800, fracture toughness $K_{IC} \geq 8 \text{ MPa} \cdot \text{m}^{1/2}$.

Coating : TiN or TiAlN, thickness 1-3 μm .

5.2 Geometric parameters

Leading angle : 5° - 20° (adjusted according to tool type).

Tip radius : 0.1-1.0 mm.

Surface roughness : $R_a \leq 1.6 \mu\text{m}$ (cutting part), $R_a \leq 0.8 \mu\text{m}$ (shank).

5.3 Dimensional tolerance

Diameter tolerance : h6 (3-6 mm) or h7 (8-25 mm).

Length tolerance : $\pm 0.2 \text{ mm}$.

Coaxiality tolerance : 0.01 mm (over the entire length).

6. Manufacturing Process

6.1 Material preparation

High speed steel: forged or rolled, annealed.

Cemented carbide: powder metallurgy, pressing pressure 150-200 MPa.

6.2 Processing Flow

Rough machining : turning or milling.

Finishing : CNC grinding, tolerance $\pm 0.01 \text{ mm}$.

Heat treatment : Quenching (HSS), sintering (carbide), temperature 1200-1450 $^{\circ}\text{C}$.

6.3 Coating

PVD process, temperature 450-500 $^{\circ}\text{C}$, bonding strength $> 70 \text{ MPa}$.

7. Test Methods

7.1 Dimensions and tolerances

Tools : CMM or Vernier Caliper.

Accuracy : $\pm 0.01 \text{ mm}$.

Reference standard : According to GB/T 3850.

7.2 Hardness test

Tools : Vickers hardness tester, load 30 kg.

Accuracy : $\pm 20 \text{ HV}$.

Reference standard : According to GB/T 3850.

7.3 Durability test

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Conditions : Steel (HB 200), Vc 50-100 m/min, fn 0.1 mm/tooth, ap 2 mm.

Procedure : Cut continuously for 30 min and measure VB.

Judgment criteria : $VB \leq 0.3$ mm.

Reference standard : According to ISO 8688-1.

8. Inspection Rules

8.1 Factory Inspection

Raw material hardness and chemical composition inspection.

8.2 Factory Inspection

Dimensions, tolerances, hardness testing.

Durability test (sampling).

9. Marking and Packaging

9.1 Logo

Indicate the type (such as M), diameter (d), length (l) and material.

Example: GB/T 5231-M-10-60-HSS.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a certificate of manufacture and testing.

10. Application Specifications

10.1 Cutting data

Cutting speed (Vc) : 20-300 m/min (adjusted according to material).

Feed rate (fn) : 0.05-0.5 mm/tooth.

Cutting depth : 0.5-5 mm.

10.2 Cooling requirements

Recommended cutting fluid, flow rate ≥ 10 L/min.

Dry cutting is limited to light loads and duration ≤ 10 min.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overload cutting to prevent tool chipping.

12. Annex

Appendix A (Informative) - Technical Parameters Reference Table

Material Type	Hardness (HV/HRC)	Cutting speed (Vc, m/min)	Tolerance grade	Surface roughness (Ra, μ m)
HSS	HRC 62-66	20-50	h6/h7	≤ 1.6
Cemented Carbide	HV 1200-1800	50-300	h6/h7	≤ 1.6

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Appendix B (Normative) - Table of Conditions of Use

Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth(mm)
Steel (HB 200)	50-100	0.1-0.2	1-3
cast iron	70-120	0.2-0.3	2-4
Aluminum Alloy	100-300	0.1-0.5	1-5

13. Index

Cutting Tools

Technical requirements

Test Method

Usage Guidelines

14. Publication Information

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Chinese National Standard GB/T 20323-2020

GB/T 20323-2020

Milling cutters code (integral/toothed/indexable)

— Designation system for solid/tooth-insertable/indexable types

1. Scope

This standard specifies the code system for milling cutters (including integral, insert and indexable types) to identify the type, structure, size, material and other technical characteristics of milling cutters. This standard applies to various milling cutters used in metal cutting processing, and aims to achieve consistent product identification and international interoperability. It does not apply to non-cutting tools or special milling cutters of non-standard design.

1.1 Scope of application

Suitable for solid, insert and indexable milling cutters.

Covers code conventions and identification methods.

1.2 Exclusions

Non-cutting tools.

Special milling cutters with non-standard designs.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 5231-2019, *Cutting tools — General technical conditions*.

GB/T 16665-2017, *Hardmetals — Technical requirements and test methods*.

ISO 5608:2012, *Milling cutters — Designation*.

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Solid Milling Cutter

A milling cutter made of a single material, with the cutting part and the shank being one piece.

3.2 Tooth-Insertable Milling Cutter

A milling cutter in which the cutting teeth are fixed to the milling cutter body in an inlaid manner.

3.3 Indexable Milling Cutter

Milling cutters that use replaceable cutting inserts that can be rotated or flipped over to use new cutting edges.

3.4 Designation

Standardized code combination used to identify the characteristics of milling cutters.

4. Symbols and Abbreviations

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d : Diameter (mm).

l : Total Length (mm).

HSS : High-Speed Steel.

WC : Tungsten Carbide.

5. Designation System

5.1 Code composition

The milling cutter code consists of the following parts, arranged in order:

Type code : Identifies the structure type of the milling cutter.

Size Code : Identifies diameter and length.

Material Code : Identifies the type of material.

Additional Code : Optional, for special applications or coatings.

5.2 Type code

S : Solid.

T : Tooth-Insertable.

I : Indexable.

5.3 Size code

Format: [diameter]×[length].

Example: 10×60 means diameter 10 mm and length 60 mm.

Tolerances are in accordance with GB/T 5231.

5.4 Material code

HSS : High Speed Steel.

WC : Hard alloy.

HSS-Co : High speed steel containing cobalt.

TiN : Titanium nitride coating (additional).

5.5 Additional Code

R : Roughing.

F : Finishing.

H : Suitable for workpieces with high hardness.

6. Examples of Designation

6.1 Integral milling cutter

S-10×60-HSS : 10 mm diameter, 60 mm length, high speed steel solid milling cutter.

S-20×100-WC-TiN : 20 mm diameter, 100 mm length, carbide solid milling cutter with TiN coating.

6.2 Insert tooth milling cutter

T-12×80-HSS-Co : 12 mm diameter, 80 mm length, cobalt-containing high-speed steel insert milling cutter.

T-25×150-WC-R : 25 mm diameter, 150 mm length, carbide insert milling cutter, suitable for rough machining.

6.3 Indexable milling cutter

I-16×90-WC-F : 16 mm diameter, 90 mm length, carbide indexable milling cutter, suitable for finishing.

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I-30×120-WC-H : 30 mm diameter, 120 mm length, carbide indexable milling cutter, suitable for high hardness workpieces.

7. Marking Requirements

The code should be clearly marked on the milling cutter body or packaging.

Font height: ≥ 2 mm.

Marking method: Laser engraving or inkjet printing.

8. Inspection Rules

8.1 Code consistency check

The verification code is consistent with the actual technical parameters.

Sampling rate : 5% (minimum 1 piece).

8.2 Dimension and material verification

Dimension and material inspection shall be carried out according to GB/T 5231.

9. Packaging and Storage

Use moisture-proof and shock-proof packaging.

Storage environment: Temperature 5-30°C, humidity $\leq 60\%$.

10. Application Guidelines

The integral type is suitable for small diameter and high precision machining.

Insert type is suitable for medium load cutting.

The indexable type is suitable for large diameter or high-efficiency processing.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid misuse due to incorrect code names.

12. Annex

Appendix A (Informative) - Code Reference Table

Type Code	Structure Type	Material Examples	Additional code examples
S	Monolithic	HSS, WC	TiN, R
T	Toothed	HSS-Co, WC	F, H
I	Indexable	WC	F, H

Appendix B (Normative) - Size Ranges

Diameter range (mm)	Length range(mm)	Tolerance grade
3-10	40-100	h6
12-25	80-200	h7
30-50	100-300	h7

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Milling cutter Code system Monolithic Toothed Indexable

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Language : Chinese, English.

Chinese National Standard GB/T 25664-2010

GB/T 25664-2010

- Safety requirements for high
-speed milling cutters
— Safety requirements

1. Scope

This standard specifies the safety requirements for high-speed cutting milling cutters (applicable to milling cutters with cutting speeds exceeding 50 m/s), including safety performance specifications in design, manufacture, installation, use and maintenance. This standard applies to solid, insert-toothed or indexable milling cutters made of high-speed steel (HSS) or cemented carbide (WC), and is intended to reduce the risk of accidents during operation. It is not applicable to non-high-speed cutting applications or non-cutting tools.

1.1 Scope of application

For high speed cutting milling cutters with cutting speeds > 50 m/s.

Covers safety requirements for design, manufacture, installation, use and maintenance.

1.2 Exclusions

Conventional milling cutters with cutting speeds ≤ 50 m/s.

Non-cutting tools.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 5231-2019 , *Cutting tools — General technical conditions* .

GB/T 16665-2017 , *Hardmetals — Technical requirements and test methods* .

ISO 15641:2001 , *Milling cutters for high-speed machining — Safety requirements* .

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 High-speed Milling Cutter

Milling cutters with cutting speeds exceeding 50 m/s are usually used for efficient metal cutting operations.

3.2 Safety Performance

The ability to prevent personal injury or equipment damage during operation.

3.3 Fracture Toughness

The ability of a material to resist crack growth, usually expressed as K_{IC} .

4. Symbols and Abbreviations

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V_c : Cutting Speed (m/s).

d : Diameter (mm).

HSS : High-Speed Steel.

WC : Tungsten Carbide.

K_{1c} : Fracture Toughness (MPa·m^{1/2}).

5. Technical Requirements

5.1 Material requirements

Hardness : HSS HRC 62-66, WC HV 1200-1800.

Fracture toughness : $K_{1c} \geq 10 \text{ MPa} \cdot \text{m}^{1/2}$ (WC), $K_{1c} \geq 8 \text{ MPa} \cdot \text{m}^{1/2}$ (HSS).

Fatigue resistance : Fatigue limit $\geq 800 \text{ MPa}$.

5.2 Design requirements

Balance grade : G2.5 (according to ISO 1940-1).

Maximum speed : Calculated based on diameter, $V_c \leq 100 \text{ m/s}$.

Blade strength : tensile strength $\geq 1000 \text{ MPa}$.

5.3 Manufacturing requirements

Surface roughness : $R_a \leq 1.2 \mu\text{m}$ (cutting part), $R_a \leq 0.6 \mu\text{m}$ (shank).

Heat treatment : Quenching (HSS) or sintering (WC), residual stress $\leq 200 \text{ MPa}$.

6. Safety Requirements

6.1 Design safety

Anti-chipping design : blade tip radius 0.2-1.0 mm.

Overspeed protection : Automatically cut off power when the speed exceeds the design value by 20%.

Balance test : Dynamic balance error $\leq 2 \text{ g} \cdot \text{mm/kg}$.

6.2 Installation Safety

Clamping force : Minimum clamping force $\geq 10 \text{ kN}$ (adjusted to diameter).

Coaxiality : After installation, the coaxiality error is $\leq 0.01 \text{ mm}$.

Anti-loosening design : Use lock nut or keyway.

6.3 Safety of use

Operator Protection : Wear protective glasses, cut-resistant gloves and ear plugs.

Cutting parameter restrictions : $V_c \leq 100 \text{ m/s}$, feed rate $\leq 0.5 \text{ mm/tooth}$.

Environmental requirements : Cutting fluid flow $\geq 15 \text{ L/min}$, temperature $\leq 50^\circ\text{C}$.

6.4 Maintaining Security

Periodic inspection : Check monthly that the wear band width (VB) is $\leq 0.3 \text{ mm}$.

Replacement criteria : Replace when $\text{VB} > 0.3 \text{ mm}$ or the cutter body is cracked.

Disposal : Recycle or destroy safely to prevent injury from debris.

7. Test Methods

7.1 Balance Test

Tools : Dynamic balancing machine.

Standard : According to ISO 1940-1, G2.5 grade.

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Accuracy : $\leq 2 \text{ g}\cdot\text{mm/kg}$.

7.2 Fracture toughness test

Method : Single edge notched beam method (SENB).

Accuracy : $\pm 0.5 \text{ MPa}\cdot\text{m}^{1/2}$.

Reference standard : GB/T 16665.

7.3 Durability test

Conditions : Steel (HB 200), Vc 80 m/s, fn 0.2 mm/tooth, ap 2 mm.

Procedure : Cut continuously for 20 min and measure VB.

Judgment criteria : No chipping, $\text{VB} \leq 0.3 \text{ mm}$.

Reference standard : According to ISO 15641.

8. Inspection Rules

8.1 Factory Inspection

Raw material hardness and chemical composition inspection.

8.2 Factory Inspection

Balance grade, fracture toughness and durability tests (sampling rate 5%).

9. Marking and Packaging

9.1 Logo

Marking code (such as HS-10×60-WC) and safety warnings.

Example: GB/T 25664-HS-10×60-WC (Max Vc: 100 m/s).

9.2 Packaging

Use shockproof and moisture-proof packaging, and come with safety instructions.

10. Application Guidelines

Ensure that the machine tool spindle rigidity is $\geq 50 \text{ N}/\mu\text{m}$.

Regularly calibrate balancing and speed monitoring equipment.

11. Safety Incident Prevention

Install a protective cover to prevent flying debris.

Train operators to recognize signs of overspeed or overheating.

12. Annex

Appendix A (Informative) - Safety Parameter Reference Table

Diameter(mm)	Maximum speed (rpm)	Balance Level	Clamping force(kN)
10	30000	G2.5	10
20	15000	G2.5	15
40	7500	G2.5	25

Appendix B (Normative) - Table of Conditions of Use

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Workpiece material	Cutting speed (Vc, m/s)	Feed rate (fn, mm/tooth)	Cutting depth(mm)
Steel (HB 200)	50-80	0.1-0.3	1-3
Aluminum Alloy	80-100	0.2-0.5	1-5
Stainless steel	50-70	0.1-0.2	1-2

13. Index

High speed cutting milling cutter

Security Requirements

Designing for safety

Safe to use

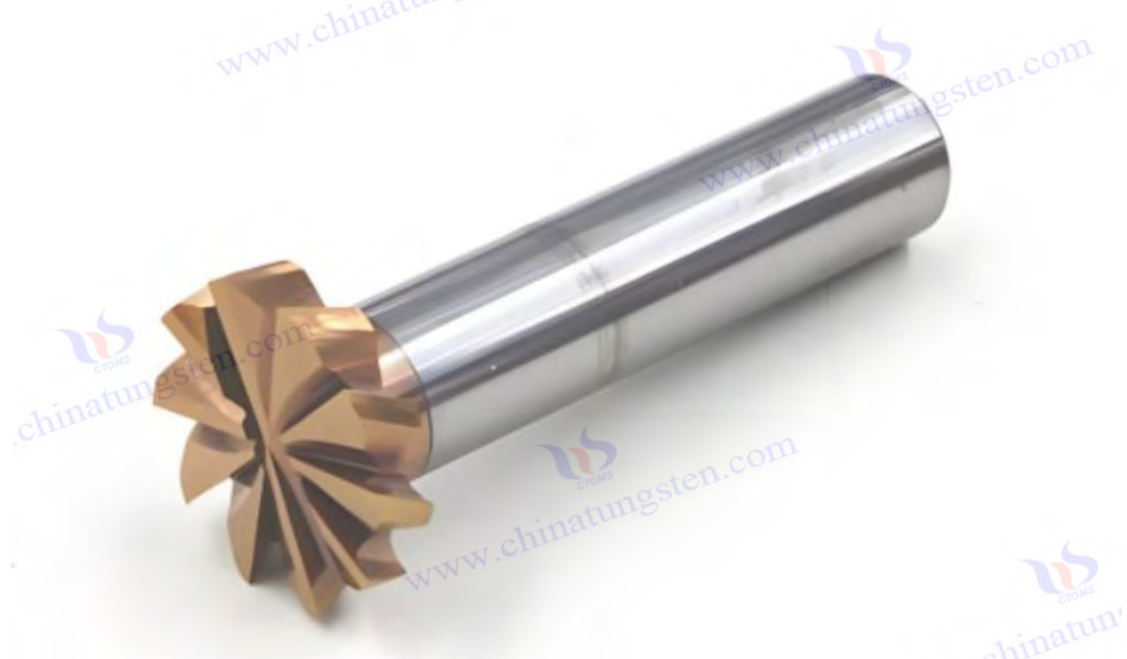
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Chinese National Standard GB/T 6122-2017

GB/T 6122-2017 -

Corner rounding milling cutters

1. Scope

This standard specifies the size, shape, manufacturing requirements, performance specifications and use conditions of rounded corner milling cutters (milling cutters used to process rounded corners of workpiece edges). This standard applies to integral or insert-toothed rounded corner milling cutters made of high-speed steel (HSS) or cemented carbide (WC), which are widely used in metal cutting processing, and is not suitable for non-cutting tools or non-rounded processing purposes.

1.1 Scope of application

Suitable for corner radius milling cutters made of high speed steel or carbide.

Covers dimensions, manufacturing and usage requirements.

1.2 Exclusions

Non-cutting tools.

Milling cutter for non-corner rounding applications.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 5231-2019 , *Cutting tools — General technical conditions* .

GB/T 16665-2017 , *Hardmetals — Technical requirements and test methods* .

ISO 5609:1999 , *Tool shanks with 7/24 taper for automatic tool changes* .

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Corner Rounding Milling Cutter

A milling cutter with a specific corner radius used to round or chamfer the edges of a workpiece.

3.2 Corner Radius

The arc radius of the edge of the milling cutter cutting part, in mm.

3.3 Application Conditions

The cutting parameters and environmental requirements of the corner milling cutter during the machining process.

4. Symbols and Abbreviations

R : Corner Radius (mm).

d : Diameter (mm).

l : Total Length (mm).

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HSS : High-Speed Steel.

WC : Tungsten Carbide.

5. Technical Requirements

5.1 Dimensions and tolerances

Diameter range : 6 mm to 40 mm.

Corner radius (R) : 1 mm to 10 mm (standard values: 1, 2, 3, 4, 6, 8, 10 mm).

Length range : 50 mm to 150 mm.

Tolerance : diameter h6 (6-10 mm) or h7 (12-40 mm), length ± 0.2 mm.

5.2 Material requirements

High Speed Steel (HSS) : Hardness HRC 62-66, heat resistance $\leq 600^{\circ}\text{C}$.

Cemented Carbide (WC) : Hardness HV 1200-1800, fracture toughness $K_{IC} \geq 10 \text{ MPa}\cdot\text{m}^{1/2}$.

Coating : TiN or TiAlN, thickness 1-3 μm .

5.3 Geometric parameters

Main deflection angle : 5° - 15° .

Helix angle : 15° - 30° (adjusted according to diameter).

Surface roughness : $R_a \leq 1.6 \mu\text{m}$ (cutting part), $R_a \leq 0.8 \mu\text{m}$ (shank).

6. Manufacturing Process

6.1 Material preparation

High speed steel: forged or rolled, annealed.

Cemented carbide: powder metallurgy, pressing pressure 150-200 MPa.

6.2 Processing Flow

Rough machining : turning or milling.

Finishing : CNC grinding, corner radius tolerance ± 0.05 mm.

Heat treatment : Quenching (HSS) or sintering (WC), temperature 1200 - 1450°C .

6.3 Coating

PVD process, temperature 450 - 500°C , bonding strength > 70 MPa.

7. Test Methods

7.1 Dimensions and tolerances

Tools : Coordinate measuring machine.

Accuracy : ± 0.01 mm.

Reference standard : According to GB/T 5231.

7.2 Hardness test

Tools : Vickers hardness tester, load 30 kg.

Accuracy : ± 20 HV.

Reference standard : According to GB/T 16665.

7.3 Durability test

Conditions : Steel (HB 200), V_c 50 m/min, f_n 0.1 mm/tooth, a_p 1 mm.

Procedure : Cut continuously for 30 min and measure the wear band width (VB).

Judgment criteria : $VB \leq 0.3$ mm.

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Reference standard : According to ISO 8688-1.

8. Inspection Rules

8.1 Factory Inspection

Raw material hardness and chemical composition inspection.

8.2 Factory Inspection

Dimensions, tolerances, hardness testing.

Durability test (sampling rate 5%).

9. Marking and Packaging

9.1 Logo

Mark the code (such as CR-10-R2-HSS) and the fillet radius.

Example: GB/T 6122-CR-10-R2-HSS.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a certificate of manufacture and testing.

10. Application Specifications

10.1 Cutting data

Cutting speed (Vc) : 20-100 m/min (adjusted according to material).

Feed rate (fn) : 0.05-0.3 mm/tooth.

Cutting depth : 0.5-2 mm.

10.2 Cooling requirements

Recommended cutting fluid, flow rate ≥ 10 L/min.

Dry cutting is limited to light loads and duration ≤ 10 min.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overload cutting to prevent tool chipping.

12. Annex

Appendix A (Informative) - Dimension Reference Table

Diameter(mm)	Corner radius (R, mm)	Length(mm)	Tolerance grade
6	1-2	50-80	h6
12	2-4	80-120	h7
25	4-10	100-150	h7

Appendix B (Normative) - Table of Conditions of Use

Workpiece	Cutting speed (Vc, mm/min)	Feed rate (fn, mm/tooth)	Cutting

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material	m/min)		depth(mm)
Steel (HB 200)	50-80	0.1-0.2	0.5-1.5
Aluminum Alloy	80-100	0.2-0.3	0.5-2
cast iron	60-90	0.1-0.25	0.5-1.5

13. Index

Corner milling cutter

Technical requirements

Usage Guidelines

Dimensional tolerance

14. Publication Information

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Chinese National Standard GB/T 1127-2023

GB/T 1127-2023 - Half-round

keyway milling cutters

1. Scope

This standard specifies the size, shape, manufacturing requirements, performance specifications and use conditions of semicircular keyway milling cutters (special milling cutters used to process semicircular keyways). This standard applies to semicircular keyway milling cutters made of high-speed steel (HSS) or cemented carbide (WC), which are mainly used for keyway processing of mechanical transmission parts (such as shafts and hubs), and is not suitable for non-cutting tools or non-semicircular keyway applications.

1.1 Scope of application

For semicircular keyway milling cutters made of high speed steel or carbide.

Covers dimensions, manufacturing and usage requirements.

1.2 Exclusions

Non-cutting tools.

Milling cutter for non-semi-circular keyway machining.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 5231-2019, *Cutting tools — General technical conditions*.

GB/T 16665-2017, *Hardmetals — Technical requirements and test methods*.

ISO 3338-1:2012, *Keyway milling cutters — Part 1: General dimensions*.

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Half-round Keyway Milling Cutter

A milling cutter with a semicircular cutting edge used to machine a semicircular keyway to accommodate a semicircular key.

3.2 Keyway Width

The width of the cutting portion of a semicircular keyway milling cutter matches the actual size of the keyway.

3.3 Application Conditions

Cutting parameters and environmental requirements of semicircular keyway milling cutters during machining.

4. Symbols and Abbreviations

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W : Keyway Width (mm).

d : Diameter (mm).

L : Total Length (mm).

HSS : High-Speed Steel.

WC : Tungsten Carbide.

5. Technical Requirements

5.1 Dimensions and tolerances

Diameter range : 4 mm to 25 mm.

Keyway width (W) : 1 mm to 8 mm (standard values: 1, 2, 3, 4, 5, 6, 8 mm).

Length range : 40 mm to 120 mm.

Tolerance : diameter h6 (4-10 mm) or h7 (12-25 mm), width ± 0.02 mm.

5.2 Material requirements

High Speed Steel (HSS) : Hardness HRC 62-66, heat resistance $\leq 600^{\circ}\text{C}$.

Cemented Carbide (WC) : Hardness HV 1200-1800, fracture toughness $K_{IC} \geq 10 \text{ MPa}\cdot\text{m}^{1/2}$.

Coating : TiN or AlTiN, thickness 1-3 μm .

5.3 Geometric parameters

Cutting edge radius : Matches keyway width, tolerance ± 0.01 mm.

Helix angle : 10° - 20° (adjusted according to diameter).

Surface roughness : $R_a \leq 1.6 \mu\text{m}$ (cutting part), $R_a \leq 0.8 \mu\text{m}$ (shank).

6. Manufacturing Process

6.1 Material preparation

High speed steel: forged or rolled, annealed.

Cemented carbide: powder metallurgy, pressing pressure 150-200 MPa.

6.2 Processing Flow

Rough machining : turning or milling.

Finishing : CNC grinding, keyway width tolerance ± 0.02 mm.

Heat treatment : Quenching (HSS) or sintering (WC), temperature 1200 - 1450°C .

6.3 Coating

PVD process, temperature 450 - 500°C , bonding strength > 70 MPa.

7. Test Methods

7.1 Dimensions and tolerances

Tools : Coordinate measuring machine.

Accuracy : ± 0.01 mm.

Reference standard : According to GB/T 5231.

7.2 Hardness test

Tools : Vickers hardness tester, load 30 kg.

Accuracy : ± 20 HV.

Reference standard : According to GB/T 16665.

7.3 Durability test

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Conditions : Steel (HB 200), Vc 40 m/min, fn 0.1 mm/tooth, ap 1 mm.

Procedure : Cut continuously for 30 min and measure the wear band width (VB).

Judgment criteria : $VB \leq 0.3$ mm.

Reference standard : According to ISO 8688-1.

8. Inspection Rules

8.1 Factory Inspection

Raw material hardness and chemical composition inspection.

8.2 Factory Inspection

Dimensions, tolerances, hardness testing.

Durability test (sampling rate 5%).

9. Marking and Packaging

9.1 Logo

Mark the code (such as HK-6-W2-HSS) and keyway width.

Example: GB/T 1127-HK-6-W2-HSS.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a certificate of manufacture and testing.

10. Application Specifications

10.1 Cutting data

Cutting speed (Vc) : 20-80 m/min (adjusted according to material).

Feed rate (fn) : 0.05-0.2 mm/tooth.

Cutting depth : 0.5-1.5 mm.

10.2 Cooling requirements

Recommended cutting fluid, flow rate ≥ 10 L/min.

Dry cutting is limited to light loads and duration ≤ 10 min.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overload cutting to prevent tool chipping.

12. Annex

Appendix A (Informative) - Dimension Reference Table

Diameter(mm)	Keyway width (W, mm)	Length(mm)	Tolerance grade
4	1-2	40-60	h6
10	2-4	60-90	h6
20	4-8	90-120	h7

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Appendix B (Normative) - Table of Conditions of Use

Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth(mm)
Steel (HB 200)	40-60	0.05-0.15	0.5-1
Aluminum Alloy	60-80	0.1-0.2	0.5-1.5
cast iron	50-70	0.05-0.15	0.5-1

13. Index

Half round keyway milling cutter

Technical requirements

Usage Guidelines

Dimensional tolerance

14. Publication Information

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Chinese National Standard GB/T 20773-2006

GB/T 20773-2006 -

Milling cutters for dies and moulds

1. Scope

This standard specifies the size, shape, manufacturing requirements, performance specifications and use conditions of mold milling cutters (milling cutters specially used for mold and die processing). This standard applies to integral or indexable mold milling cutters made of high-speed steel (HSS) or cemented carbide (WC), which are mainly used for precision mold manufacturing and finishing, and is not suitable for non-cutting tools or non-mold processing purposes.

1.1 Scope of application

Suitable for mold milling cutters made of high-speed steel or carbide.

Covers dimensions, manufacturing and usage requirements.

1.2 Exclusions

Non-cutting tools.

Milling cutters not intended for mold processing.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 5231-2019 , *Cutting tools — General technical conditions* .

GB/T 16665-2017 , *Hardmetals — Technical requirements and test methods* .

ISO 5609:1999 , *Tool shanks with 7/24 taper for automatic tool changes* .

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Milling Cutter for Dies and Moulds

Milling cutters designed for mold and die machining with high precision and complex geometries.

3.2 Number of Teeth

The number of cutting edges of mold milling cutters affects processing efficiency and surface quality.

3.3 Application Conditions

Cutting parameters and environmental requirements of mold milling cutters during processing.

4. Symbols and Abbreviations

d : Diameter (mm).

l : Total Length (mm).

Z : Number of Teeth.

HSS : High-Speed Steel.

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WC : Tungsten Carbide.

5. Technical Requirements

5.1 Dimensions and tolerances

Diameter range : 3 mm to 20 mm.

Length range : 50 mm to 150 mm.

Tolerance : diameter h6 (3-10 mm) or h7 (12-20 mm), length ± 0.2 mm.

Number of blades (Z) : 2-6 (adjusted according to diameter).

5.2 Material requirements

High Speed Steel (HSS) : Hardness HRC 62-66, heat resistance $\leq 600^{\circ}\text{C}$.

Cemented Carbide (WC) : Hardness HV 1300-1800, fracture toughness $K_{IC} \geq 10 \text{ MPa} \cdot \text{m}^{1/2}$.

Coating : TiN, TiAlN or AlCrN, thickness 1-3 μm .

5.3 Geometric parameters

Main deflection angle : 5° - 15° .

Helix angle : 20° - 40° (adjusted according to the processed material).

Surface roughness : $R_a \leq 1.6 \mu\text{m}$ (cutting part), $R_a \leq 0.8 \mu\text{m}$ (shank).

6. Manufacturing Process

6.1 Material preparation

High speed steel: forged or rolled, annealed.

Cemented carbide: powder metallurgy, pressing pressure 150-200 MPa.

6.2 Processing Flow

Rough machining : turning or milling.

Finishing : CNC grinding, tolerance ± 0.01 mm.

Heat treatment : Quenching (HSS) or sintering (WC), temperature 1200 - 1450°C .

6.3 Coating

PVD process, temperature 450 - 500°C , bonding strength > 70 MPa.

7. Test Methods

7.1 Dimensions and tolerances

Tools : Coordinate measuring machine.

Accuracy : ± 0.01 mm.

Reference standard : According to GB/T 5231.

7.2 Hardness test

Tools : Vickers hardness tester, load 30 kg.

Accuracy : ± 20 HV.

Reference standard : According to GB/T 16665.

7.3 Durability test

Conditions : Steel (HB 200), V_c 60 m/min, f_n 0.1 mm/tooth, a_p 0.5 mm.

Procedure : Cut continuously for 30 min and measure the wear band width (VB).

Judgment criteria : $VB \leq 0.3$ mm.

Reference standard : According to ISO 8688-1.

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8. Inspection Rules

8.1 Factory Inspection

Raw material hardness and chemical composition inspection.

8.2 Factory Inspection

Dimensions, tolerances, hardness testing.

Durability test (sampling rate 5%).

9. Marking and Packaging

9.1 Logo

Mark the code (such as MD-6-Z4-WC) and the number of blades.

Example: GB/T 20773-MD-6-Z4-WC.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a certificate of manufacture and testing.

10. Application Specifications

10.1 Cutting data

Cutting speed (Vc) : 30-120 m/min (adjusted according to material).

Feed rate (fn) : 0.05-0.2 mm/tooth.

Cutting depth : 0.2-1 mm.

10.2 Cooling requirements

Recommended cutting fluid, flow rate ≥ 10 L/min.

Dry cutting is limited to light loads and duration ≤ 10 min.

11. Safety Requirements

Wear protective glasses and gloves when handling.

Avoid overload cutting to prevent tool chipping.

12. Annex

Appendix A (Informative) - Dimension Reference Table

Diameter(mm)	Length(mm)	Number of blades (Z)	Tolerance grade
3	50-80	2-3	h6
10	80-120	3-4	h6
20	100-150	4-6	h7

Appendix B (Normative) - Table of Conditions of Use

Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth(mm)

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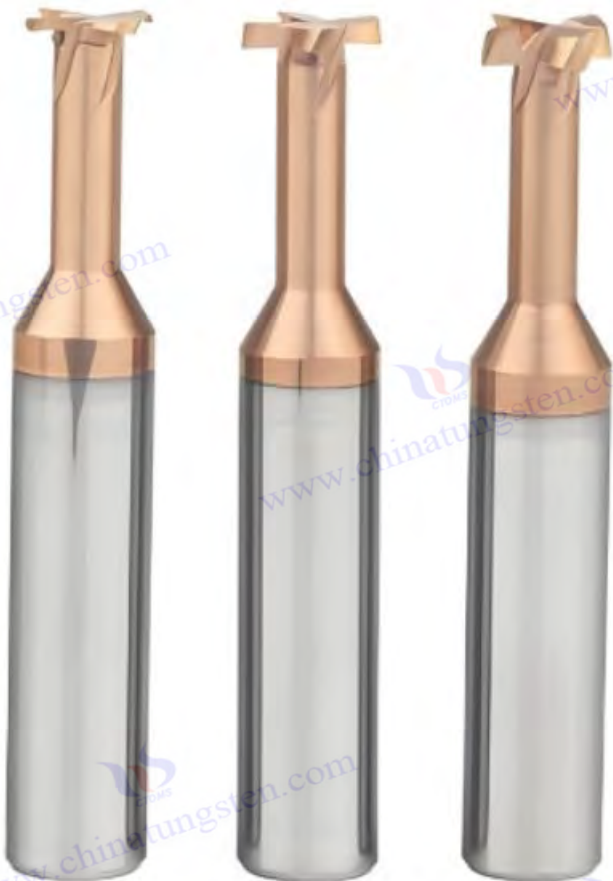
Steel (HB 200)	60-80	0.05-0.15	0.2-0.5
Aluminum Alloy	80-120	0.1-0.2	0.2-1
Mold Steel	50-70	0.05-0.1	0.2-0.5

13. Index

Mould milling cutter
Technical requirements
Usage Guidelines
Dimensional tolerance

14. Publication Information

Release date : June 1, 2006.
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Chinese National Standard GB/T 14301-2008

GB/T 14301-2008 - Solid carbide

saw-blade milling cutters

1. Scope

This standard specifies the size, shape, manufacturing requirements, performance specifications and use conditions of solid carbide saw blade milling cutters (milling cutters made of solid carbide with serrated cutting edges). This standard applies to saw blade milling cutters made of solid carbide materials, mainly used for grooving, cutting and trimming of metal and non-metallic materials, and is not applicable to non-cutting tools or non-solid carbide structures.

1.1 Scope of application

Suitable for saw blade milling cutters made of solid carbide.

Covers dimensions, manufacturing and usage requirements.

1.2 Exclusions

Non-cutting tools.

Milling cutter with non-solid carbide structure.

2. Normative References

The documents listed below become an integral part of this standard through reference in this standard. Only the version on a specific date applies to this standard. Any subsequent revision or amendment does not apply to this standard unless otherwise stated.

GB/T 5231-2019, *Cutting tools — General technical conditions*.

GB/T 16665-2017, *Hardmetals — Technical requirements and test methods*.

ISO 6987:2012, *Indexable hard material inserts with rounded corners*.

Note : The latest version of the referenced document may be updated after publication. It is recommended to consult the National Standard Information Public Service Platform to obtain the latest information.

3. Terms and Definitions

For the purpose of this standard, the following terms and definitions apply:

3.1 Solid Carbide Saw-blade Milling Cutter

Milling cutters made entirely of carbide with serrated cutting edges for grooving and stock removal.

3.2 Number of Teeth

The number of cutting teeth on a saw blade milling cutter affects processing efficiency and surface quality.

3.3 Application Conditions

Cutting parameters and environmental requirements of saw blade milling cutters during processing.

4. Symbols and Abbreviations

d : Diameter (mm).

l : Total Length (mm).

Z : Number of Teeth.

WC : Tungsten Carbide.

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5. Technical Requirements

5.1 Dimensions and tolerances

Diameter range : 2 mm to 25 mm.

Thickness range : 0.5 mm to 3 mm.

Length range : 40 mm to 120 mm.

Tolerance : diameter h6 (2-10 mm) or h7 (12-25 mm), thickness ± 0.02 mm.

Number of teeth (Z) : 4-20 (adjusted according to diameter).

5.2 Material requirements

Cemented Carbide (WC) : Hardness HV 1300-1800, fracture toughness $K_{IC} \geq 10 \text{ MPa} \cdot \text{m}^{1/2}$.

Coating : TiN, TiAlN or AlCrN, thickness 1-3 μm .

5.3 Geometric parameters

Tooth angle : 5° - 15° (adjusted according to the processing material).

Helix angle : 0° - 30° (straight teeth or helical teeth available).

Surface roughness : $R_a \leq 1.6 \mu\text{m}$ (cutting part), $R_a \leq 0.8 \mu\text{m}$ (shank).

6. Manufacturing Process

6.1 Material preparation

Cemented carbide: powder metallurgy, pressing pressure 150-200 MPa.

6.2 Processing Flow

Rough machining : turning or milling.

Finishing : CNC grinding, tooth profile tolerance ± 0.01 mm.

Heat treatment : Sintering, temperature 1350-1450°C.

6.3 Coating

PVD process, temperature 450-500°C, bonding strength > 70 MPa.

7. Test Methods

7.1 Dimensions and tolerances

Tools : Coordinate measuring machine.

Accuracy : ± 0.01 mm.

Reference standard : According to GB/T 5231.

7.2 Hardness test

Tools : Vickers hardness tester, load 30 kg.

Accuracy : ± 20 HV.

Reference standard : According to GB/T 16665.

7.3 Durability test

Conditions : Steel (HB 200), V_c 80 m/min, f_n 0.1 mm/tooth, a_p 0.5 mm.

Procedure : Cut continuously for 30 min and measure the wear band width (VB).

Judgment standard : $VB \leq 0.3$ mm.

Reference standard : According to ISO 8688-1.

8. Inspection Rules

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8.1 Factory Inspection

Raw material hardness and chemical composition inspection.

8.2 Factory Inspection

Dimensions, tolerances, hardness testing.

Durability test (sampling rate 5%).

9. Marking and Packaging

9.1 Logo

Mark the code (such as SC-10-Z10-WC) and the number of teeth.

Example: GB/T 14301-SC-10-Z10-WC.

9.2 Packaging

Use moisture-proof and shock-proof packaging.

Comes with a certificate of manufacture and testing.

10. Application Specifications

10.1 Cutting data

Cutting speed (Vc) : 50-150 m/min (adjusted according to material).

Feed rate (fn) : 0.05-0.2 mm/tooth.

Cutting depth : 0.2-1 mm.

10.2 Cooling requirements

Recommended cutting fluid, flow rate ≥ 10 L/min.

Dry cutting is limited to light loads and duration ≤ 10 min.

11. Safety Requirements

Wear protective glasses and gloves when operating.

Avoid overloading and cutting to prevent tool chipping.

12. Annex

Appendix A (Informative) - Dimension Reference Table

Diameter(mm)	Thickness(mm)	Length(mm)	Number of teeth (Z)	Tolerance grade
2	0.5-1	40-60	4-6	h6
10	1-2	60-90	8-12	h6
25	2-3	90-120	12-20	h7

Appendix B (Normative) - Table of Conditions of Use

Workpiece material	Cutting speed (Vc, m/min)	Feed rate (fn, mm/tooth)	Cutting depth(mm)
Steel (HB 200)	80-120	0.05-0.15	0.2-0.5
Aluminum Alloy	100-150	0.1-0.2	0.2-1
Wood materials	50-80	0.05-0.1	0.2-0.5

13. Index

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Solid Carbide Saw Blade Milling Cutter Technical requirements Usage Guidelines
Dimensional tolerance

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appendix:

Introduction of Carbide Stamping Die

The cemented carbide stamping die is a high-performance mold tool. It uses tungsten carbide (WC) as the core material and is manufactured through advanced powder metallurgy technology. It is designed for high-precision, high-strength metal forming and stamping processing. With its excellent hardness, wear resistance, high temperature resistance and corrosion resistance, cemented carbide stamping dies are widely used in automobile manufacturing, electronics, aerospace, hardware products, medical equipment and other industries. It can efficiently complete processes such as blanking, stretching, bending, and forming, significantly improving the mold life, processing accuracy and production efficiency. This article comprehensively introduces the performance and value of cemented carbide stamping dies from the aspects of material properties, types and technical indicators, manufacturing processes, uses and application scenarios, product advantages, technical challenges and improvement directions.

1. Material composition and characteristics of cemented carbide stamping dies

1.1 Material composition

The formulation of cemented carbide stamping dies is precisely designed to achieve the optimal balance of hardness, toughness and corrosion resistance:

Hard phase

Tungsten carbide (WC, 80-95%) provides ultra-high hardness and wear resistance. Some formulas are doped with titanium carbide (TiC, 15%) or tantalum carbide (TaC, 0.52%) to improve high temperature stability and oxidation resistance.

Adhesive Phase

Cobalt (Co, 515%) enhances toughness and impact resistance; Nickel (Ni, 510%) is used in corrosion-resistant formulas, suitable for acidic or humid environments.

additive

Trace amounts of chromium (Cr, 0.11%), vanadium (V, 0.050.5%), and molybdenum (Mo, 0.10.8%) are used to refine grains, inhibit grain growth, and improve corrosion resistance and high-temperature oxidation resistance.

1.2 Key Features

The performance of cemented carbide stamping dies comes from their optimized microstructure and material formulation:

hardness

HRA 8692 (HV 12001700), far superior to high speed steel (HSS, HRC 6065), is suitable for stamping materials with a hardness of up to HRC 50.

Fracture toughness

6.510 MPa·m^{1/2}, which is better than ordinary cemented carbide (57 MPa·m^{1/2}), and the impact fracture resistance is improved by 30%.

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Wear resistance

The wear rate is 0.010.02 mm³/N·m (ASTM G65), which is 1.52 times lower than that of high chromium die steel, and the die life is extended by 310 times.

Compression strength

4000-6000 MPa, able to withstand high impact pressure (maximum impact pressure up to 2000 kN).

density

13.815.2 g/cm³, moderate weight, suitable for high-precision processing.

Corrosion resistance

In a neutral or slightly acidic environment (pH 49), the corrosion rate is <0.07 mm/year; nickel-based formulations or coatings can withstand pH 210 with a corrosion rate of <0.05 mm/year.

Temperature resistance

The operating temperature ranges from 20°C to 800°C. The coating formula can withstand an instantaneous temperature of 1000°C, making it suitable for high-temperature stamping.

1.3 Microstructure advantages

The cemented carbide stamping die adopts fine grain (0.52 micron) or ultra-fine grain (0.20.5 micron) structure, which brings the following advantages:

High hardness and strength: Small grains increase grain boundary density, follow the Hall-Petch effect, and improve wear resistance.

Excellent toughness: Grain refinement disperses stress, reduces the risk of crack propagation, and improves impact resistance by 2030%.

Surface stability: reduce wear and tear, keep the mold surface smooth, and extend processing accuracy and life.

2. Types and technical indicators

There are many types of cemented carbide stamping dies, covering a variety of functions and uses. The following is a comprehensive classification, technical indicators and usage table (reference ISO standards, ASTM specifications and manufacturer data).

2.1 Types and uses of cemented carbide stamping dies

type	describe	Main uses and application scenarios	Typical Specifications
Blanking Die Blanking Die	Used for punching sheets and cutting precise shapes or holes.	Automobile manufacturing (body panels), electronics (circuit board frames), hardware (metal gaskets), punching steel sheets, stainless steel, aluminum alloys.	Size 50300 mm, thickness 1050 mm, HRA 8790, life span 502 million punching times.
Stretching die Drawing Die	Used for stretching sheet metal into deep	Automobile manufacturing (fuel tanks, car doors), home appliances (metal casings), containers	Diameter 20200 mm, depth 20100 mm, HRA 8689, life span 301.5

	cups or complex shapes.	(aluminum cans), drawing of low carbon steel, stainless steel, copper alloys.	million punching times.
Bending die Bending Die	Used to bend sheets into specific angles or shapes.	Automobile manufacturing (brackets), construction (steel structures), electronics (chassis), bent steel plates, aluminum plates, stainless steel.	Size 50400 mm, angle 15°180°, HRA 8689, life span 502 million punching times.
Forming die Forming Die	Used for forming complex three-dimensional shapes.	Aerospace (titanium alloy parts), automotive (instrument panels), medical (housings), forming stainless steel, aluminum alloys, and magnesium alloys.	Size 100500 mm, HRA 8790, life span 301.5 million punching times.
Compound mold Compound Die	Integrate multiple processes to complete multiple processes at one time.	Electronics (connectors), automobiles (small parts), hardware (complex gaskets), processing steel plates, copper alloys, and aluminum alloys.	Size 50200 mm, HRA 8790, life span 502 million punching times.
Progressive Die Progressive Die	Multi-station continuous processing, suitable for mass production.	Automobile manufacturing (fasteners), electronics (terminals), home appliances (metal accessories), punching, bending, forming steel plates, stainless steel.	Size 2001000 mm, HRA 8790, life span 1003 million punching times.
Fine punching die Fine Blanking Die	High-precision punching, smooth edges without burrs.	Automobile manufacturing (gears, bearing gaskets), electronics (precision parts), medical (equipment parts), fine blanking steel plates, stainless steel.	Size 50200 mm, tolerance ±0.005 mm, HRA 8992, life span 502 million punching times.
Extrusion Die Extrusion Die	Used for metal extrusion forming bars, tubes or special-shaped parts.	Aerospace (aluminum profiles), construction (door and window frames), automobiles (pipe fittings), extruded aluminum alloys, copper alloys, magnesium alloys.	Diameter 20100 mm, HRA 8689, life span 201 million punching times.
Cold Heading Die Cold Heading Die	Used for cold heading of fasteners such as bolts and	Automobile manufacturing (bolts), construction (fasteners), machinery (rivets), cold heading of mild steel, stainless steel, copper.	Diameter 1050 mm, HRA 8790, life span 502 million punchings.

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	nuts.		
Deep drawing die Deep Drawing Die	Specially designed for ultra-deep drawing and processing of parts with high aspect ratio.	Automobile manufacturing (fuel filter), household appliances (stainless steel pots), medical (metal cans), deep drawn stainless steel, aluminum alloy, copper.	Diameter 20150 mm, depth 50200 mm, HRA 8689, life span 201 million punching times.
Powder forming die Powder Forming Die	Used for pressing and forming powder metallurgy parts.	Automobile (gears), electronics (magnetic cores), aviation (lightweight parts), pressed iron powder, copper powder, and cemented carbide powder.	Size 50200 mm, HRA 8992, life span 502 million punching times.

2.2 Technical indicators

size

Length/width: 50-1000 mm (commonly used 50-300 mm).

Thickness: 10100 mm (commonly 1050 mm).

Tolerance: ± 0.005 mm (fine stamping die) to ± 0.02 mm (general purpose die).

weight

0.150 kg per piece, suitable for punching machines or automated production lines.

Surface roughness

Ra 0.10.8 μm , reducing workpiece adhesion and friction.

Hardness Grade

Standard: HRA 8689 (general purpose stamping).

High hardness: HRA 8992 (fine blanking, powder forming).

Material formula

WCCo (general purpose): Cobalt content 612%, HRA 8791, high toughness.

WCNi (corrosion resistant type): nickel content 510%, resistant to acid and alkali environment.

WCTiCTaC (high temperature type): temperature resistance 8001000°C.

Stamping parameters

Punching force: 1002000 kN (depending on the mold type).

Punching speed: 501000 times/minute (maximum for progressive die).

Workpiece thickness: 0.110 mm (0.55 mm is commonly used).

Surface treatment

Polishing: Ra 0.050.4 μm , reduces friction heat.

coating

TiN: Hardness HV 20002500, wear resistance increased by 2 times.

TiAlN: Temperature resistant to 900°C, suitable for high temperature stamping.

AlCrSi/TiN: temperature resistance 1000°C, life extended 3 times.

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DLC: Friction coefficient 0.10.2, suitable for aluminum alloy and copper alloy.

Standards Compliance

ISO 9001 quality management system.

ISO 8020 (punch and die specifications), ASTM B771 (wear test), ISO 3878 (hardness test).

3. Manufacturing process of cemented carbide stamping die

The manufacture of cemented carbide stamping dies adopts advanced powder metallurgy technology to ensure that material properties, geometric accuracy and surface quality meet top standards.

3.1 Raw material preparation

High-purity tungsten carbide (WC, purity>99.95%), cobalt (Co, purity>99.9%) and additives (such as TiC, TaC, Cr) are selected. The powder is mixed through a wet grinding process (the medium is alcohol or deionized water, ball milling for 2472 hours), and the average particle size is controlled at 0.21 microns. VC or Cr₃C₂ (0.10.5%) is added as a grain inhibitor to prevent grain growth during high-temperature sintering.

3.2 Forming

Cold isostatic pressing (CIP): The powder is pressed into a green body at a pressure of 200-400 kg, with a density of 50-60% of the theoretical value.

Precision moulding: High-precision moulds (tolerance ± 0.1 mm) are used to mould complex cavities or punches.

Spray drying: prepare flowable particles and improve the uniformity and strength of green bodies.

3.3 Sintering

Pre-sintering: 900-1100°C, to remove organic additives.

Hot isostatic pressing (HIP): 1350-1500°C, 100-200 MPa, argon atmosphere, sintering for 24 hours, density 99.8-100%.

Cooling control: Progressive cooling (1020°C/min) to avoid micro cracks caused by thermal stress.

3.4 Post-processing

Precision grinding: Use diamond grinding wheel or CBN tool to process to tolerance ± 0.005 mm and surface roughness Ra 0.10.8 μm .

Electrospark machining (EDM): Processing complex mold cavities with an accuracy of ± 0.01 mm, suitable for fine stamping dies and progressive dies.

Surface strengthening: sandblasting, polishing or coating (TiN, TiAlN, AlCrSi/TiN, DLC) to improve wear resistance and heat resistance.

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Quality Inspection:

Hardness test: HRA/HV, error ± 0.5 .

Microstructural analysis: Scanning electron microscopy (SEM) was used to examine the grain size (0.22 μm).

Dimension measurement: three-dimensional measuring instrument, accuracy ± 0.002 mm.

Non-destructive testing: Ultrasonic testing to check for internal defects.

4. Uses and application scenarios of cemented carbide stamping dies

Carbide stamping dies are widely used in the following fields and scenarios due to their high precision, wear resistance and long life:

4.1 Automobile Manufacturing

Carbide punching die

Punching body panels and brackets, processing low carbon steel and stainless steel, accuracy ± 0.02 mm, life of 502 million times, used in the production of car doors and engine hoods.

Carbide drawing die

Stretching fuel tank, instrument panel, processing aluminum alloy, stainless steel, depth 50200 mm, life span 301.5 million times, suitable for mass production.

Carbide cold heading die

Formed bolts and nuts, processed low carbon steel, life span 502 million times, used in fastener manufacturing.

4.2 Electronics and electrical appliances

Carbide Progressive Die

Processing connectors and terminals, punching copper alloy and stainless steel, accuracy ± 0.01 mm, life 100-300 million times, suitable for high-speed stamping.

Carbide precision punching die

Produce circuit board frames, precision parts, and process steel plates with edge roughness Ra 0.2 μm and life of 502 million times. Applied in mobile phone and computer manufacturing.

Cemented Carbide Powder Forming Die

Pressing magnetic cores, electronic components, processing iron powder, copper powder, life of 502 million times, suitable for small parts production.

4.3 Aerospace

Carbide forming die

Forming titanium alloy and aluminum alloy parts, such as wing connectors, with an accuracy of ± 0.01 mm, a service life of 301.5 million times, and a temperature resistance of 800°C.

Carbide Extrusion Die

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Extruding lightweight profiles, processing magnesium alloy and aluminum alloy, with a service life of 201 million times, used in fuselage structural parts.

Cemented Carbide Composite Die

Processing complex connectors, punching + stretching titanium alloy, life span 502 million times, suitable for high-precision parts.

4.4 Hardware and Construction

Carbide bending die

Bending steel plates and aluminum plates, processing building brackets and metal accessories, with an angle accuracy of $\pm 0.5^\circ$ and a service life of 502 million times, it is used in steel structure, door and window manufacturing.

Carbide punching die

Punching metal gaskets and fasteners, processing stainless steel and copper, with a service life of 502 million times, suitable for hardware product production.

Carbide Extrusion Die

Extruded pipes and profiles, processed aluminum alloy, life span 201 million times, used in building decoration.

4.5 Medical Devices

Carbide precision punching die

Processing surgical instrument parts, punching stainless steel and titanium alloy, accuracy of ± 0.005 mm, life of 502 million times, used in the manufacture of bone screws and implants.

Carbide forming die

Forming medical housing, processing aluminum alloy, stainless steel, surface roughness Ra 0.2 μm , life 301.5 million times, suitable for medical container production.

Carbide cold heading die

Formed micro fasteners, processed from stainless steel, with a lifespan of 502 million cycles, used in medical device assembly.

5. Advantages of carbide stamping dies

Carbide stamping dies take the lead in the die industry with their excellent performance:

Ultra-long life: Wear resistance and hardness extend the life by 310 times and reduce the single stamping cost by 3060%.

Efficient processing: Supports high-speed stamping (501,000 times/minute) and high punching force (1,002,000 kN), and increases production efficiency by 2050%.

High precision: processing accuracy ± 0.005 mm (fine punching die), surface roughness Ra 0.10.8 μm , meeting the high requirements of aviation and electronics.

Flexible customization: Diverse types (punching, drawing, progressive, etc.), sizes (501000 mm) and coatings (TiN, TiAlN) to suit different working conditions.

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Environmental adaptability: high temperature resistance (800-1000°C), corrosion resistance (pH 2-10), adaptable to dry, wet and chemical environments.

Green Manufacturing: High durability reduces mold changes and waste, in line with sustainable development goals.

6. Technical challenges and improvement directions of cemented carbide stamping dies

6.1 Technical Challenges

Processing difficulty: Cemented carbide has high hardness (HRA 86-92), which places extremely high demands on processing equipment and tools. Diamond grinding wheels or CBN tools wear quickly, and it is difficult to stabilize the processing accuracy (tolerance $\leq \pm 0.005$ mm).

Brittleness risk: High-hardness materials may produce microcracks or breakage under high impact pressure (> 2000 kN) or improper design, which will affect the service life.

Thermal management issues: High-speed stamping (> 500 times/minute) generates friction heat, which may cause softening of the mold surface or peeling of the coating, especially under high temperature conditions.

Adaptability to complex workpieces: Thin plates (< 0.5 mm), high-strength steel (HRC > 50) or composite materials have high requirements on mold geometry and surface treatment, and are prone to wear or sticking.

Extreme working conditions: Under ultra-high temperature ($> 1000^\circ\text{C}$) or strong acid environment (pH < 2), the performance of traditional coatings and bonding phases deteriorates, and the service life is shortened by 50-70%.

6.2 Technical Improvement Direction of Cemented Carbide Stamping Dies

Advanced processing technology: Develop laser micromachining and electrospark machining, with accuracy increased to ± 0.003 mm, tool wear reduced by 30%, suitable for complex mold cavities (such as progressive dies and fine stamping dies).

Toughness-enhanced design: Adopting gradient structure (high-hardness HRA 90-92 on the surface, high-toughness fracture toughness > 10 MPa·m^{1/2} on the inside) or CoNi composite bonding phase, the impact resistance is increased by 20-30% and the risk of cracking is reduced.

Efficient thermal management: Optimize mold cooling channels (coolant pressure 5-10 MPa, flow rate 3-10 L/min) to reduce operating temperature 100-150°C; develop adaptive coatings (such as TiAlN/AlCrSi, temperature resistance 1100°C) to reduce thermal softening.

Optimization of complex workpieces: Design low-friction coatings (such as DLC, friction coefficient 0.1-0.2) and optimize cavity geometry (corner radius 0.1-0.5 mm) to reduce thin plate sticking and wear; develop PCD (polycrystalline diamond) inlay molds with hardness increased to HV 8000 and service life extended by 20 times.

Adaptation to extreme working conditions: Research and develop nano multilayer coatings (such as AlCrSi/TiN, thickness 25 μm, hardness HV 3500) or ceramic matrix composite materials (WCSiC),

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with temperature resistance increased to 1200°C and strong acid (pH 12) corrosion rate <0.03 mm/year.

Intelligent design: AI is used to simulate punching force (error <5%) and wear behavior, optimize cavity angle (deviation <0.5°) and surface treatment (roughness Ra <0.1 μm), and improve processing stability; self-diagnostic molds are developed to monitor temperature and wear in real time, extending service life by 1020%.

Carbide stamping dies have become the preferred mold tools in the fields of automobile manufacturing, electronic appliances, aerospace, hardware products, medical equipment, etc. due to their high hardness (HRA 8692), excellent toughness ($6.510 \text{ MPa} \cdot \text{m}^{1/2}$) and ultra-long life (203 million stampings). Its rich variety (punching dies, drawing dies, progressive dies, fine punching dies, etc.) and precise specifications (tolerance $\pm 0.005 \text{ mm}$, size 501000 mm) meet the diverse needs from sheet metal blanking to deep drawing. Technical indicators show that its life is 310 times that of high-speed steel dies, production efficiency is increased by 2050%, and processing accuracy reaches IT6/IT8 level.

Through advanced powder metallurgy processes and coating technologies (such as TiAlN and DLC), stamping dies perform well in harsh environments such as high temperature (800-1000°C) and corrosion (pH 210). In the future, through laser processing, PCD inlay, nano coating, AI optimization and intelligent design, cemented carbide stamping dies will further improve performance and expand application scenarios, providing solid support for the efficient, precise and sustainable development of the global industry.



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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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appendix:

Introduction of Carbide Wire Drawing Die

Carbide wire drawing dies are a high-performance die tool that uses tungsten carbide (WC) as the core material. They are manufactured through advanced powder metallurgy processes and are designed specifically for metal wire drawing. With excellent hardness, wear resistance, high temperature resistance, and corrosion resistance, carbide wire drawing dies are widely used in wire and cable, wire rope, spring manufacturing, medical guidewires, aerospace wires, and other fields. It can efficiently draw metal materials such as steel, copper, aluminum, and titanium, significantly improving the surface quality, dimensional accuracy, and die life of the wire. This article comprehensively introduces the performance and value of carbide wire drawing dies from the aspects of material properties, types and technical indicators, manufacturing processes, uses and application scenarios, product advantages, technical challenges, and improvement directions.

1. Material composition and characteristics of cemented carbide wire drawing dies

1.1 Material composition of cemented carbide wire drawing die

The formulation of carbide drawing dies is precisely designed to achieve the best balance of hardness, toughness and corrosion resistance:

Hard phase

Tungsten carbide (WC, 85-95%) provides ultra-high hardness and wear resistance. Some formulas are doped with titanium carbide (TiC, 0.53%) or tantalum carbide (TaC, 0.52%) to improve high temperature stability and oxidation resistance.

Adhesive Phase

Cobalt (Co, 5.12%) enhances toughness and impact resistance; Nickel (Ni, 5.10%) is used in corrosion-resistant formulas, suitable for acidic or humid environments.

additive

Trace amounts of chromium (Cr, 0.10.8%), vanadium (V, 0.050.4%), and molybdenum (Mo, 0.10.6%) are used to refine grains, inhibit grain growth, and improve corrosion resistance and high-temperature oxidation resistance.

1.2 Key characteristics of cemented carbide wire drawing dies

The performance of cemented carbide wire drawing dies comes from their optimized microstructure and material formulation:

hardness

HRA 8892 (HV 14001800), far exceeding high speed steel (HSS, HRC 6065), is suitable for materials with tensile hardness up to HRC 40.

Fracture toughness

6.09.0 MPa·m^{1/2}, which is better than ordinary cemented carbide (57 MPa·m^{1/2}), and the crack growth resistance is improved by 25%.

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Wear resistance

The wear rate is 0.0080.015 mm³/N·m (ASTM G65), which is 1.52 times lower than that of high chromium die steel, and the die life is extended by 515 times.

Compression strength

45006500 MPa, resistant to high tensile forces (maximum tensile force up to 500 kN).

density

14.015.0 g/cm³, moderate weight, suitable for precision machining.

Corrosion resistance

In a neutral or slightly acidic environment (pH 49), the corrosion rate is <0.05 mm/year; nickel-based formulations or coatings can withstand pH 210 with a corrosion rate of <0.03 mm/year.

Temperature resistance

The operating temperature is from 20°C to 700°C, and the coating formula can withstand instantaneous temperatures of 900°C, making it suitable for high-temperature wire drawing.

1.3 Microstructure advantages of cemented carbide wire drawing dies

The cemented carbide wire drawing die adopts ultra-fine grain (0.20.5 micron) or fine grain (0.51 micron) structure, which brings the following advantages:

High hardness and strength: Small grains increase grain boundary density, follow the Hall-Petch effect, and improve wear resistance.

Excellent toughness: Grain refinement disperses stress, reduces the risk of crack propagation, and improves impact resistance by 2030%.

Surface stability: reduce wear and tear, keep the die hole smooth, and extend the surface quality of the wire and the life of the die.

2. Types and technical indicators of cemented carbide wire drawing dies

There are many types of carbide wire drawing dies, covering different wire types and drawing requirements. The following is a comprehensive classification, technical indicators and usage table (reference ISO standards, ASTM specifications and manufacturer data).

2.1 Types and uses of cemented carbide wire drawing dies

type	describe	Main uses and application scenarios	Typical Specifications
Round wire drawing die Round Wire Die	Standard round die hole, suitable for round wire drawing.	Wires and cables (copper and aluminum wires), wire ropes (high carbon steel wires), springs (piano wires), tensile copper, aluminum, and steel.	Die hole diameter 0.0110 mm, die body diameter 20100 mm, HRA 8892, life 500-2000 tons of wire.
Special-shaped wire drawing die	Non-circular die holes (such as square,	Electronics (flat wire), hardware (square steel wire), medical (special-shaped guide wire), drawn	Die hole size 0.18 mm, die body diameter 2080 mm, HRA 8992, life 3001500 tons of wire.

Shaped Wire Die	hexagonal, and oval) are used for special-shaped wires.	copper, stainless steel, titanium alloy.	
Micro Wire Drawing Die	Extra small die hole, specially designed for thin wire drawing.	Medical (guide wire, suture), electronics (ultra-fine copper wire), aviation (titanium alloy filament), drawing titanium, copper, stainless steel.	Die hole diameter 0.005-0.5 mm, die body diameter 1050 mm, HRA 9092, life 100500 tons of wire.
Multi-stage drawing die	Multi-die continuous stretching, suitable for mass production.	Wires and cables (high voltage cable core), steel cord (for tires), springs (high-strength steel wire), tensile steel, copper, and aluminum.	Die hole diameter 0.18 mm, die body diameter 50150 mm, HRA 8891, life 10003000 tons of wire.
Pipe drawing die	Used for stretching the outer diameter or inner diameter of the pipe to optimize the pipe wall thickness.	Energy (stainless steel pipes), medical (catheters), automotive (exhaust pipes), drawing stainless steel, copper, aluminum alloys.	Die hole diameter 250 mm, die body diameter 50120 mm, HRA 8790, life 5002000 tons of pipe.
Tube Drawing Die			
Rod drawing die	Large diameter die hole, suitable for drawing rods or thick wires.	Construction (rebars), machinery (shaft parts), hardware (thick steel wire), stretched low carbon steel, stainless steel, copper.	Die hole diameter 530 mm, die body diameter 50150 mm, HRA 8790, life 5002000 tons of bar.
Bar Drawing Die			
High temperature wire drawing die	High temperature resistant design, suitable for high temperature wire drawing.	Aerospace (nickel-based alloy wire), energy (high-temperature wire), military industry (titanium alloy wire), stretched titanium alloy, nickel-based alloy.	Die hole diameter 0.15 mm, die body diameter 2080 mm, HRA 8992, life 3001000 tons of wire.
High Temp Die			
Composite Die	Designed for stretching composite or coated wires to reduce delamination.	Electronics (coated conductors), aviation (carbon fiber composite wires), energy (composite cables), stretched copper clad steel, carbon fiber composite materials.	Die hole diameter 0.15 mm, die body diameter 2080 mm, HRA 8992, life 200800 tons of wire.

2.2 Technical indicators of cemented carbide wire drawing dies

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Carbide drawing die size

Die hole diameter: 0.00550 mm (commonly used 0.0110 mm).
Diameter of phantom: 10-150 mm (commonly used 20-100 mm).
Tolerance: ± 0.001 mm (micro mold) to ± 0.01 mm (general mold).

Carbide drawing die weight

Single piece weighs 0.055 kg, suitable for wire drawing machines or automated production lines.

Surface roughness of cemented carbide wire drawing die

Die hole Ra 0.050.2 μm , wire surface Ra 0.10.4 μm .

Hardness Grade of Carbide Wire Drawing Dies

Standard: HRA 8891 (general purpose drawing).
High hardness: HRA 9092 (micro, high temperature drawing).

Cemented Carbide Wire Drawing Die Material Formula

WCCo (general purpose): Cobalt content 510%, HRA 8891, high toughness.
WCNi (corrosion resistant type): nickel content 510%, resistant to acid and alkali environment.
WCTiCTaC (high temperature type): temperature resistance 700-900°C.

Carbide wire drawing die drawing parameters

Drawing speed: 130 m/s (microwire 15 m/s, steel wire 1030 m/s).
Tensile force: 10500 kN (depending on material diameter and material).
Reduction rate: 1030% (single stretch).

Surface treatment of cemented carbide wire drawing dies

Polishing: Die hole Ra 0.020.1 μm , reduce friction heat.

Carbide Wire Drawing Die Coating

TiN: Hardness HV 2000.2500, wear resistance increased by 2 times.
TiAlN: Temperature resistant to 900°C, suitable for high temperature wire drawing.
AlCrSi/TiN: temperature resistance 1000°C, life extended 3 times.
DLC: Friction coefficient 0.080.15, suitable for copper and aluminum wires.

Carbide Wire Drawing Die Standard Compliance

ISO 9001 quality management system.
ISO 1684 (wire drawing die specification), ASTM B771 (wear test), ISO 3878 (hardness test).

3. Manufacturing process of cemented carbide wire drawing die

The manufacture of cemented carbide wire drawing dies adopts advanced powder metallurgy technology to ensure that the material performance, die hole accuracy and surface quality reach the

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top standards.

3.1 Preparation of raw materials for cemented carbide wire drawing dies

High-purity tungsten carbide (WC, purity>99.95%), cobalt (Co, purity>99.9%) and additives (such as TiC, TaC, Cr) are selected. The powder is mixed through wet grinding process (medium is alcohol or deionized water, ball milling for 2472 hours), and the average particle size is controlled at 0.20.8 microns. VC or Cr₃C₂ (0.10.4%) is added as a grain inhibitor to prevent grain growth during high-temperature sintering.

3.2 Carbide wire drawing die forming

Cold isostatic pressing (CIP): The powder is pressed into a green body at 200-400 MPa with a density of 50-60% of the theoretical value.

Precision molding: High-precision molds (tolerance ± 0.05 mm) are used to form the mold body and the initial mold hole.

Spray drying: prepare flowable particles and improve the uniformity and strength of green bodies.

3.3 Sintering of cemented carbide wire drawing die

Pre-sintering: 9001100°C, to remove organic additives.

Hot isostatic pressing (HIP): 13501450°C, 100200 MPa, argon environment, sintering for 23 hours, density 99.8100%.

Cooling control: Progressive cooling (1015°C/min) to avoid micro cracks caused by thermal stress.

3.4 Post-processing of cemented carbide wire drawing dies

Precision grinding: Use a diamond grinding wheel to process the die hole to a tolerance of ± 0.001 mm and a surface roughness of Ra 0.050.2 μm .

Laser processing: fine-tune the shape of the mold hole (round, special shape), with an accuracy of ± 0.0005 mm, suitable for micro molds.

Polishing: Ultra-precision polishing, die hole Ra 0.020.1 μm , optimize the surface quality of the wire.

Surface strengthening: coatings (TiN, TiAlN, AlCrSi/TiN, DLC) improve wear resistance and heat resistance.

Quality Inspection:

Hardness test: HRA/HV, error ± 0.5 .

Microstructural analysis: Scanning electron microscopy (SEM) was used to examine the grain size (0.20.8 μm).

Dimension measurement: optical measuring instrument, accuracy ± 0.0005 mm.

Non-destructive testing: Ultrasonic testing to check for internal defects.

4. Uses and application scenarios of cemented carbide wire drawing dies

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Carbide wire drawing dies are widely used in the following fields and scenarios due to their high precision, wear resistance and long life:

4.1 Carbide wire drawing die wire and cable

Carbide wire drawing die round wire drawing die

Stretching copper and aluminum conductors to produce power cables and communication lines, with a wire diameter accuracy of ± 0.002 mm and a service life of 500-2000 tons, is used in the manufacture of high-voltage cables and network cables.

Carbide wire drawing die multi-stage wire drawing die

Continuously stretch thin copper wire and process ultra-fine wire with wire diameter of 0.01-0.1 mm and service life of 1000-3000 tons, suitable for the production of data cables and headphone cables.

Carbide wire drawing dies Special-shaped wire drawing dies

Stretching flat or square wires, processing wires for electronic equipment, life span 300-1500 tons, used in connectors and circuit boards.

4.2 Carbide wire drawing die wire and spring

Carbide wire drawing die round wire drawing die

Stretching high carbon steel wire to produce steel wire rope and spring steel wire, wire diameter 0.110 mm, service life 500-2000 tons, used in elevator wire rope and automobile suspension spring.

Carbide wire drawing dies, rod wire drawing dies

Stretching thick steel wire or steel bar, processing construction steel, wire diameter 530mm, life 5002000 tons, suitable for bridges and building structures.

Carbide wire drawing die High temperature wire drawing die

Stretching music wire to produce high-strength springs with a temperature resistance of 700°C and a service life of 300-1000 tons, used in industrial springs and valve springs.

4.3 Carbide wire drawing dies for medical devices

Carbide wire drawing die Micro wire drawing die

Stretching titanium alloy and stainless steel guide wires to produce cardiovascular guide wires and sutures, with a wire diameter of 0.005-0.5 mm, an accuracy of ± 0.001 mm, and a service life of 100500 tons, suitable for interventional medical treatment.

Carbide wire drawing dies Special-shaped wire drawing dies

Stretching special-shaped medical wires, processing orthopedic fixation wires, with a service life of 200,800 tons, used in the manufacture of bone screws and implants.

Carbide wire drawing dies Composite material wire drawing dies

Stretched composite guidewire, processed coated wire, life span 200800 tons, suitable for neurointerventional equipment.

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4.4 Aerospace

Carbide wire drawing die High temperature wire drawing die

Stretching nickel-based alloy and titanium alloy wires to produce aviation engine wires and fasteners, wire diameter 0.15 mm, temperature resistance 900°C, life 300-1000 tons, used in turbine blades and fuselage connectors.

Carbide wire drawing dies Composite material wire drawing dies

Stretched carbon fiber composite wire, processing lightweight wire, life of 200800 tons, suitable for UAV and satellite components.

Carbide wire drawing die Micro wire drawing die

Stretching ultra-fine titanium wire to produce aviation sensor wire, wire diameter 0.010.5 mm, life span 100500 tons, used in precision instruments.

4.5 Hardware and Energy

Carbide wire drawing die pipe drawing die

Stretching stainless steel and copper tubes, producing energy conduits and heat exchange tubes, with a diameter of 250 mm and a service life of 500-2000 tons, which are used in nuclear power and oil pipelines.

Carbide wire drawing dies, rod wire drawing dies

Stretching copper and aluminum bars, processing hardware parts and conductive bars, rod diameter 530 mm, service life 500-2000 tons, suitable for power equipment.

Carbide wire drawing die round wire drawing die

Stretching steel wire to produce steel cord and wire mesh, wire diameter 0.15 mm, life span 500-2000 tons, used in tires and protective nets.

5. Product advantages

Carbide wire drawing dies take the lead in the wire drawing die market with their excellent performance:

Ultra-long life: Wear resistance and hardness extend the life by 515 times, and the cost of a single wire drawing is reduced by 4070%.

Efficient processing: Supports high-speed stretching (130 m/s) and high tensile force (10,500 kN), increasing production efficiency by 2050%.

High precision: die hole accuracy ± 0.001 mm, wire surface roughness Ra 0.10.4 μm , meeting the high requirements of medical and aviation.

Flexible customization: Various types (round, special-shaped, miniature, etc.), die hole sizes (0.00550 mm) and coatings (TiN, DLC) are available to suit different working conditions.

Environmental adaptability: high temperature resistance (700-900°C), corrosion resistance (pH 210), adaptable to dry, wet and chemical environments.

Green Manufacturing: High durability reduces mold changes and waste, in line with sustainable development goals.

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6. Technical challenges and improvement directions of cemented carbide wire drawing dies

6.1 Technical Challenges of Carbide Wire Drawing Dies

Processing difficulty

Cemented carbide has high hardness (HRA 8892), which places extremely high demands on processing equipment and tools. Diamond grinding wheels wear quickly, and the die hole accuracy is difficult to stabilize (tolerance $\leq \pm 0.001$ mm).

Fragility risk

High-hardness materials may produce microcracks or die hole collapse under high tensile force (>500 kN) or improper design, which will affect the service life.

Thermal management issues

High-speed stretching (>20 m/s) generates frictional heat, which may cause softening of the die surface or peeling of the coating, especially under high temperature conditions.

Complex material adaptability

High-strength steel (HRC >40), titanium alloy or composite wire has high requirements on die hole geometry and surface treatment, and is prone to wear or wire surface defects.

Extreme working conditions limitations

Under ultra-high temperature ($>900^{\circ}\text{C}$) or strong acid environment (pH <2), the performance of traditional coatings and bonding phases deteriorates and the service life is shortened by 5070%.

6.2 Technical improvement direction of cemented carbide wire drawing dies

Advanced processing technology

Develop laser micromachining and ultra-precision grinding, improve the mold hole accuracy to ± 0.0005 mm, reduce tool wear by 30%, and make it suitable for micro and special-shaped molds.

Toughness Enhanced Design

The use of gradient structure (high hardness HRA 9092 on the surface, high toughness fracture toughness >9 MPa $\cdot\text{m}^{1/2}$ inside) or CoNi composite bonding phase can increase the crack growth resistance by 2030% and reduce die hole cracking.

Efficient thermal management

Optimize the die cooling system (coolant pressure 510 MPa, flow rate 25 L/min) to reduce the working temperature by $100\text{--}150^{\circ}\text{C}$; develop adaptive coatings (such as TiAlN/AlCrSi, temperature resistance 1000°C) to reduce thermal softening.

Complex material optimization

Design low-friction coatings (such as DLC, friction coefficient 0.080.15) and optimize die hole geometry (entrance angle $5^{\circ}\text{--}15^{\circ}$, reduced surface area length 0.52 mm) to reduce wire surface defects; develop PCD (polycrystalline diamond) die holes, increase the hardness to HV 8000, and extend the service life by 20 times.

Extreme working conditions adaptation

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Develop nano-multilayer coatings (such as AlCrSi/TiN, thickness 13 μm , hardness HV 3500) or ceramic-based composite materials (WCSiC), with temperature resistance increased to 1100°C and strong acid (pH 12) corrosion rate <0.02 mm/year.

Intelligent design

AI is used to simulate drawing force (error < 5%) and wear behavior, optimize die hole angle (deviation < 0.2°) and surface roughness ($R_a < 0.05 \mu\text{m}$), and improve wire drawing stability; self-diagnostic wire drawing dies are developed to monitor temperature and wear in real time, extending life by 1020%.

7. Conclusion

Carbide wire drawing dies have become the preferred die tools in the fields of wire and cable, wire rope, spring manufacturing, medical guide wire, aerospace wire, etc. due to their high hardness (HRA 8892), excellent toughness ($6.09.0 \text{ MPa}\cdot\text{m}^{1/2}$) and ultra-long life (1003000 tons of wire). Its rich variety (circular die, micro die, special-shaped die, multi-stage die, etc.) and precise specifications (die hole diameter 0.00550 mm, tolerance $\pm 0.001 \text{ mm}$) meet the diverse drawing needs from ultra-fine guide wire to thick rod. Technical indicators show that its life is 515 times that of high-speed steel dies, production efficiency is increased by 2050%, and the surface quality of the wire reaches $R_a 0.10.4 \mu\text{m}$.

Through advanced powder metallurgy processes and coating technologies (such as TiAlN and DLC), wire drawing dies perform well in harsh environments such as high temperature (700-900°C) and corrosion (pH 12). In the future, through laser processing, PCD die holes, nano-coating, AI optimization and intelligent design, cemented carbide wire drawing dies will further improve performance and expand application scenarios, providing solid support for the efficient, precise and sustainable development of the global industry.



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appendix:

Carbide Nozzle

The cemented carbide nozzle is a high-performance fluid control component, made of tungsten carbide (WC) as the main material, manufactured by powder metallurgy, and designed for jetting applications in high-pressure, high-wear and corrosive environments. Its excellent hardness, wear resistance, high temperature resistance and corrosion resistance make it widely used in sandblasting, spraying, water jet cutting, oil drilling, chemical industry, agricultural irrigation and food processing. This article systematically explains the performance and application value of cemented carbide nozzles from the aspects of material properties, classification and technical parameters, manufacturing process, application fields, performance advantages, challenges and technology development trends.

1. Material composition and performance characteristics

Material composition and performance characteristics of cemented carbide nozzles

The material and performance characteristics of carbide nozzles determine their excellent performance in harsh environments.

Carbide Nozzle Material Composition

The material formula of carbide nozzles is optimized to balance hardness, toughness and corrosion resistance.

Tungsten carbide (WC, 8595 wt%) hard phase of cemented carbide nozzle

provides high hardness and wear resistance. Some formulations add titanium carbide (TiC, 0.53 wt%) or tantalum carbide (TaC, 0.52 wt%) to enhance high temperature stability and oxidation resistance.

The cemented carbide nozzle binder phase contains

cobalt (Co, 512 wt%), which improves toughness and impact resistance; nickel (Ni, 510 wt%), which is used in corrosion-resistant formulations and is suitable for acidic or humid environments.

Trace

amounts of chromium (Cr, 0.10.8 wt%), vanadium (V, 0.050.4 wt%), and molybdenum (Mo, 0.10.6 wt%) are used to refine grains, inhibit grain growth, and improve corrosion resistance and high temperature performance.

Carbide Nozzle Performance Characteristics

The performance of cemented carbide nozzles comes from their optimized microstructure and material formulation.

The hardness of carbide nozzles is

HRA 8892 (HV 14001800), which is significantly higher than that of stainless steel (HRC 2040) and is suitable for highly abrasive blasting.

The fracture toughness of the cemented carbide nozzle is

6.09.0 MPa·m^{1/2}, which is about 25% higher than that of ordinary cemented carbide (57 MPa·m^{1/2}), effectively resisting crack propagation.

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of the cemented carbide nozzle

is 0.0080.015 mm³/N·m (ASTM G65), which is 1.52 times lower than that of high chromium alloy and the service life is extended by 515 times.

The compression strength of the cemented carbide nozzle

is 4500-6500 MPa and can withstand a maximum injection pressure of 500 MPa.

The density of the cemented carbide nozzle is

14.015.0 g/cm³, suitable for high-precision installation.

The corrosion resistance of cemented carbide nozzles

is <0.05 mm/year in a neutral or weakly acidic environment (pH 49); the nickel-based or coated formula can withstand pH 210 with a corrosion rate of <0.03 mm/year.

resistance of cemented carbide nozzles

ranges from 20°C to 800°C, and the coating formula can withstand instantaneous temperatures of 1000°C.

Microstructure characteristics of cemented carbide nozzles

Cemented carbide nozzles adopt ultrafine grain (0.20.5 μm) or fine grain (0.51 μm) structure, which has the following advantages:

High hardness and strength: Small grains increase grain boundary density, follow the Hall-Petch effect, and improve wear resistance.

Improved toughness: Grain refinement disperses stress, reduces the risk of crack propagation, and improves impact resistance by 2030%.

Surface stability: reduce wear and tear, maintain the surface finish of the nozzle hole, and ensure injection accuracy and service life.

2. Classification and technical parameters of cemented carbide nozzles

Classification and technical parameters of cemented carbide nozzles

Cemented carbide nozzles are divided into various types according to the spraying medium and application scenarios to meet different industrial needs.

Classification and Use of Carbide Nozzles

The following is a summary of the classification, technical parameters and uses of carbide nozzles (based on ISO standards, ASTM specifications and industry data):

Classification and application table of cemented carbide nozzles

type	describe	Main uses and application scenarios	Typical Specifications
Sandblasting nozzle Sandblasting Nozzle	High wear-resistant design, suitable for abrasive blasting.	Surface treatment (rust removal, deburring), shipbuilding (hull sandblasting), construction (concrete cleaning), blasting sand, steel shot.	Nozzle diameter 212 mm, length 50200 mm, HRA 8892, life 5002000 hours.

Water jet nozzle Waterjet Nozzle	High-pressure water jet, suitable for cutting hard materials.	Aerospace (titanium alloy cutting), automotive (composite material cutting), stone processing (marble), high-pressure water jet (300400 MPa).	Nozzle diameter 0.12 mm, length 20100 mm, HRA 9092, life 2001000 hours.
Spray Nozzle Spray Coating Nozzle	Precise application of paint or ceramic coatings.	Aviation (turbine blade coating), automotive (engine coating), electronics (circuit board spraying), spraying ceramics, metal powders.	Nozzle diameter 0.55 mm, length 30150 mm, HRA 8891, life 3001500 hours.
Oilfield Nozzles Oilfield Nozzle	High pressure and corrosion resistance, suitable for drilling jetting.	Oil drilling (drilling fluid injection), natural gas exploration (downhole cleaning), mining (mud injection), injection drilling fluid, chemical fluid.	Nozzle diameter 315 mm, length 50150 mm, HRA 8992, life 5002000 hours.
Atomizing nozzle Atomizing Nozzle	Fine atomized spray, suitable for liquid dispersion.	Agriculture (pesticide spraying), chemical industry (liquid atomization), environmental protection (waste gas treatment), spraying water, chemical liquid, oil.	Nozzle diameter 0.23 mm, length 20100 mm, HRA 8891, life 5002000 hours.
Combustion nozzle Burner Nozzle	High temperature resistant design, suitable for fuel or gas injection.	Energy (boiler combustion), chemical industry (high temperature reaction), metallurgy (furnace injection), injection fuel oil, natural gas.	Nozzle diameter 110 mm, length 30120 mm, HRA 8992, life 3001500 hours.
Micro Nozzle Micro Nozzle	Ultra-small nozzle hole, suitable for high-precision injection.	Medical (drug spray), electronics (chip cleaning), aviation (precision coating), spraying liquids, gases, and particles.	Nozzle diameter 0.050.5 mm, length 1050 mm, HRA 9092, life 2001000 hours.
Corrosion resistant nozzles CorrosionResistant Nozzle	Resistant to strong acids and alkalis, suitable for chemical environments.	Chemical industry (acid and alkali solution injection), environmental protection (desulfurization and denitrification), marine engineering (seawater injection), injection of strong acid, strong alkali and seawater.	Nozzle diameter 110 mm, length 30150 mm, HRA 8891, life 5002000 hours.
Milk powder manufacturing	Specially designed for spray drying to	Food processing (milk powder, milk powder production),	Nozzle diameter 0.53 mm, length 20100 mm, HRA 8891,

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nozzle	evenly	atomize	agriculture	(dairy	product	life 5002000 hours.
Milk	Powder	emulsions.	processing),	spraying	emulsion,	
Spray Nozzle			whely liquid,	production of infant	milk powder,	milk powder.

Technical parameters of cemented carbide nozzles

The technical parameters of cemented carbide nozzles ensure their adaptability to a variety of industrial applications:

size:

Nozzle diameter: 0.0515 mm (0.112 mm is commonly used).

Nozzle length: 10200 mm (commonly 20150 mm).

Tolerance: ± 0.001 mm (micro nozzles, milk powder manufacturing nozzles) to ± 0.01 mm (universal nozzles).

Weight: 0.011 kg per piece, suitable for manual or automated equipment.

Surface roughness: nozzle hole Ra 0.050.2 μm , injection surface Ra 0.10.4 μm .

Hardness Grade:

Standard: HRA 8891 (general purpose spraying, milk powder manufacturing).

High hardness: HRA 9092 (water jet, micro nozzle).

Material formula:

WCCo (general purpose): Cobalt content 510%, HRA 8891, high toughness.

WCNi (corrosion-resistant type): Nickel content 510%, resistant to acid and alkali environments, suitable for milk powder manufacturing.

WCTiCTaC (high temperature type): temperature resistance 8001000°C.

Injection parameters:

Injection pressure: 0.1500 MPa (the highest for water jet, 0.55 MPa for milk powder manufacturing).

Jet velocity: 101000 m/s (depending on the medium).

Flow rate: 0.01100 L/min (milk powder manufacturing 0.110 L/min).

Surface treatment:

Polishing: spray hole Ra 0.020.1 μm , reduces friction and clogging, suitable for milk powder manufacturing.

coating:

TiN: Hardness HV 20002500, wear resistance increased by 2 times.

TiAlN: Temperature resistant to 900°C, suitable for high-temperature spraying.

AlCrSi/TiN: temperature resistance 1000°C, life span extended by 3 times.

DLC: Friction coefficient 0.080.15, suitable for liquid spraying and emulsion spraying.

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Standards Compliance:

ISO 9001 quality management system.

ASTM B771 (wear test), ISO 3878 (hardness test).

Food grade certification: The milk powder manufacturing nozzle complies with FDA/EU food contact standards.

3. Manufacturing process of cemented carbide nozzle

The manufacture of cemented carbide nozzles adopts advanced powder metallurgy technology to ensure that the material properties, nozzle accuracy and surface quality meet the industry standards.

The raw materials for cemented carbide nozzles

are high-purity tungsten carbide (WC, purity>99.95%), cobalt (Co, purity>99.9%) and additives (such as TiC, TaC, Cr). The powders are mixed by wet grinding (medium is alcohol or deionized water, ball milling for 2472 hours), and the average particle size is controlled at 0.20.8 μm . VC or Cr₃C₂ (0.10.4 wt%) is added as a grain inhibitor to prevent grain growth during high-temperature sintering.

Carbide Nozzle Forming

Cold isostatic pressing (CIP): The powder is pressed into a green body at 200-400 MPa with a density of 50-60% of the theoretical value.

Precision molding: High-precision molds (tolerance ± 0.05 mm) are used to mold the nozzle body and the initial spray hole.

Spray drying: prepare flowable particles and improve the uniformity and strength of green bodies.

Sintering of cemented carbide nozzle

Pre-sintering: 9001100°C, to remove organic additives.

Hot isostatic pressing (HIP): 13501450°C, 100200 MPa, argon environment, sintering for 23 hours, density 99.8100%.

Cooling control: Progressive cooling (1015°C/min) to avoid micro cracks caused by thermal stress.

Post-processing of cemented carbide nozzles

Precision Grinding

Use a diamond grinding wheel to machine the nozzle hole to a tolerance of ± 0.001 mm and a surface roughness of Ra 0.050.2 μm .

Laser Processing

Fine-tune the nozzle shape (circular, fan-shaped), with an accuracy of ± 0.0005 mm, suitable for micro nozzles and milk powder manufacturing nozzles.

polishing

Ultra-precision polishing, spray hole Ra 0.020.1 μm , optimized spray uniformity, especially suitable for emulsion spraying.

Surface strengthening

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Coatings (TiN, TiAlN, AlCrSi/TiN, DLC) improve wear resistance and heat resistance;

Food grade DLC coating is preferred for milk powder manufacturing nozzles.

Quality Inspection

Hardness test: HRA/HV, error ± 0.5 .

Microstructural analysis: Scanning electron microscopy (SEM) was used to examine the grain size (0.20.8 μm).

Dimension measurement: optical measuring instrument, accuracy ± 0.0005 mm.

Nondestructive testing: Ultrasonic testing to detect internal defects.

Food grade certification: The milk powder manufacturing nozzle has passed the FDA/EU food contact material test.

4. Uses and application scenarios of cemented carbide nozzles

Uses and Applications of Carbide Nozzles

Carbide nozzles are widely used in the following fields due to their high wear resistance, corrosion resistance and precise spraying ability:

Surface treatment of carbide nozzle

Sandblasting nozzle

It can spray sand and steel shot for ship rust removal, automobile parts deburring and concrete surface cleaning. The pressure is 1050 MPa and the service life is 500-2000 hours. It is suitable for shipbuilding and construction industries.

Spray Nozzle

Spraying ceramic and metal powders to produce aviation turbine blade coatings and automobile engine wear-resistant coatings with a service life of 300-1500 hours, used in aviation and automobile manufacturing.

Water jet nozzle

High-pressure water cutting of titanium alloy, composite materials, marble, pressure 300-400 MPa, life 200-1000 hours, suitable for aerospace and stone processing.

Carbide Nozzles Oil & Energy

Oilfield Nozzles

Jet drilling fluid, chemical fluid, used for oil drilling, downhole cleaning, pressure 50200 MPa, life 5002000 hours, corrosion resistance (pH 210), used in deep well drilling.

Combustion nozzle

It is used for spraying fuel oil and natural gas, and is used for combustion in boilers and furnaces. It has a temperature resistance of 800°C and a service life of 300-1500 hours. It is suitable for thermal power generation and metallurgical industries.

Water jet nozzle

For cleaning heat exchangers and pipelines, pressure 100-300 MPa, life 200-1000 hours, used in nuclear power and petrochemical industry.

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Cemented Carbide Nozzle Chemical Industry and Environmental Protection

Corrosion resistant nozzles

Spray acid and alkali solutions, seawater, used for chemical reactions, desulfurization and denitrification, resistant to pH 210, life span 500-2000 hours, suitable for chemical industry and marine engineering.

Atomizing nozzle

Atomized chemical liquid, waste gas treatment liquid, used for waste gas purification, cooling tower, flow rate 0.110 L/min, life 500-2000 hours, used in environmental protection and chemical industry.

Spray Nozzle

Spray anti-corrosion coating, used for storage tank and pipeline protection, with a service life of 300-1500 hours, suitable for chemical equipment manufacturing.

Carbide Nozzles Agriculture and Food Processing

Atomizing nozzle

Spraying pesticides and fertilizers for precision agricultural irrigation, flow rate 0.055 L/min, life 500-2000 hours, suitable for spraying field crops and orchards.

Milk powder manufacturing nozzle

Spray drying emulsion and whey liquid, producing infant milk powder and milk powder, pressure 0.55 MPa, flow rate 0.110 L/min, life 500-2000 hours, in line with food grade standards, suitable for dairy processing and food industry.

Corrosion resistant nozzles

Spray cleaning liquid and disinfectant for cleaning agricultural equipment, resistant to pH 210, life 500-2000 hours, suitable for greenhouses and farms.

Carbide Nozzles Medical and Electronics

Micro Nozzle

Spray drug atomization liquid and cleaning liquid for inhaler and chip cleaning, with a nozzle size of 0.05-0.5 mm and a service life of 200-1000 hours, suitable for the medical and electronics industries.

Corrosion resistant nozzles

Spray disinfectant, used for cleaning medical equipment, resistant to pH 210, life 500-2000 hours, suitable for hospitals and laboratories.

Spray Nozzle

Spraying conductive coating, used for circuit board manufacturing, life span 300-1500 hours, suitable for semiconductor industry.

Carbide Nozzles Aerospace

Water jet nozzle

Cutting carbon fiber composite materials and titanium alloys with an accuracy of ± 0.01 mm and a service life of 200-1000 hours. Suitable for manufacturing aircraft wings and satellite components.

Spray Nozzle

Spraying ceramic coating, used in aircraft engines, with a service life of 300-1500 hours, suitable for high-precision coating process.

Micro Nozzle

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Spraying precision gas and liquid, used for sensor manufacturing, nozzle hole 0.05-0.5 mm, life span 200-1000 hours, suitable for aviation instruments.

Uses and application scenarios of cemented carbide nozzles

With its high wear resistance, corrosion resistance and precise spraying ability, carbide nozzles are widely used in surface treatment, petroleum and energy, chemical and environmental protection, agriculture and food processing, medical and electronics, aerospace and other fields. The following are the specific uses and application scenarios in various fields, which are systematically listed in table form.

industry field	Product (Nozzle Type)	Purpose and application scenarios	Performance parameters
Surface treatment	Sandblasting nozzle Sandblasting Nozzle	Sand and steel shot blasting is used for rust removal of ships, deburring of automobile parts and cleaning of concrete surfaces.	Pressure 1050 MPa, life 500-2000 hours, suitable for shipbuilding and construction industries.
	Spray Nozzle Spray Coating Nozzle	Spraying ceramic and metal powders to produce aviation turbine blade coatings and automobile engine wear-resistant coatings.	Lifespan 300-1500 hours, suitable for aviation and automobile manufacturing.
	Water jet nozzle Waterjet Nozzle	High pressure water cutting of titanium alloy, composite materials and marble.	Pressure 300-400 MPa, life 200-1000 hours, suitable for aerospace and stone processing.
Oil and Energy	Oilfield Nozzles Oilfield Nozzle	Jetting drilling fluid and chemical fluid for oil drilling and downhole cleaning.	Pressure 50200 MPa, life 5002000 hours, corrosion resistance (pH 210), used in deep well drilling.
	Combustion nozzle Burner Nozzle	Inject fuel oil and natural gas for combustion in boilers and furnaces.	With a temperature resistance of 800°C and a service life of 300-1500 hours, it is suitable for thermal power generation and metallurgical industries.
	Water jet nozzle Waterjet Nozzle	Clean heat exchangers and pipes.	Pressure 100-300 MPa, life 200-1000 hours, used in nuclear power and petrochemical industry.

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Chemical Industry and Environmental Protection	Corrosion resistant nozzles CorrosionResistant Nozzle	Spray acid and alkali solutions and seawater for chemical reactions, desulfurization and denitrification.	Resistant to pH 210, life span 500-2000 hours, suitable for chemical industry and marine engineering.
	Atomizing nozzle Atomizing Nozzle	Atomized chemical liquid, waste gas treatment liquid, used for waste gas purification and cooling tower.	Flow rate 0.110 L/min, life span 500-2000 hours, used in environmental protection and chemical industries.
	Spray Nozzle Spray Coating Nozzle	Spraying anti-corrosion coating for tank and pipeline protection.	Lifespan 300-1500 hours, suitable for chemical equipment manufacturing.
Agriculture and food processing	Atomizing nozzle Atomizing Nozzle	Spray pesticides and fertilizers for precision agricultural irrigation.	Flow rate 0.055 L/min, life span 500-2000 hours, suitable for spraying field crops and orchards.
	Milk powder manufacturing nozzle Milk Powder Spray Nozzle	Spray drying of emulsions and whey liquids to produce infant milk powder and milk powder.	Pressure 0.55 MPa, flow rate 0.110 L/min, life 500-2000 hours, in line with food grade standards, suitable for dairy processing and food industry.
	CorrosionResistant Nozzle	Spray cleaning fluid and disinfectant for cleaning agricultural equipment.	Resistant to pH 210, lifespan 500-2000 hours, suitable for greenhouses and farms.
Medical and Electronics	Micro Nozzle	Spray drug atomization liquid and cleaning liquid for cleaning inhalers and chips.	The nozzle hole is 0.05-0.5 mm and the service life is 200-1000 hours. It is suitable for medical and electronic industries.
	Corrosion resistant nozzles CorrosionResistant Nozzle	Spray disinfectant for cleaning medical equipment.	Resistant to pH 210, life span 500-2000 hours, suitable for hospitals and laboratories.
	Spray Coating Nozzle	Spraying conductive coatings for circuit board manufacturing.	Lifespan 300-1500 hours, suitable for semiconductor industry.
Aerospace	Waterjet Nozzle	Cutting carbon fiber composites, titanium alloys.	Accuracy: ± 0.01 mm, lifespan: 200-1000 hours, suitable for manufacturing aircraft wings and satellite components.

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	Spray Coating Nozzle	Spraying ceramic coatings for aircraft engines.	Lifespan 300-1500 hours, suitable for high-precision coating processes.
	Micro Nozzle	Injection of precision gases and liquids for sensor manufacturing.	The nozzle hole is 0.05-0.5 mm and the service life is 200-1000 hours, which is suitable for aviation instruments.

5. Performance Advantages

Carbide nozzle performance advantages

Carbide nozzles have significant advantages in the field of injection equipment:

Ultra-long life

Wear resistance and hardness extend the lifespan by 515 times and reduce the cost per use by 4070%.

Efficient spraying

It supports high-pressure injection (0.1500 MPa) and high-speed fluid (101000 m/s), and the injection efficiency is improved by 2050%.

High precision

The nozzle hole accuracy is ± 0.001 mm and the spray surface roughness is Ra 0.10.4 μm , which meets the high requirements of aviation, medical and food processing.

Flexible customization

A variety of types (sandblasting, water jet, atomization, milk powder manufacturing, etc.), nozzle sizes (0.0515 mm) and coatings (TiN, DLC) are available to suit different working conditions.

Environmental adaptability

High temperature resistant (8001000°C), corrosion resistant (pH 210), adaptable to abrasives, chemical liquids, emulsions, and high temperature environments.

Green Manufacturing

High durability reduces nozzle changes and waste, meeting sustainability goals.

6. Technical challenges and improvement directions

Technical challenges and improvement directions of cemented carbide nozzles

Cemented carbide nozzles face several technical challenges in practical applications and need to achieve performance breakthroughs through continuous improvement.

Technical Challenges of Carbide Nozzles

Difficulty in machining carbide nozzles

Cemented carbide has high hardness (HRA 8892), which places extremely high demands on processing equipment and tools. Diamond grinding wheels wear quickly, and the nozzle hole accuracy is difficult to stabilize (tolerance $< \pm 0.001$ mm).

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Risk of carbide nozzle brittleness

High-hardness materials may produce microcracks or nozzle collapse under high pressure (>500 MPa) or improper design, which will affect the service life.

Thermal management issues of cemented carbide nozzles

High temperature spraying (>800°C) or high-speed abrasive spraying may cause softening of the orifice surface or coating peeling, especially in dry conditions.

Complex media adaptability

High-viscosity liquids (such as emulsions), highly corrosive chemical liquids or super-hard abrasives have high requirements on nozzle geometry and surface treatment, and are prone to wear or clogging.

Extreme working conditions of cemented carbide nozzles

Under ultra-high temperatures (>1000°C) or strong acid environments (pH<2), the performance of traditional coatings and adhesive phases deteriorates and their service life is shortened by 5070%.

Technology improvement direction of cemented carbide nozzles

Advanced processing technology of cemented carbide nozzles

Developed laser micromachining and ultra-precision grinding, the nozzle hole accuracy is improved to ± 0.0005 mm, and tool wear is reduced by 30%, which is suitable for micro and milk powder manufacturing nozzles.

Toughness Enhanced Design of Carbide Nozzle

The use of gradient structure (high hardness HRA 9092 on the surface, high toughness fracture toughness $>9 \text{ MPa} \cdot \text{m}^{1/2}$ inside) or CoNi composite bonding phase can increase the crack growth resistance by 2030% and reduce nozzle collapse.

Efficient thermal management of carbide nozzles

Optimize the nozzle cooling channel (coolant pressure 510 MPa, flow rate 25 L/min) to reduce the operating temperature by 100-150°C; develop adaptive coatings (such as TiAlN/AlCrSi, temperature resistance 1100°C) to reduce thermal softening.

Optimization of carbide nozzles for complex media

Design low-friction coatings (such as DLC, friction coefficient 0.080.15) and optimize nozzle geometry (inlet angle $10^\circ 20^\circ$, injection zone length 0.52 mm) to reduce clogging and wear; develop PCD (polycrystalline diamond) nozzles, increase the hardness to HV 8000, and extend the life by 20 times.

Carbide nozzles are suitable for extreme working conditions

Develop nano-multilayer coatings (such as AlCrSi/TiN, thickness 13 μm , hardness HV 3500) or ceramic-based composite materials (WCSiC), with temperature resistance increased to 1200°C and strong acid (pH 12) corrosion rate <0.02 mm/year.

Intelligent design of cemented carbide nozzle

Use AI to simulate injection pressure (error $<5\%$) and wear behavior, optimize the nozzle angle (deviation $<0.2^\circ$) and surface roughness ($R_a <0.05 \mu\text{m}$), and improve injection stability; develop self-diagnostic nozzles to monitor temperature and wear in real time, extending life by 1020%.

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7. Conclusion

With its high hardness (HRA 8892), excellent toughness ($6.09.0 \text{ MPa} \cdot \text{m}^{1/2}$) and ultra-long life (2002000 hours), cemented carbide nozzles have become the preferred fluid control components in the fields of sandblasting, spraying, water jet cutting, oil drilling, chemical industry, agricultural irrigation, food processing, etc. Its diverse types (sandblasting nozzles, water jet nozzles, atomizing nozzles, milk powder manufacturing nozzles, etc.) and precise specifications (spray hole diameter 0.0515 mm , tolerance $\pm 0.001 \text{ mm}$) meet a wide range of needs from precision spraying to high-pressure cutting. Technical indicators show that its life is 515 times that of ordinary materials, the spraying efficiency is increased by 2050%, and the spraying surface quality reaches $Ra 0.10.4 \mu\text{m}$.

Through advanced powder metallurgy and coating technologies (such as TiAlN and DLC), the nozzles perform well in harsh environments such as high temperature ($800\text{-}1000^\circ\text{C}$) and corrosion ($\text{pH } 210$). In the future, through laser processing, PCD nozzle holes, nano-coating, AI optimization and intelligent design, cemented carbide nozzles will further improve performance and expand application scenarios, providing important support for the efficient, precise and sustainable development of the global industry.



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Customized processing of carbide nozzles

Carbide nozzles have the characteristics of wear resistance, corrosion resistance, high temperature resistance and long service life . They are widely used in sand blasting, spraying, water jet cutting, oil drilling, chemical industry, agriculture, food processing and other fields.

Main features of carbide nozzles

Hardness : HRA 8892

Precision: nozzle tolerance ± 0.001 mm, surface roughness Ra 0.10.4 μm .

Adaptability: temperature resistance 8001000°C, corrosion resistance pH 210.

Efficiency: Supports high-pressure (0.1500 MPa) injection, with efficiency increased by 2050%.

Lifespan: Excellent wear resistance, lifespan is 515 times that of ordinary materials.

Customization: various types (sandblasting, atomization, milk powder manufacturing, etc.), suitable for various working conditions.

Main types of carbide nozzles

type	describe	Main uses and application scenarios	Typical Specifications
Sandblasting nozzle Sandblasting Nozzle	High wear-resistant design, suitable for abrasive blasting.	Rust removal of ships, deburring of automobile parts, and concrete cleaning.	Nozzle diameter 212 mm, Length 50200 mm,
Water jet nozzle Waterjet Nozzle	High-pressure water jet, suitable for cutting hard materials.	Aerospace titanium alloy cutting, automotive composite material cutting, stone processing.	The nozzle diameter is 0.12 mm. Length 20100 mm,
Spray Nozzle Spray Coating Nozzle	Precise spraying of paint or ceramic coatings.	Aviation turbine blade coating, automobile engine coating, electronic circuit board spraying.	The nozzle diameter is 0.55 mm. Length 30150 mm,
Oilfield Nozzles Oilfield Nozzle	High pressure and corrosion resistance, suitable for drilling jetting.	Oil drilling fluid injection, natural gas downhole cleaning, mining mud injection.	Nozzle diameter 315 mm, Length 50150 mm,
Atomizing nozzle Atomizing Nozzle	Fine atomized spray, suitable for liquid dispersion.	Agricultural pesticide spraying, chemical liquid atomization, environmental waste gas treatment.	The nozzle diameter is 0.23 mm. Length 20100 mm,
Combustion nozzle	High temperature	Energy boiler combustion,	Nozzle diameter

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Burner Nozzle	resistant design, suitable for fuel or gas injection.	chemical high temperature reaction, metallurgical furnace injection.	110 mm, Length 30120 mm,
Micro Nozzle Micro Nozzle	Ultra-small nozzle hole, suitable for high-precision injection.	Medical drug spray, electronic chip cleaning, aviation precision coating.	Nozzle diameter 0.050.5 mm, length 1050
Corrosion resistant nozzles CorrosionResistant Nozzle	Resistant to strong acids and alkalis, suitable for chemical environments.	Chemical acid and alkali solution injection, environmental protection desulfurization and denitrification, marine engineering seawater injection.	Nozzle diameter 110 mm, Length 30150 mm,
Milk powder manufacturing nozzle Milk Powder Spray Nozzle	Specially designed for spray drying to evenly atomize emulsions.	Food processing milk powder production, agricultural dairy product processing, in compliance with FDA/EU food contact standards.	The nozzle diameter is 0.53 mm. Length 20100 mm,

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Customized processing of cemented carbide stamping dies

Carbide stamping dies have the characteristics of wear resistance, corrosion resistance, high temperature resistance and long service life. They are widely used in automobile manufacturing, electronic component processing, hardware products, aerospace, medical equipment and other fields.

Main features of cemented carbide stamping dies

- Hardness: HRA 8892.
- Precision: mold tolerance ± 0.001 mm, surface roughness Ra 0.10.4 μm .
- Adaptability: temperature resistance 8001000°C, corrosion resistance pH 210.
- Efficiency: Supports high-frequency stamping, with efficiency increased by 2050%.
- Lifespan: Excellent wear resistance, lifespan is 515 times that of ordinary molds.
- Customization: Various types (drawing die, punching die, compound die, etc.), suitable for various working conditions.

Main types of cemented carbide stamping dies

type	describe	Main uses and application scenarios	Typical Specifications
Stretching die Drawing Die	High wear-resistant design, suitable for metal stretch forming.	Automobile body panels, metal containers, and aluminum alloy shell stretching.	The die diameter is 10200 mm, the thickness is 20100 mm, and the service life is 502 million punching times.
Blanking Die Blanking Die	High-precision punching, suitable for thin plate cutting.	Electronic component lead frames, automotive parts, and hardware accessories punching.	The die gap is 0.010.1 mm, the thickness is 1580 mm, and the service life is 301.5 million times of stamping.
Compound mold Compound Die	Integrated multi-step stamping, suitable for complex parts.	Aerospace connectors, medical equipment parts, and precision hardware composite processing.	The die diameter is 20150 mm, the thickness is 20100 mm, and the service life is 401.8 million punching times.
Oilfield Dies Oilfield Die	High pressure and corrosion resistant, suitable for heavy-load stamping.	Oil drilling equipment parts, natural gas pipeline accessories, mining machinery parts.	The die diameter is 30200 mm, the thickness is 30120 mm, and the service life is 301.2 million stamping times.
HighSpeed Stamping Die	High temperature resistant and high frequency design, suitable for rapid	Automotive fasteners, electronic connectors, continuous high-speed stamping production	The die has a diameter of 10100 mm, a thickness of 1580 mm, and a service life of 602.5 million

	stamping.	lines.	punchings.
Heavy load model HeavyDuty Die	High strength design, suitable for thick plate stamping.	Heavy machinery parts, ship structures, and building hardware thick plate stamping.	The die diameter is 50300 mm, the thickness is 30120 mm, and the service life is 301.2 million stamping times.
Micro mold Micro Die	Ultra-small size, suitable for high-precision micro stamping.	Micro parts for medical devices, micro connectors for electronics, and components for aviation sensors.	The die has a diameter of 550 mm, a thickness of 1040 mm, and a service life of 20.8 million punchings.
Corrosion resistant mold CorrosionResistant Die	Resistant to strong acids and alkalis, suitable for stamping in chemical environments.	Chemical equipment parts, marine engineering accessories, and corrosive material stamping.	The die diameter is 15150 mm, the thickness is 2080 mm, and the service life is 502 million punching times.
Food grade mold FoodGrade Die	Specially designed for stamping of food related parts, in compliance with standards.	Food packaging molds and dairy processing equipment parts comply with FDA/EU food contact standards.	The die diameter is 10100 mm, the thickness is 1580 mm, and the service life is 502 million punching times.

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Customized processing of carbide ball gear

Carbide ball teeth have the characteristics of wear resistance, corrosion resistance, high temperature resistance and long service life. They are widely used in mining, tunneling, road milling, oil drilling, construction engineering, coal mining and other fields.

Main types of carbide ball teeth

type	describe	Main uses and application scenarios	Typical specifications mm
Cutting Pick	High wear-resistant design, suitable for hard rock cutting.	Coal mining, tunneling, and hard rock mining.	Tooth diameter 1050, length 50150
Tunneling Tooth	High-strength design, suitable for tunneling equipment.	Subway tunnels, railway tunnels, and underground engineering excavation.	Tooth diameter 1560 Length 60180
Milling Tooth	Resistant to high temperature and high frequency cutting, suitable for road milling.	Highway maintenance, runway milling, urban road repair.	Tooth diameter 830, length 40120
Drilling Tooth	It is resistant to high pressure and corrosion and is suitable for drilling operations.	Oil drilling, natural gas exploration, geological survey.	Tooth diameter 1040, length 50140
Rotary digging teeth Rotary Digging Tooth	High toughness design, suitable for rotary drilling equipment.	Building pile foundation, bridge foundation, port terminal construction.	Tooth diameter 2080, length 70200
Coal Mining Tooth	Impact-resistant design, suitable for coal mining.	Open pit coal mines, underground coal mining, coal washing equipment.	Tooth diameter 1550, length 50160
Micro Tooth	Ultra-small size, suitable for high-precision cutting.	Precision geological exploration, micro-drilling equipment, and aviation parts processing.	Tooth diameter 520, length 2080
Corrosion resistant teeth Corrosion-Resistant	Resistant to strong acids and alkalis, suitable for cutting	Seabed mining, chemical mineral mining, acid soil engineering.	Tooth diameter 1050, length 50150

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Tooth	in corrosive environments.		
HeavyDuty Tooth	High-strength design, suitable for cutting super-hard materials.	Hard rock mines, iron ore mining, large-scale engineering crushing.	Tooth diameter 20100, length 80220

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What is Carbide Mold ?

Carbide dies are high-performance tools designed for metal stamping, drawing, cold extrusion and precision forming, and are intended for efficient processing of steel, nonferrous metals or non-metallic materials. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and durability under high pressure, high speed and complex working conditions. As the core component of precision manufacturing, the mold directly affects product accuracy, surface quality and production cost, and is widely used in automotive parts, electronic components and mechanical processing. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of the mold.

Physical and chemical properties of cemented carbide molds

Cemented carbide molds use tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\%\pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\%\pm 0.1\%$, VC $<1\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$, NbC $0.5\%-1.5\%\pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C}\pm 10^\circ\text{C}$, pressure $45-55\text{ MPa}\pm 1\text{ MPa}$, holding time $5-10\text{ min}\pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C}\pm 10^\circ\text{C}$, pressure $150-200\text{ MPa}\pm 5\text{ MPa}$, holding time $30-60\text{ min}\pm 5\text{ min}$), ensuring that the material reaches $99.9\%\pm 0.1\%$ of the theoretical density and the porosity is $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\%\pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\%\pm 1\%$.

The geometric design of the mold is customized according to the application, including punches, dies or forming blocks, with a size range of $5-50\text{ mm}\pm 1\text{ mm}$ (depending on the workpiece), and is installed on the mold base (made of high-strength alloy steel, such as Cr12MoV or D2, quenching hardness HRC $58-62\pm 2$). Fixing methods include high-frequency induction welding (temperature $1200-1300^\circ\text{C}\pm 20^\circ\text{C}$, welding strength $>800\text{ MPa}\pm 50\text{ MPa}$) or mechanical fastening (fastening force $>15\text{ kN}\pm 1\text{ kN}$), ensuring stable operation under high pressure ($50-300\text{ MPa}\pm 10\text{ MPa}$, peak value up to $500\text{ MPa}\pm 20\text{ MPa}$). Multi-layer coatings (such as TiN, TiAlN or AlCrN, thickness $0.5-3\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$) can be applied to the working surface, reducing the friction coefficient to $<0.2\pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<1.5\%\pm 0.5\%$). The design integrates molding mechanics and heat conduction optimization, with an entry angle of $15^\circ-30^\circ\pm 5^\circ$ and a back tilt angle of $5^\circ-10^\circ\pm 2^\circ$, suitable for a variety of materials with a tensile strength of $300-1000\text{ MPa}$.

Characteristics and working principle of cemented carbide molds

Material properties of cemented carbide molds

WC provides high hardness (HV $1800-2200\pm 30$, locally up to $2400-2600\pm 50$), and its hexagonal

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crystal structure gives excellent wear and erosion resistance (oxidation starting temperature $>800^{\circ}\text{C} \pm 20^{\circ}\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value up to 18 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$), and absorbs impact energy ($>80 \text{ J} \pm 5 \text{ J}$, instantaneous peak value $>200 \text{ J} \pm 10 \text{ J}$). Fine grains and optimized microstructure, wear rate $<0.04 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$ (preferably $<0.02 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), density $14.8\text{-}15.2 \text{ g/cm}^3 \pm 0.1 \text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^{\circ}\text{C} \pm 0.5 \times 10^{-6} / ^{\circ}\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$, Cl^- resistance $>3000 \text{ hours} \pm 100 \text{ hours}$); TaC and NbC increase high temperature hardness ($>900^{\circ}\text{C} \pm 20^{\circ}\text{C}$ to maintain $90\% \pm 2\%$ of initial hardness, thermal stability $>95\% \pm 2\%$).

Working principle

The die is formed into metal or non-metal materials by extrusion and shearing under the action of a stamping machine or cold extrusion equipment (pressure $50\text{-}300 \text{ MPa} \pm 10 \text{ MPa}$, speed $10\text{-}50 \text{ m/s} \pm 2 \text{ m/s}$, power $50\text{-}400 \text{ kW} \pm 50 \text{ kW}$). The working surface is subjected to high pressure and thermal load (surface temperature $400\text{-}700^{\circ}\text{C} \pm 50^{\circ}\text{C}$, instantaneously up to $900^{\circ}\text{C} \pm 50^{\circ}\text{C}$), and the base steel provides structural support (tensile strength $>1300 \text{ MPa} \pm 50 \text{ MPa}$), heat conduction (thermal conductivity $40\text{-}50 \text{ W/m} \cdot \text{K} \pm 2 \text{ W/m} \cdot \text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load $>200 \text{ MPa} \pm 20 \text{ MPa}$). The precision design of the mold ensures tolerance control within $\pm 0.01 \text{ mm} \pm 0.005 \text{ mm}$ and surface roughness $R_a < 0.2 \mu\text{m} \pm 0.05 \mu\text{m}$.

When processing low carbon steel (tensile strength 400 MPa), aluminum alloy (500 MPa) and hard plastic (300 MPa), the optimized mold life exceeds $500\text{-}800 \text{ hours} \pm 50 \text{ hours}$ (depending on the hardness of the material), and the production efficiency reaches $1000\text{-}3000 \text{ pieces/h} \pm 100 \text{ pieces/h}$ (up to $4000 \text{ pieces/h} \pm 100 \text{ pieces/h}$, power $>300 \text{ kW} \pm 50 \text{ kW}$). SEM analysis shows no obvious wear on the surface, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($>95\% \pm 2\%$), and thermal imaging shows that the thermal stress distribution is $<120 \text{ MPa} \pm 10 \text{ MPa}$.

Factors affecting the performance of cemented carbide molds

The Co content of

$6\%\text{-}12\% \pm 1\%$ achieves the best balance between hardness and toughness. $<6\% \pm 1\%$ leads to a $10\% \pm 2\%$ increase in crack rate, $>12\% \pm 1\%$ reduces the hardness by $5\% \pm 1\%$ and increases thermal expansion (CTE $6 \times 10^{-6} / ^{\circ}\text{C} \pm 0.5 \times 10^{-6} / ^{\circ}\text{C}$). $8\%\text{-}10\% \pm 0.5\%$ is preferred to balance performance and cost.

Grain size

$0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $<0.02 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), $1\text{-}1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness materials, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by $15\% \pm 3\%$ and reduces toughness by $10\% \pm 2\%$. Geometric

angles

: die angle $15^{\circ}\text{-}30^{\circ} \pm 5^{\circ}$ optimizes forming efficiency (pressure $<50 \text{ MPa} \pm 5 \text{ MPa}$, energy consumption $<20 \text{ kWh/m}^3 \pm 2 \text{ kWh/m}^3$), $>35^{\circ} \pm 5^{\circ}$ reduces efficiency by $10\% \pm 2\%$, $<15^{\circ} \pm 5^{\circ}$ easily leads to $5\% \pm 1\%$ risk of cracking.

Surface treatment:

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working surface thickness $3-5\text{ mm}\pm 0.1\text{ mm}$ improves wear resistance (life extension by $20\%\pm 3\%$), $<3\text{ mm}\pm 0.1\text{ mm}$ shortens life by $20\%\pm 3\%$, $>5\text{ mm}\pm 0.1\text{ mm}$ increases the cost by $15\%\pm 2\%$. TiAlN coating (thickness $0.5-2\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, deposition temperature $400-500^{\circ}\text{C}\pm 20^{\circ}\text{C}$) reduces the friction coefficient ($<0.25\pm 0.05$) and improves heat resistance ($>800^{\circ}\text{C}\pm 20^{\circ}\text{C}$). The

heat-treated

base steel is quenched (hardness HRC $58-62\pm 2$, depth $2-4\text{ mm}\pm 0.2\text{ mm}$, quenching temperature $850-900^{\circ}\text{C}\pm 20^{\circ}\text{C}$) to enhance the supporting performance, the unquenched base life is reduced by $15\%\pm 3\%$, and tempering ($200-250^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $2-4\text{ hours}\pm 0.5\text{ hours}$) reduces the residual stress by $5\%\pm 1\%$.

The working environment

temperature $>700^{\circ}\text{C}\pm 50^{\circ}\text{C}$ reduces the hardness by $3\%\pm 1\%$, the water content $>5\%\pm 1\%$ or the impurity content $>3\%\pm 0.5\%$ increases the wear by $5\%\pm 1\%$, and the Cl^{-} - containing environment (concentration $>0.5\%\pm 0.1\%$) increases the corrosion rate to $0.015\text{ mm/year}\pm 0.002\text{ mm/year}$.

Types of Carbide Dies

Standard stamping dies

are suitable for low carbon steel (tensile strength $300-500\text{ MPa}$), with a size of $10-20\text{ mm}\pm 1\text{ mm}$, excellent wear resistance (lifetime $>600\text{ hours}\pm 50\text{ hours}$), and are often used for automotive plates. In 2024, the production efficiency of a certain automotive project is $2000\text{ pieces/h}\pm 100\text{ pieces/h}$.

Stretching dies

are suitable for aluminum alloys ($500-700\text{ MPa}$), with a size of $15-30\text{ mm}\pm 1\text{ mm}$, strong impact resistance ($>100\text{ J}\pm 10\text{ J}$), and are suitable for electronic housings. In 2023, the life of a certain electronics factory is $700\text{ hours}\pm 50\text{ hours}$.

Cold extrusion dies

are used for high-strength steel ($800-1000\text{ MPa}$), with a size of $20-50\text{ mm}\pm 1\text{ mm}$, excellent high pressure resistance ($>300\text{ MPa}\pm 10\text{ MPa}$), and are suitable for bearing processing. In 2025, a certain bearing project has a pressure resistance of $350\text{ MPa}\pm 10\text{ MPa}$.

Special molding molds

include high temperature resistant ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ maintaining $95\%\pm 2\%$) and corrosion resistant types, suitable for high temperature or corrosive materials, with a test life of $550\text{ hours}\pm 50\text{ hours}$ in 2025.

Application of carbide dies

Auto parts

are used for stamping sheets (tensile strength $300-500\text{ MPa}$), with a life of $600-800\text{ hours}\pm 50\text{ hours}$, in line with QC/T 480 standards. In 2024, the accuracy of a certain automotive project is $\pm 0.01\text{ mm}\pm 0.005\text{ mm}$.

Electronic components

are used for aluminum alloy stretching ($500-700\text{ MPa}$), and the impact resistance ($>80\text{ J}$, peak $200\text{ J}\pm 10\text{ J}$) ensures efficient forming, in line with IPC-6012 standards. In 2023, the efficiency of a certain electronics factory is $2500\text{ pieces/h}\pm 100\text{ pieces/h}$.

Machining

is used for cold extrusion of high-strength steel ($800-1000\text{ MPa}$), reducing waste ($<2\%\pm 0.5\%$), and meeting ISO 286 standards. In 2024, the surface roughness of a certain factory is $\text{Ra} < 0.2\text{ }\mu\text{m}$

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$\pm 0.05 \mu\text{m}$.

Corrosive environment

is used for salt-containing materials, resistant to seawater corrosion ($>4000 \text{ hours} \pm 100 \text{ hours}$, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$), in line with DNVGL-RP-C203 standard. In 2025, the corrosion resistance of a certain offshore project is $> 99\% \pm 1\%$.

Complex molding

is used for high temperature or high hardness materials, with wear resistance $> 95\% \pm 2\%$, and the test efficiency in 2025 is $2800 \text{ pieces/h} \pm 100 \text{ pieces/h}$.

Aerospace parts

are used for titanium alloy stamping (tensile strength 800-1200 MPa), with a life of 500-700 hours $\pm 50 \text{ hours}$, in line with AMS 4911 standard. In 2024, the tolerance of a certain aviation project is $\pm 0.01 \text{ mm} \pm 0.005 \text{ mm}$.

Medical devices

are used for stainless steel tensile (600-900 MPa), corrosion resistance ($> 3000 \text{ hours} \pm 100 \text{ hours}$), in line with ISO 13485 standard. In 2023, the efficiency of a medical factory is $1500 \text{ pieces/h} \pm 100 \text{ pieces/h}$.

Energy equipment

is used for cold extrusion of high-pressure valve bodies (1000-1500 MPa), with pressure resistance ($>400 \text{ MPa} \pm 10 \text{ MPa}$), meeting API 6A standards. In 2025, the life of an energy project is $600 \text{ hours} \pm 50 \text{ hours}$.

Home appliance manufacturing

is used for aluminum shell stretching (400-600 MPa), with surface finish $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, in line with IEC 60335 standards. In 2024, the efficiency of a home appliance project is $3000 \text{ pieces/h} \pm 100 \text{ pieces/h}$.

Construction hardware

is used for cold extrusion of steel bolts (700-900 MPa), reducing waste ($<1\% \pm 0.5\%$), and meeting ASTM A307 standards. In 2023, the productivity of a construction project is $2000 \text{ pieces/h} \pm 100 \text{ pieces/h}$.

Technological progress and future development

New materials

introduce nano WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness ($\text{HV } 2200-2600 \pm 50$), add TaC and NbC to enhance high temperature stability ($>900^\circ\text{C} \pm 20^\circ\text{C}$ to maintain $95\% \pm 2\%$). Research in 2024: oxidation resistance of AlCrN coating (oxygen weight gain $<0.1\% \pm 0.05\%/h$).

Intelligent monitoring

integrated sensor (accuracy $\pm 0.05\%$) real-time monitoring of wear (depth $>1 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($<800^\circ\text{C} \pm 20^\circ\text{C}$), optimize replacement cycle (error $<5\% \pm 1\%$), and a company successfully tested it in 2025.

3D printing technology

uses SLM (layer thickness $40-60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex molds, reducing material waste by $10\% \pm 2\%$, and the strength will reach $1600 \text{ MPa} \pm 50 \text{ MPa}$ in 2024.

Environmental adaptability:

Development of corrosion-resistant and high-pressure resistant molds (pressure resistance > 400

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MPa $\pm$ 10 MPa), with heat resistance reaching 98% $\pm$ 2% by 2025.

Sustainable

recycling of WC powder (recycling rate > 80% $\pm$ 5%) reduces carbon footprint (CO₂ reduction of 20% $\pm$ 3%), in compliance with ISO 14040 standards.

Domestic and international standards for cemented carbide molds

Domestic and international standards include all the following relevant standards and their numbers:

QC/T 480 (Automotive Parts Manufacturing Standard)

IPC-6012 (Electronic Component Manufacturing Standard)

ISO 286 (Geometrical product specifications and tolerances)

DNVGL-RP-C203 (Design rules for offshore structures)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)

DIN 17350 (German metal material standard)

JIS B 4053 (Japanese mold design standard)

AMS 4911 (Aerospace Titanium Alloy Standard)

ISO 13485 (Quality Management System for Medical Devices)

API 6A (Standard for Oil and Gas Equipment)



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What are carbide tools ?

Carbide cutting tools are high-performance tools designed for metal cutting, forming and processing. They are widely used in turning, milling, drilling, stamping and other processes, and are designed to efficiently process steel, cast iron, non-ferrous metals and difficult-to-process materials. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric design and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and long life under high speed, high load and complex working conditions. As a key component in machining and mold manufacturing, carbide cutting tools directly affect machining accuracy, surface quality and production efficiency, and are widely used in automotive, aerospace, energy and medical fields.

Physical and chemical properties of cemented carbide tools

Cemented carbide tools use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase and cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 0.5 % - 2 % $\pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC 1%-3% $\pm 0.2\%$, NbC 0.5%-1.5% $\pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m} \pm 0.01 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the tool is customized according to the application, including turning tools, milling cutters, drills or punches, with a cutting edge width of $2 - 20 \text{ mm} \pm 0.5 \text{ mm}$ and a length of $50 - 200 \text{ mm} \pm 2 \text{ mm}$, mounted on a tool holder or mold base (made of high-strength steel such as H13 or Cr12MoV, quenching hardness HRC $50 - 62 \pm 2$). The fixing method includes mechanical clamping (clamping force $>10 \text{ kN} \pm 1 \text{ kN}$) or welding (welding strength $>700 \text{ MPa} \pm 50 \text{ MPa}$) to ensure stable operation under high cutting forces or pressures ($50 - 300 \text{ N} \pm 10 \text{ N}$, peak value up to $400 \text{ N} \pm 20 \text{ N}$). Multi-layer coatings (such as TiN, TiAlN or Al_2O_3 , thickness $0.5 - 4 \mu\text{m} \pm 0.1 \mu\text{m}$) can be applied to the cutting edge or working surface, reducing the friction coefficient to $<0.2 \pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<1\% \pm 0.5\%$). The design integrates cutting/forming mechanics and heat conduction optimization, with a rake angle of $5^\circ - 15^\circ \pm 2^\circ$ and a back rake angle of $5^\circ - 10^\circ \pm 2^\circ$, suitable for a variety of materials with a tensile strength of $300 - 1500 \text{ MPa}$.

Characteristics and working principle of cemented carbide tools

Material properties of cemented carbide tools

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WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure gives excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C, oxidation resistance >95%±2%); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5), and absorbs impact energy (>60 J±5 J, instantaneous peak value >150 J±10 J). Fine grains and optimized microstructure, wear rate <0.03 mm³/N·m ± 0.01 mm³/N·m (preferably <0.015 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶/°C±0.5×10⁻⁶/°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, Cl⁻ resistance >3000 hours±100 hours); TaC and NbC increase high temperature hardness (>900°C±20°C maintains 90%±2% of the initial hardness, thermal stability >95%±2%).

Working principle of cemented carbide tools

tools process materials by shearing, friction or extrusion under the action of CNC machine tools, punching machines or forming equipment (cutting speed 50-300 m/min±10 m/min or pressure 50-300 MPa±10 MPa, power 30-400 kW±50 kW). The cutting edge or working surface is subjected to high cutting forces/pressures and thermal loads (surface temperature 500-1000°C±50°C), and the base steel provides structural support (tensile strength >1200 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life >10⁶ times±10⁵ times, cyclic load >150 MPa±20 MPa). The precision design of the tools ensures tolerance control of ±0.01 mm±0.005 mm and surface roughness Ra<0.1 μm±0.05 μm.

The performance test of cemented carbide tools

shows that the optimized tool life exceeds 300-600 hours ± 50 hours (depending on the process) when processing 45# steel (tensile strength 600 MPa), aluminum alloy (500 MPa), titanium alloy (1000 MPa) or stamping low carbon steel (400 MPa), and the cutting/forming efficiency reaches 100-500 cm³/min ± 10 cm³/min or 1000-3000 pieces/h ± 100 pieces/h (power > 200 kW ± 50 kW). SEM analysis shows no obvious cracking on the cutting edge, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (> 95% ± 2%), and thermal imaging shows that the thermal stress distribution is < 120 MPa ± 10 MPa.

Factors affecting the performance of cemented carbide tools

The Co content of

6%-12%±1% achieves the best balance between hardness and toughness. <6%±1% leads to a 10%±2% increase in crack rate, >12%±1% reduces the hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶/°C±0.5×10⁻⁶/°C). 8%-10%±0.5% is preferred to balance performance and cost.

Grain size

0.5-1 μm±0.01 μm effectively reduces wear and microcracks (wear rate <0.015 mm³/N·m ± 0.01 mm³/N·m), 1-1.5 μm±0.01 μm is suitable for medium hardness materials, >2 μm±0.01 μm increases wear rate by 15%±3% and reduces toughness by 10%±2%.

Geometric angle

Rake angle 5°-15°±2° or die angle 15°-30°±5° optimizes cutting/forming efficiency (cutting force

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$<50 \text{ N} \pm 5 \text{ N}$ or pressure $<50 \text{ MPa} \pm 5 \text{ MPa}$, energy consumption $<15 \text{ kWh/m}^3 \pm 2 \text{ kWh/m}^3$), $>15^\circ \pm 2^\circ$ or $>35^\circ \pm 5^\circ$ reduces efficiency by $10\% \pm 2\%$, $<5^\circ \pm 2^\circ$ or $<15^\circ \pm 5^\circ$ easily leads to $5\% \pm 1\%$ risk of chipping/fracture.

Surface treatment

edge/working surface thickness $2\text{-}4 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extension by $20\% \pm 3\%$), $<2 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $>4 \text{ mm} \pm 0.1 \text{ mm}$ increases cost by $15\% \pm 2\%$. TiAlN coating (thickness $0.5\text{-}2 \text{ }\mu\text{m} \pm 0.1 \text{ }\mu\text{m}$, deposition temperature $400\text{-}500^\circ\text{C} \pm 20^\circ\text{C}$) reduces friction coefficient ($<0.25 \pm 0.05$) and improves heat resistance ($>900^\circ\text{C} \pm 20^\circ\text{C}$). The

heat-treated

base steel is quenched (hardness HRC $50\text{-}62 \pm 2$, depth $1.5\text{-}4 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850\text{-}900^\circ\text{C} \pm 20^\circ\text{C}$) to enhance the supporting performance, the unquenched base life is reduced by $15\% \pm 3\%$, and tempering ($200\text{-}250^\circ\text{C} \pm 10^\circ\text{C}$, $2\text{-}4 \text{ hours} \pm 0.5 \text{ hours}$) reduces the residual stress by $5\% \pm 1\%$.

The working environment

temperature $>800^\circ\text{C} \pm 50^\circ\text{C}$ reduces the hardness by $3\% \pm 1\%$, the water content $>5\% \pm 1\%$ or the impurity content $>3\% \pm 0.5\%$ increases the wear by $5\% \pm 1\%$, and the Cl^- - containing environment (concentration $>0.5\% \pm 0.1\%$) increases the corrosion rate to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$.

Equipment parameters:

cutting speed $50\text{-}300 \text{ m/min} \pm 10 \text{ m/min}$, feed rate $0.1\text{-}0.5 \text{ mm/r} \pm 0.05 \text{ mm/r}$ or pressure $50\text{-}300 \text{ MPa} \pm 10 \text{ MPa}$, power $30\text{-}400 \text{ kW} \pm 50 \text{ kW}$ affect tool life and efficiency. Too high parameters ($>$ upper limit $10\% \pm 1\%$) shorten tool life by $15\% \pm 2\%$.

Types of Carbide Tools

Carbide turning tools

are suitable for low carbon steel (tensile strength $300\text{-}600 \text{ MPa}$), with a cutting edge width of $5\text{-}10 \text{ mm} \pm 0.5 \text{ mm}$ and a life of $> 400 \text{ hours} \pm 50 \text{ hours}$, and are often used for shaft processing.

Carbide milling tools

are suitable for aluminum alloys ($500\text{-}700 \text{ MPa}$), with a diameter of $10\text{-}20 \text{ mm} \pm 0.5 \text{ mm}$, strong impact resistance ($> 80 \text{ J} \pm 5 \text{ J}$), and are suitable for plane milling.

Carbide drilling tools

are used for high-strength steel ($800\text{-}1200 \text{ MPa}$), with a diameter of $5\text{-}15 \text{ mm} \pm 0.5 \text{ mm}$, excellent high pressure resistance ($> 150 \text{ MPa} \pm 10 \text{ MPa}$), and are suitable for deep hole drilling.

Carbide stamping tools

are suitable for low carbon steel stamping ($400\text{-}600 \text{ MPa}$), with a size of $10\text{-}30 \text{ mm} \pm 1 \text{ mm}$ and impact resistance ($> 100 \text{ J} \pm 10 \text{ J}$).

Special carbide tools

include high temperature resistant ($>900^\circ\text{C} \pm 20^\circ\text{C}$ maintain $95\% \pm 2\%$) and corrosion resistant types, suitable for titanium alloys or nickel-based alloys.

Application of cemented carbide tools

Automobile manufacturing

is used for engine cylinder turning (tensile strength $600\text{-}800 \text{ MPa}$), life $400\text{-}600 \text{ hours} \pm 50 \text{ hours}$,

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in line with QC/T 480 standards.

Aerospace

is used for titanium alloy milling (1000-1500 MPa), impact resistance ($> 60 \text{ J}$, peak $150 \text{ J} \pm 10 \text{ J}$) to ensure efficient cutting, in line with AMS 4911 standards.

Mold processing

is used for steel mold drilling (800-1000 MPa), reducing waste ($< 2\% \pm 0.5\%$), meeting ISO 286 standards.

Corrosive environment

is used for salt-containing stainless steel cutting, seawater corrosion resistance ($> 4000 \text{ hours} \pm 100 \text{ hours}$, Cl^- concentration resistance $> 3.5\% \pm 0.5\%$), in line with DNVGL-RP-C203 standards.

Complex material processing

is used for nickel-based alloy turning (1200-1500 MPa), wear resistance $> 95\% \pm 2\%$, test efficiency in 2025.

Energy equipment

is used for oil drill pipe milling (1000-1300 MPa), pressure resistance ($> 200 \text{ MPa} \pm 10 \text{ MPa}$), meeting API 6A standards.

Electronic components

are used for aluminum alloy drilling (400-600 MPa), surface finish $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, meeting IPC-6012 standards.

Railway manufacturing

is used for rail turning (700-900 MPa), reducing waste ($< 1\% \pm 0.5\%$), meeting EN 13674 standards.

Shipbuilding industry

is used for ship steel plate milling (600-800 MPa), impact resistance ($> 50 \text{ J}$, peak $120 \text{ J} \pm 10 \text{ J}$), meeting ISO 8062 standards.

Medical equipment

is used for stainless steel drilling (600-900 MPa), corrosion resistance ($> 3000 \text{ hours} \pm 100 \text{ hours}$), meeting ISO 13485 standards.

Home appliance manufacturing

is used for stamping aluminum housings (400-600 MPa), with a surface roughness of $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, in line with IEC 60335 standards.

Architectural hardware

is used for stamping steel bolts (700-900 MPa), reducing waste ($< 1\% \pm 0.5\%$), meeting ASTM A307 standards.

Technological progress and future development of cemented carbide tools

New materials

introduce nano WC (grain $< 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness ($\text{HV } 2200\text{-}2600 \pm 50$), and add TaC and NbC to enhance high temperature stability ($> 900^\circ\text{C} \pm 20^\circ\text{C}$ to maintain $95\% \pm 2\%$). Research in 2024: Anti-oxidation property of Al_2O_3 coating (oxygen weight gain $< 0.1\% \pm 0.05\%/h$).

Intelligent monitoring

integrated sensor (accuracy $\pm 0.05\%$) monitors wear (depth $> 0.8 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($< 900^\circ\text{C} \pm 20^\circ\text{C}$) in real time, optimizes replacement cycle (error $< 5\% \pm 1\%$), and a company

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successfully tested it in 2025.

3D printing technology

uses SLM (layer thickness $40\text{--}60\text{ }\mu\text{m}\pm 5\text{ }\mu\text{m}$) to manufacture complex tools, reducing material waste by $10\%\pm 2\%$, and reaching a strength of $1500\text{ MPa}\pm 50\text{ MPa}$ in 2024.

Environmental adaptability

Development of corrosion-resistant and high-pressure resistant tools (pressure resistance $>250\text{ MPa}\pm 10\text{ MPa}$), recycling of WC powder (recycling rate $>80\%\pm 5\%$), reducing carbon footprint (CO_2 reduction of $20\%\pm 3\%$), in compliance with ISO 14040 standards.

Domestic and international standards for cemented carbide tools

Domestic and international standards include all the following relevant standards and their numbers:

QC/T 480 (Automotive Parts Manufacturing Standard)

AMS 4911 (Aerospace Titanium Alloy Standard)

ISO 286 (Geometrical product specifications and tolerances)

DNVGL-RP-C203 (Design rules for offshore structures)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)

DIN 17350 (German metal material standard)

JIS B 4053 (Japanese mold design standard)

API 6A (Standard for Oil and Gas Equipment)

IPC-6012 (Electronic Component Manufacturing Standard)

EN 13674 (railway rail standard)

ISO 8062 (casting tolerance standard)

ISO 13485 (Quality Management System for Medical Devices)

IEC 60335 (Household Appliance Safety Standard)

ASTM A307 (Standard for Construction Bolts)



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What are Carbide Cutting Tools ?

Carbide cutting tools are highly efficient tools designed for metal cutting, turning, milling and drilling, and are intended for efficient processing of steel, cast iron, non-ferrous metals and difficult-to-process materials. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized tool geometry and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and long life under high speed, high load and complex working conditions. As a key component of mechanical processing, cutting tools directly affect processing accuracy, surface quality and production efficiency, and are widely used in automobile manufacturing, aerospace and mold processing. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of cutting tools.

Physical and chemical properties of cemented carbide cutting tools

Cemented carbide cutting tools use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$) or hot isostatic pressing (HIP, temperature $1400^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the tool is customized according to the processing requirements, including turning tools, milling cutters or drills, with a cutting edge width of $2-20\text{ mm} \pm 0.5\text{ mm}$ and a length of $50-150\text{ mm} \pm 2\text{ mm}$, mounted on a tool holder (made of high-strength steel such as H13 or M2, quenched hardness HRC $50-58 \pm 2$). The fixing methods include mechanical clamping (clamping force $>10\text{ kN} \pm 1\text{ kN}$) or welding (welding strength $>700\text{ MPa} \pm 50\text{ MPa}$) to ensure stable operation under high cutting forces ($50-200\text{ N} \pm 10\text{ N}$, peak value up to $300\text{ N} \pm 20\text{ N}$). Multi-layer coatings (such as TiN, TiAlN or Al_2O_3 , thickness $0.5-4\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the cutting edge surface, reducing the friction coefficient to $<0.2 \pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<1\% \pm 0.5\%$). The design integrates cutting mechanics and heat conduction optimization, with a rake angle of $5^\circ-15^\circ \pm 2^\circ$ and a back angle of $5^\circ-10^\circ \pm 2^\circ$, suitable for a variety of materials with a tensile strength of $300-1500\text{ MPa}$.

Characteristics

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of cemented carbide cutting tools WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure gives excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C, oxidation resistance >95%±2%); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} 12-16 MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5), and absorbs impact energy (>60 J±5 J, instantaneous peak value >150 J±10 J). Fine grains and optimized microstructure, wear rate <0.03 mm³/N·m ± 0.01 mm³/N·m (preferably <0.015 mm³/N·m ± 0.01 mm³/N·m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶/°C±0.5×10⁻⁶/°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, Cl⁻ resistance >3000 hours±100 hours); TaC and NbC increase high temperature hardness (>900°C±20°C maintains 90%±2% of the initial hardness, thermal stability >95%±2%).

Working principle of cemented carbide cutting tools

The tool removes material by shearing and friction under the action of CNC machine tools or lathes (cutting speed 50-300 m/min±10 m/min, feed rate 0.1-0.5 mm/r±0.05 mm/r, power 30-250 kW±50 kW). The cutting edge is subjected to high cutting forces and thermal loads (surface temperature 500-900°C±50°C, instantaneous up to 1000°C±50°C), and the tool handle steel provides structural support (tensile strength >1200 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life >10⁶ times±10⁵ times, cyclic load >150 MPa±20 MPa). The precision design of the tool ensures that the tolerance is controlled within ±0.01 mm±0.005 mm and the surface roughness Ra<0.1 μm±0.05 μm.

The performance of cemented carbide cutting tools

is optimized to have a tool life of more than 300-600 hours ± 50 hours (depending on the hardness of the material) when processing 45# steel (tensile strength 600 MPa), aluminum alloy (500 MPa) and titanium alloy (1000 MPa), with a cutting efficiency of 100-500 cm³/min ± 10 cm³/min (up to 600 cm³/min ± 10 cm³/min, power >200 kW ± 50 kW). SEM analysis shows no obvious cracking of the cutting edge, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (>95% ± 2%), and thermal imaging shows that the thermal stress distribution is <100 MPa ± 10 MPa.

Factors affecting the performance of cemented carbide cutting tools

The Co content of

6%-12%±1% achieves the best balance between hardness and toughness. <6%±1% leads to a 10%±2% increase in crack rate, >12%±1% reduces the hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶/°C±0.5×10⁻⁶/°C). 8%-10%±0.5% is preferred to balance performance and cost.

Grain size of

0.5-1 μm±0.01 μm effectively reduces wear and microcracks (wear rate <0.015 mm³/N·m ± 0.01 mm³/N·m), 1-1.5 μm±0.01 μm is suitable for medium hardness materials, >2 μm±0.01 μm increases wear rate by 15%±3% and reduces toughness by 10%±2%.

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Geometric

rake angle of 5° - $15^{\circ} \pm 2^{\circ}$ optimizes cutting efficiency (cutting force $< 50 \text{ N} \pm 5 \text{ N}$, energy consumption $< 15 \text{ kWh/m}^3 \pm 2 \text{ kWh/m}^3$), $> 15^{\circ} \pm 2^{\circ}$ reduces efficiency by $10\% \pm 2\%$, $< 5^{\circ} \pm 2^{\circ}$ easily leads to a risk of chipping of $5\% \pm 1\%$.

Surface treatment

edge thickness of $2\text{-}4 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extended by $20\% \pm 3\%$), $< 2 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $> 4 \text{ mm} \pm 0.1 \text{ mm}$ increases cost by $15\% \pm 2\%$. TiAlN coating (thickness $0.5\text{-}2 \text{ }\mu\text{m} \pm 0.1 \text{ }\mu\text{m}$, deposition temperature $400\text{-}500^{\circ}\text{C} \pm 20^{\circ}\text{C}$) reduces the friction coefficient ($< 0.25 \pm 0.05$) and improves heat resistance ($> 900^{\circ}\text{C} \pm 20^{\circ}\text{C}$).

Heat-treated

shank steel quenching (hardness HRC $50\text{-}58 \pm 2$, depth $1.5\text{-}3 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850\text{-}900^{\circ}\text{C} \pm 20^{\circ}\text{C}$) enhances support performance, reduces the life of unquenched shanks by $15\% \pm 3\%$, and tempering ($200\text{-}250^{\circ}\text{C} \pm 10^{\circ}\text{C}$, $2\text{-}4 \text{ hours} \pm 0.5 \text{ hours}$) reduces residual stress by $5\% \pm 1\%$.

Working environment

temperature $> 800^{\circ}\text{C} \pm 50^{\circ}\text{C}$ reduces hardness by $3\% \pm 1\%$, water content $> 5\% \pm 1\%$ or impurity content $> 3\% \pm 0.5\%$ increases wear by $5\% \pm 1\%$, and Cl^{-} - containing environment (concentration $> 0.5\% \pm 0.1\%$) increases corrosion rate to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$.

Equipment parameters:

cutting speed $50\text{-}300 \text{ m/min} \pm 10 \text{ m/min}$, feed rate $0.1\text{-}0.5 \text{ mm/r} \pm 0.05 \text{ mm/r}$, power $30\text{-}250 \text{ kW} \pm 50 \text{ kW}$ affect tool life and efficiency. Too high parameters ($>$ upper limit $10\% \pm 1\%$) shorten tool life by $15\% \pm 2\%$.

Types of Carbide Cutting Tools

Standard turning tools

are suitable for low carbon steel (tensile strength $300\text{-}600 \text{ MPa}$), with a cutting edge width of $5\text{-}10 \text{ mm} \pm 0.5 \text{ mm}$ and a life of $> 400 \text{ hours} \pm 50 \text{ hours}$, and are often used for shaft processing.

Milling tools

are suitable for aluminum alloys ($500\text{-}700 \text{ MPa}$), with a diameter of $10\text{-}20 \text{ mm} \pm 0.5 \text{ mm}$, strong impact resistance ($> 80 \text{ J} \pm 5 \text{ J}$), and suitable for plane milling. Drill

bits

are used for high-strength steel ($800\text{-}1200 \text{ MPa}$), with a diameter of $5\text{-}15 \text{ mm} \pm 0.5 \text{ mm}$, excellent high pressure resistance ($> 150 \text{ MPa} \pm 10 \text{ MPa}$), and suitable for deep hole drilling.

Special cutting tools

include high temperature resistant ($> 900^{\circ}\text{C} \pm 20^{\circ}\text{C}$ to maintain $95\% \pm 2\%$) and corrosion resistant types, suitable for titanium alloys or nickel-based alloys.

Application of cemented carbide cutting tools

Automobile manufacturing

, used for engine cylinder turning (tensile strength $600\text{-}800 \text{ MPa}$), service life $400\text{-}600 \text{ hours} \pm 50 \text{ hours}$, in line with QC/T 480 standards.

Aerospace

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is used for titanium alloy milling (1000-1500 MPa), impact resistance (>60 J, peak $150 \text{ J} \pm 10 \text{ J}$) to ensure efficient cutting, in line with AMS 4911 standards.

Mold processing

is used for steel mold drilling (800-1000 MPa), reducing waste ($<2\% \pm 0.5\%$), and meeting ISO 286 standards.

Corrosive environment

is used for salt-containing stainless steel cutting, seawater corrosion resistance (>4000 hours ± 100 hours, Cl^- concentration resistance $> 3.5\% \pm 0.5\%$), in line with DNVGL-RP-C203 standards.

Complex material processing

is used for nickel-based alloy turning (1200-1500 MPa), wear resistance $>95\% \pm 2\%$.

Energy equipment

is used for oil drill pipe milling (1000-1300 MPa), pressure resistance ($>200 \text{ MPa} \pm 10 \text{ MPa}$), meeting API 6A standards.

Electronic components

are applied to aluminum alloy drilling (400-600 MPa), with surface finish $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, in accordance with IPC-6012 standard.

Railway manufacturing

for rail turning (700-900 MPa) with reduced scrap ($<1\% \pm 0.5\%$), meeting EN 13674 standards.

Shipbuilding industry

: used for milling of ship steel plates (600-800 MPa), impact resistance (>50 J, peak $120 \text{ J} \pm 10 \text{ J}$), in accordance with ISO 8062.

Medical equipment:

used for drilling of stainless steel (600-900 MPa), corrosion resistance (>3000 hours ± 100 hours), in accordance with ISO 13485.

Technological progress and future development of cemented carbide cutting tools

New Materials

The introduction of nano-WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) improves hardness (HV 2200-2600 ± 50), and the addition of TaC and NbC enhances high temperature stability ($>900^\circ\text{C} \pm 20^\circ\text{C}$ maintains $95\% \pm 2\%$).

Intelligent monitoring

integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth $>0.8 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($<900^\circ\text{C} \pm 20^\circ\text{C}$) in real time, optimizing replacement cycles (error $<5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex tools, reducing material waste by $10\% \pm 2\%$.

Environmental adaptability

develops corrosion-resistant and high-pressure resistant tools (pressure resistance $>250 \text{ MPa} \pm 10 \text{ MPa}$)

Sustainable

recycling of WC powder (recycling rate $>80\% \pm 5\%$) reduces carbon footprint (CO_2 emissions reduction $20\% \pm 3\%$), in line with ISO 14040 standards.

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GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)

DIN 17350 (German metal material standard)

JIS B 4053 (Japanese mold design standard)

API 6A (Standard for Oil and Gas Equipment)

IPC-6012 (Electronic Component Manufacturing Standard)

EN 13674 (railway rail standard)

ISO 8062 (casting tolerance standard)

ISO 13485 (Quality Management System for Medical Devices)

What is Carbide Extrusion Die ?

Carbide extrusion dies are high-performance tools designed for cold extrusion, hot extrusion and precision molding, and are intended to efficiently process high-strength steel, non-ferrous metals and complex-shaped parts. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with optimized geometric structure and wear-resistant coating, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and long life under high pressure, high temperature and complex working conditions. As a key component in precision manufacturing, carbide extrusion dies are widely used in automotive transmission parts, aviation structural parts and electronic connector manufacturing with their unparalleled performance and reliability, directly affecting part accuracy, surface quality and production costs. The industry's technological progress in 2025 further enhanced its application potential, and the latest data shows that its performance in high-strength material processing is particularly outstanding.

Physical and chemical properties of cemented carbide extrusion

dies Cemented carbide extrusion dies use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $8\% - 12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\% - 3\% \pm 0.2\%$, NbC $0.5\% - 1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400 - 1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$) or spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m} \pm 0.01 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the die is customized according to the extrusion requirements, including the extrusion barrel, punch or die, with a size range of $10 - 50 \text{ mm} \pm 1 \text{ mm}$ (depending on the part), mounted on the die base (made of high-strength alloy steel, such as H13 or D2, quenching hardness HRC $50 - 58 \pm 2$). The fixing methods include high-frequency induction welding (temperature $1200 - 1300^\circ\text{C} \pm 20^\circ\text{C}$, welding strength $>800 \text{ MPa} \pm 50 \text{ MPa}$) or mechanical fastening (fastening force $>15 \text{ kN} \pm 1 \text{ kN}$), ensuring stable operation under high pressure ($200 - 500 \text{ MPa} \pm 20 \text{ MPa}$, peak value up to $600 \text{ MPa} \pm 30 \text{ MPa}$). The working surface can be coated with multiple layers (such as TiN, TiAlN or AlCrN, thickness $1 - 3 \mu\text{m} \pm 0.1 \mu\text{m}$), the friction coefficient is reduced to $<0.2 \pm 0.05$, and the wear resistance and anti-adhesion (adhesion rate $<1.5\% \pm 0.5\%$) are improved. The design integrates extrusion mechanics and heat conduction optimization, with an entry angle of $15^\circ - 30^\circ \pm 5^\circ$ and a back tilt angle of $5^\circ - 10^\circ \pm 2^\circ$, suitable for a variety of materials with a tensile strength of $600 - 1500 \text{ MPa}$.

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Characteristics of cemented carbide extrusion dies

WC provides high hardness (HV 1800-2200±30, locally up to 2400-2600±50), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature >800°C±20°C, oxidation resistance >95%±2%); Co enhances toughness (K_{IC} 12-16 MPa·m^{1/2}±0.5, peak value up to 18 MPa·m^{1/2}±0.5) through solid solution strengthening and plastic deformation, and absorbs impact energy (>100 J±10 J, instantaneous peak value >250 J±20 J). Fine grains and optimized microstructure, wear rate <0.04 mm³/N·m±0.01 mm³/N·m (preferably <0.02 mm³/N·m±0.01 mm³/N·m), density 14.8-15.2 g/cm³±0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶/°C±0.5×10⁻⁶/°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm±0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year±0.001 mm/year, Cl⁻ resistance >3000 hours±100 hours); TaC and NbC increase high temperature hardness (>900°C±20°C maintains 90%±2% of the initial hardness, thermal stability >95%±2%).

Working principle of cemented carbide extrusion die

The die is used to form metal materials by extrusion and plastic deformation under the action of hydraulic press or extrusion equipment (pressure 200-500 MPa±20 MPa, speed 5-20 m/s±2 m/s, power 100-500 kW±50 kW). The working surface is subjected to high pressure and thermal load (surface temperature 500-1000°C±50°C, up to 1100°C±50°C during hot extrusion), and the base steel provides structural support (tensile strength>1300 MPa±50 MPa), heat conduction (thermal conductivity 40-50 W/m·K±2 W/m·K) and fatigue resistance (fatigue life>10⁶ times±10⁵ times, cyclic load>250 MPa±20 MPa). The precision design of the mold ensures that the tolerance is controlled at ±0.01 mm±0.005 mm and the surface roughness Ra<0.2 μm±0.05 μm.

The performance of cemented carbide extrusion dies

is optimized to have a die life of more than 400-700 hours±50 hours when processing high-strength steel (1000 MPa), aluminum alloy (600 MPa) or copper alloy (500 MPa), and a production efficiency of 500-2000 pieces/h±100 pieces/h (up to 2500 pieces/h±100 pieces/h, power >400 kW±50 kW). SEM analysis shows no obvious wear on the surface, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (>95%±2%), and thermal imaging shows that the thermal stress distribution is <150 MPa±10 MPa.

Factors affecting the performance of cemented carbide extrusion dies

The Co content of

8%-12%±1% achieves the best balance between hardness and toughness. <8%±1% leads to an increase in crack rate of 10%±2%. >12%±1% reduces the hardness by 5%±1% and increases thermal expansion (CTE 6×10⁻⁶/°C±0.5×10⁻⁶/°C). 9%-11%±0.5% is preferred to balance performance and cost.

Grain size

0.5-1 μm±0.01 μm effectively reduces wear and microcracks (wear rate <0.02 mm³/N·m±0.01 mm³/N·m), 1-1.5 μm±0.01 μm is suitable for medium hardness materials, >2 μm±0.01 μm increases wear rate by 15%±3% and reduces toughness by 10%±2%. Geometric

angles

: die angle 15°-30°±5° optimizes extrusion efficiency (pressure <200 MPa±10 MPa, energy

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consumption $<25 \text{ kWh/m}^3 \pm 2 \text{ kWh/m}^3$), $>35^\circ \pm 5^\circ$ reduces efficiency by $10\% \pm 2\%$, $<15^\circ \pm 5^\circ$ easily leads to $5\% \pm 1\%$ risk of cracking.

Surface treatment:

working surface thickness $3-5 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extension by $20\% \pm 3\%$), $<3 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $>5 \text{ mm} \pm 0.1$ The cost of mm increases by $15\% \pm 2\%$. TiAlN coating (thickness $1-2 \mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature $400-500^\circ\text{C} \pm 20^\circ\text{C}$) reduces the friction coefficient ($<0.25 \pm 0.05$) and improves heat resistance ($>1000^\circ\text{C} \pm 20^\circ\text{C}$). The

heat-treated

base steel is quenched (hardness HRC $50-58 \pm 2$, depth $2-4 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $850-900^\circ\text{C} \pm 20^\circ\text{C}$) to enhance the supporting performance, the unquenched base life is reduced by $15\% \pm 3\%$, and tempering ($200-250^\circ\text{C} \pm 10^\circ\text{C}$, $2-4 \text{ hours} \pm 0.5 \text{ hours}$) reduces the residual stress by $5\% \pm 1\%$.

The working environment

temperature $>1000^\circ\text{C} \pm 50^\circ\text{C}$ reduces the hardness by $3\% \pm 1\%$, the water content $>5\% \pm 1\%$ or the impurity content $>3\% \pm 0.5\%$ increases the wear by $5\% \pm 1\%$, and the Cl^- - containing environment (concentration $>0.5\% \pm 0.1\%$) increases the corrosion rate to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$.

Equipment parameters

pressure $200-500 \text{ MPa} \pm 20 \text{ MPa}$, speed $5-20 \text{ m/s} \pm 2 \text{ m/s}$, power $100-500 \text{ kW} \pm 50 \text{ kW}$ affect mold life and efficiency. Excessive parameters ($>$ upper limit $10\% \pm 1\%$) shorten the life by $15\% \pm 2\%$.

Types of carbide extrusion dies

Cold extrusion dies

are suitable for high-strength steel ($800-1200 \text{ MPa}$), with a size of $20-50 \text{ mm} \pm 1 \text{ mm}$, excellent high-pressure resistance ($>400 \text{ MPa} \pm 20 \text{ MPa}$), and are often used for transmission shafts.

Hot extrusion dies

are suitable for aluminum alloys ($500-700 \text{ MPa}$), with a size of $15-40 \text{ mm} \pm 1 \text{ mm}$, strong high-temperature resistance ($>1000^\circ\text{C} \pm 20^\circ\text{C}$ to maintain $95\% \pm 2\%$), and are used for aviation structural parts.

Precision forming dies

are used for copper alloys or stainless steel ($600-1000 \text{ MPa}$), with a size of $10-30 \text{ mm} \pm 1 \text{ mm}$, high precision (tolerance $\pm 0.01 \text{ mm} \pm 0.005 \text{ mm}$), and are suitable for electronic connectors.

Special extrusion dies

include corrosion-resistant and ultra-high-pressure types (pressure resistance $>500 \text{ MPa} \pm 20 \text{ MPa}$), suitable for extreme environments.

Application of carbide extrusion dies

Automotive transmission parts

are used for cold extrusion of transmission shafts ($1000-1200 \text{ MPa}$), with a service life of $500-700 \text{ hours} \pm 50 \text{ hours}$, in line with QC/T 480 standards.

Aviation structural parts

are used for hot extrusion of aluminum alloys ($500-700 \text{ MPa}$), and high temperature resistance ($>1000^\circ\text{C} \pm 20^\circ\text{C}$) ensures efficient forming, in line with AMS 4911 standards.

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Electronic connectors

are used for precision extrusion of copper alloys (500-800 MPa), with a surface roughness of $Ra < 0.2 \mu\text{m} \pm 0.05 \mu\text{m}$, meeting IPC-6012 standards.

Energy equipment

is used for high-pressure valve body extrusion (1200-1500 MPa), with pressure resistance ($> 500 \text{ MPa} \pm 20 \text{ MPa}$), in line with API 6A standards.

Corrosive environment

is suitable for salt-containing stainless steel extrusion, anti-seawater corrosion ($> 4000 \text{ hours} \pm 100 \text{ hours}$, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$), in line with DNVGL-RP-C203 standard.

Medical devices

are used for stainless steel precision extrusion (600-900 MPa), corrosion resistance ($> 3000 \text{ hours} \pm 100 \text{ hours}$), in line with ISO 13485 standard.

Railway components

are used for cold extrusion of steel bushings (800-1000 MPa), reducing waste ($< 2\% \pm 0.5\%$), meeting EN 13674 standard.

Shipbuilding industry

is used for hot extrusion of marine aluminum alloys (500-700 MPa), impact resistance ($> 100 \text{ J} \pm 10 \text{ J}$), in line with ISO 8062 standard.

Construction hardware

is used for steel nut extrusion (700-900 MPa), surface finish $Ra < 0.2 \mu\text{m} \pm 0.05 \mu\text{m}$, in line with ASTM A307 standard.

Home appliance manufacturing

for aluminum housing cold extrusion (400-600 MPa), accuracy $\pm 0.01 \text{ mm} \pm 0.005 \text{ mm}$, in line with IEC 60335 standards.

Technological progress and future development of cemented carbide extrusion dies

New materials

introduce nano WC (grain $< 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness ($\text{HV } 2200\text{-}2600 \pm 50$), and add TaC and NbC to enhance high temperature stability ($> 1000^\circ\text{C} \pm 20^\circ\text{C}$ to maintain $95\% \pm 2\%$).

Intelligent monitoring

integrated sensors (accuracy $\pm 0.05\%$) monitor wear (depth $> 1 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($< 1100^\circ\text{C} \pm 20^\circ\text{C}$) in real time, and optimize replacement cycles (error $< 5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex molds, reducing material waste by $10\% \pm 2\%$.

Environmental adaptability

develops corrosion-resistant and ultra-high pressure molds (pressure resistance $> 600 \text{ MPa} \pm 20 \text{ MPa}$).

Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 reduction $20\% \pm 3\%$) in compliance with ISO 14040 standards.

Relevant domestic and international standards

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QC/T 480 (Automotive parts manufacturing standards)

AMS 4911 (Aerospace Titanium Alloy Standard)

IPC-6012 (Electronic Component Manufacturing Standard)

ISO 286 (Geometrical product specifications and tolerances)

DNVGL-RP-C203 (Design rules for offshore structures)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)

DIN 17350 (German metal material standard)

API 6A (Standard for Oil and Gas Equipment)

ISO 8062 (casting tolerance standard)



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Carbide fluid control seals

Carbide fluid control seals are high-performance sealing components designed for high-pressure, high-corrosive and high-temperature environments, and are widely used in the fields of oil and gas, chemical industry, aerospace and water treatment. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and corrosion-resistant coatings, to provide excellent hardness, wear resistance, corrosion resistance and high temperature resistance, ensuring the maintenance of sealing integrity and long-term reliability under extreme working conditions. As a key component in the fluid control system, carbide seals have become reliable guards in complex engineering environments with their tough characteristics and high-efficiency performance, directly affecting system efficiency, leakage rate and equipment life.

Physical and chemical properties of cemented carbide fluid control seals

Cemented carbide seals use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 10\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\% - 3\% \pm 0.2\%$, NbC $0.5\% - 1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and corrosion resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400 - 1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30 - 60 \text{ min} \pm 5 \text{ min}$) or spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5 - 10 \text{ min} \pm 1 \text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2 \mu\text{m} \pm 0.01 \mu\text{m}$ (preferably $0.8 - 1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the seal is customized according to the application requirements, including annular seals, valve seats or sleeves, with a size range of $5 - 50 \text{ mm} \pm 0.5 \text{ mm}$ (depending on the pipeline), installed on a stainless steel or titanium alloy substrate (tensile strength $>1000 \text{ MPa} \pm 50 \text{ MPa}$, hardness HRC $40 - 50 \pm 2$). The fixing methods include mechanical press fit (press fit force $>10 \text{ kN} \pm 1 \text{ kN}$) or high-frequency welding (welding strength $>700 \text{ MPa} \pm 50 \text{ MPa}$), ensuring stable operation under high pressure ($50 - 300 \text{ MPa} \pm 10 \text{ MPa}$, peak value up to $400 \text{ MPa} \pm 20 \text{ MPa}$). Multi-layer coatings (such as TiN, CrN or WC/C, thickness $0.5 - 2 \mu\text{m} \pm 0.1 \mu\text{m}$) can be applied to the sealing surface, reducing the friction coefficient to $<0.15 \pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<1\% \pm 0.5\%$). The design combines fluid mechanics and heat conduction optimization, with a contact angle of $5^\circ - 15^\circ \pm 2^\circ$ and is suitable for operating temperatures from -50°C to $500^\circ\text{C} \pm 20^\circ\text{C}$.

Material properties of cemented carbide fluid control seals

WC provides high hardness (HV $1800 - 2200 \pm 30$, locally up to $2400 - 2600 \pm 50$), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^\circ\text{C} \pm 20^\circ\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness (K_{IC} $12 - 16 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value up to $18 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$) through solid solution strengthening and

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plastic deformation, and absorbs impact energy ($> 50 \text{ J} \pm 5 \text{ J}$, instantaneous peak value $> 120 \text{ J} \pm 10 \text{ J}$). Fine grains and optimized microstructure, wear rate $< 0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$ (preferably $< 0.015 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), density $14.8\text{-}15.2 \text{ g/cm}^3 \pm 0.1 \text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $< 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $< 0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$, Cl^- resistance $> 5000 \text{ hours} \pm 200 \text{ hours}$); TaC and NbC increase high temperature hardness ($> 900^\circ\text{C} \pm 20^\circ\text{C}$ maintains $90\% \pm 2\%$ of the initial hardness, thermal stability $> 95\% \pm 2\%$).

Working principle of cemented carbide fluid control seals

prevent fluid leakage through close contact and elastic deformation under the action of valves, pumps or pipeline systems (pressure $50\text{-}300 \text{ MPa} \pm 10 \text{ MPa}$, flow rate $1\text{-}10 \text{ m/s} \pm 1 \text{ m/s}$, power $50\text{-}300 \text{ kW} \pm 50 \text{ kW}$). The sealing surface is subjected to high pressure and thermal load (surface temperature -50°C to $500^\circ\text{C} \pm 20^\circ\text{C}$, extreme up to $600^\circ\text{C} \pm 30^\circ\text{C}$), and the matrix material provides structural support (tensile strength $> 1000 \text{ MPa} \pm 50 \text{ MPa}$), heat conduction (thermal conductivity $30\text{-}40 \text{ W/m}\cdot\text{K} \pm 2 \text{ W/m}\cdot\text{K}$) and fatigue resistance (fatigue life $> 10^6$ times $\pm 10^5$ times, cyclic load $> 150 \text{ MPa} \pm 20 \text{ MPa}$). The precision design of the seal ensures that the tolerance is controlled at $\pm 0.005 \text{ mm} \pm 0.002 \text{ mm}$, the surface roughness $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, and the leakage rate is $< 0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$.

The performance of cemented carbide fluid control seals is optimized to have a life of more than 500-800 hours ± 50 hours when

processing high-pressure natural gas (200 MPa), seawater (containing $\text{Cl}^- > 3\% \pm 0.5\%$) or high-temperature steam ($400^\circ\text{C} \pm 20^\circ\text{C}$), and a sealing efficiency of $99.99\% \pm 0.01\%$ (leakage rate $< 0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$). SEM analysis shows no obvious wear on the surface, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($> 95\% \pm 2\%$), and thermal imaging shows that the thermal stress distribution is $< 100 \text{ MPa} \pm 10 \text{ MPa}$.

Factors affecting the performance of cemented carbide fluid control seals

Co content of

$6\%\text{-}10\% \pm 1\%$ achieves the best balance between hardness and toughness, $< 6\% \pm 1\%$ leads to an increase in crack rate of $10\% \pm 2\%$, $> 10\% \pm 1\%$ reduces the hardness by $5\% \pm 1\%$ and increases thermal expansion (CTE $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$), and $7\%\text{-}9\% \pm 0.5\%$ is preferred to take into account both performance and cost.

Grain size of

$0.5\text{-}1 \mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $< 0.015 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), $1\text{-}1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium pressure environment, $> 2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by $15\% \pm 3\%$ and reduces toughness by $10\% \pm 2\%$.

Geometric angle

contact angle of $5^\circ\text{-}15^\circ \pm 2^\circ$ optimizes sealing performance (leakage rate $< 0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$), $> 15^\circ \pm 2^\circ$ reduces sealing efficiency by $5\% \pm 1\%$, $< 5^\circ \pm 2^\circ$ easily leads to uneven contact risk of $5\% \pm 1\%$.

Surface treatment

sealing surface thickness of $2\text{-}3 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extended by $20\% \pm 3\%$),

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$<2\text{ mm}\pm 0.1\text{ mm}$ shortens life by $20\%\pm 3\%$, $>3\text{ mm}\pm 0.1\text{ mm}$ increases cost by $15\%\pm 2\%$. CrN coating (thickness $0.5\text{--}1\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, deposition temperature $400\text{--}450^{\circ}\text{C}\pm 20^{\circ}\text{C}$) reduces the friction coefficient ($<0.2\pm 0.05$) and improves corrosion resistance (Cl^{-} resistance $>6000\text{ hours}\pm 200\text{ hours}$).

Heat treatment:

Quenching of the base material (hardness HRC $40\text{--}50\pm 2$, depth $1\text{--}3\text{ mm}\pm 0.2\text{ mm}$, quenching temperature $800\text{--}850^{\circ}\text{C}\pm 20^{\circ}\text{C}$) enhances the supporting performance, the life of the unquenched base is reduced by $15\%\pm 3\%$, and tempering ($200\text{--}250^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $2\text{--}4\text{ hours}\pm 0.5\text{ hours}$) reduces the residual stress by $5\%\pm 1\%$.

Working environment

temperature $>500^{\circ}\text{C}\pm 20^{\circ}\text{C}$ reduces the hardness by $3\%\pm 1\%$, water content $>5\%\pm 1\%$ or impurity content $>3\%\pm 0.5\%$ increases wear by $5\%\pm 1\%$, and the corrosion rate in the Cl^{-} environment (concentration $>0.5\%\pm 0.1\%$) increases to $0.015\text{ mm/year}\pm 0.002\text{ mm/year}$.

Equipment parameters

pressure $50\text{--}300\text{ MPa}\pm 10\text{ MPa}$, flow rate $1\text{--}10\text{ m/s}\pm 1\text{ m/s}$, power $50\text{--}300\text{ kW}\pm 50\text{ kW}$ affect the life and efficiency of seals. Excessive parameters ($>$ upper limit $10\%\pm 1\%$) shorten the life by $15\%\pm 2\%$.

Types of carbide fluid control seals

Ring seals

are suitable for high-pressure valves ($100\text{--}200\text{ MPa}$), with a size of $10\text{--}30\text{ mm}\pm 0.5\text{ mm}$ and excellent pressure resistance ($>300\text{ MPa}\pm 10\text{ MPa}$).

Seat seals

are suitable for chemical pumps ($50\text{--}150\text{ MPa}$), with a size of $5\text{--}20\text{ mm}\pm 0.5\text{ mm}$ and strong corrosion resistance (Cl^{-} resistance $>5000\text{ hours}\pm 200\text{ hours}$).

Sleeve seals

are used in aviation hydraulic systems ($200\text{--}300\text{ MPa}$), with a size of $15\text{--}40\text{ mm}\pm 0.5\text{ mm}$ and high temperature resistance ($>500^{\circ}\text{C}\pm 20^{\circ}\text{C}$).

Special seals

include ultra-high temperature ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$) and ultra-corrosive types for extreme environments.

Application of cemented carbide fluid control seals

Oil and gas

are used for high-pressure natural gas valves ($200\text{--}300\text{ MPa}$), with a life of $600\text{--}800\text{ hours}\pm 50\text{ hours}$, in accordance with API 6A standards.

Chemical industry

is used for corrosive fluid pumps ($50\text{--}150\text{ MPa}$), resistant to Cl^{-} corrosion ($>5000\text{ hours}\pm 200\text{ hours}$), in accordance with ISO 10423 standards.

Aerospace

is used for hydraulic system seals ($200\text{--}300\text{ MPa}$), high temperature resistance ($>500^{\circ}\text{C}\pm 20^{\circ}\text{C}$) to ensure reliability, in accordance with AMS 2750 standards.

Water treatment

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is suitable for seawater pipelines (pressure 50-100 MPa), anti-seawater corrosion (>6000 hours $\pm$ 200 hours), in accordance with DNVGL-RP-C203 standards.

Energy equipment

is used for high-temperature steam valves (300-400 MPa), heat resistance (>500°C $\pm$ 20°C), in accordance with ASME B16.34 standards.

Medical equipment

is used for high-pressure liquid delivery (50-100 MPa), corrosion resistance (>4000 hours $\pm$ 100 hours), in accordance with ISO 13485 standards.

The shipbuilding industry

is used for seawater cooling systems (50-150 MPa), impact resistance (>50 J $\pm$ 5 J), in accordance with ISO 8062 standards.

Electronic manufacturing

is used for semiconductor process gas control (100-200 MPa), surface roughness $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, in accordance with SEMI F19 standards.

Railway transportation

is used for high-pressure braking systems (150-250 MPa), leakage reduction (<0.001 ml/min $\pm$ 0.0005 ml/min), in accordance with EN 13452 standards.

Building pipelines

are used for high-pressure water pipe sealing (50-100 MPa), wear resistance > 95% $\pm$ 2%, in accordance with ASTM F1476 standards.

Domestic and international standards for cemented carbide fluid control seals

Domestic and international standards include all the following relevant standards and their numbers:

API 6A (Standard for Oil and Gas Equipment)

ISO 10423 (Standard for Valves and Wellhead Equipment)

AMS 2750 (Aerospace Heat Treatment Standard)

DNVGL-RP-C203 (Design rules for offshore structures)

ASME B16.34 (Valve Pressure and Temperature Rating Standard)

ISO 13485 (Quality Management System for Medical Devices)

ISO 8062 (casting tolerance standard)

SEMI F19 (Semiconductor Manufacturing Standard)

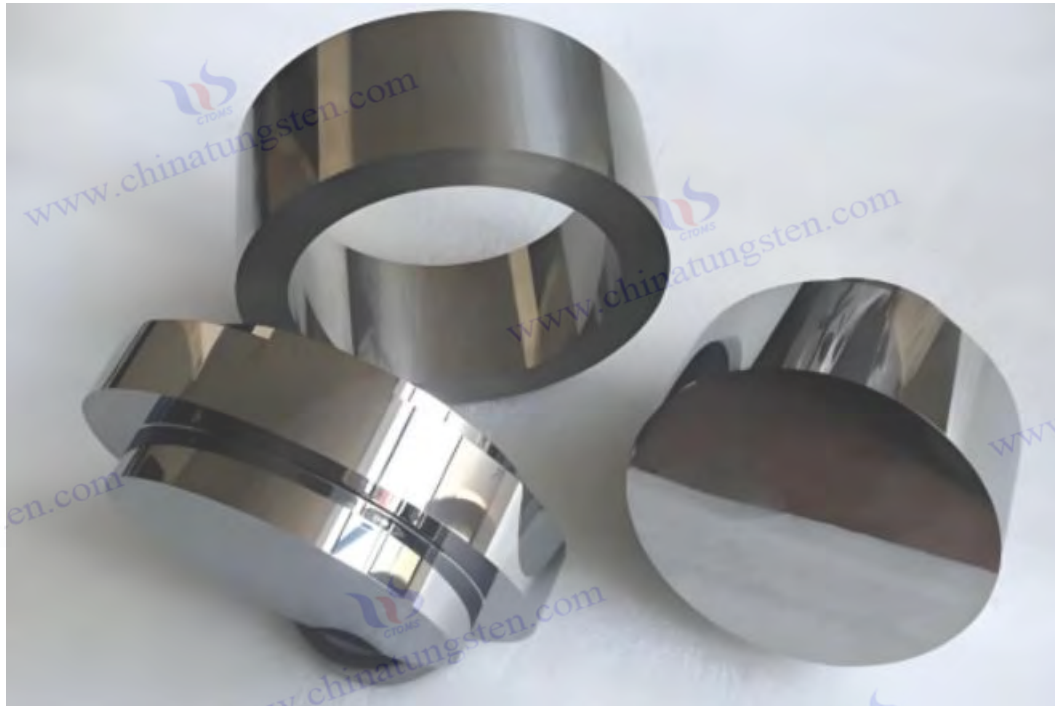
EN 13452 (Railway Braking Systems Standard)

ASTM F1476 (Standard for Piping Systems)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)

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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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Carbide Wire Drawing Dies

Carbide wire drawing dies are high-performance dies designed for drawing metal wires, bars and tubes, and are widely used in wire and cable, automotive parts and precision manufacturing. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision molding and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and long life under high drawing force, high speed and complex working conditions. As the core hero in the drawing process, carbide wire drawing dies directly affect wire precision, surface quality and production efficiency with their excellent precision and durability. The technological innovation in 2025 makes it particularly eye-catching in the processing of high-strength materials.

Physical and chemical properties of cemented carbide wire drawing

dies Cemented carbide wire drawing dies use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-10\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and high temperature resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400\text{-}1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150\text{-}200\text{ MPa} \pm 5\text{ MPa}$, holding time $30\text{-}60\text{ min} \pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350\text{-}1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45\text{-}55\text{ MPa} \pm 1\text{ MPa}$, holding time $5\text{-}10\text{ min} \pm 1\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5\text{-}2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8\text{-}1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the wire drawing die is customized according to the wire diameter, including a tapered die hole and a compression zone, with an inner hole diameter of $0.1\text{-}20\text{ mm} \pm 0.01\text{ mm}$ and a die length of $20\text{-}50\text{ mm} \pm 1\text{ mm}$, mounted on a steel die sleeve (tensile strength $>1200\text{ MPa} \pm 50\text{ MPa}$, hardness HRC $45\text{-}55 \pm 2$). The fixing methods include mechanical press fit (press fit force $>12\text{ kN} \pm 1\text{ kN}$) or bonding (bonding strength $>600\text{ MPa} \pm 50\text{ MPa}$), ensuring stable operation under high drawing forces ($50\text{-}300\text{ N} \pm 10\text{ N}$, peak value up to $400\text{ N} \pm 20\text{ N}$). Multi-layer coatings (such as TiN, TiAlN or DLC, thickness $0.5\text{-}2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the die hole surface, reducing the friction coefficient to $<0.1 \pm 0.05$, improving wear resistance and smoothness (surface roughness $R_a < 0.05\text{ }\mu\text{m} \pm 0.02\text{ }\mu\text{m}$). The design integrates drawing mechanics and heat conduction optimization, with a cone angle of $10^\circ\text{-}20^\circ \pm 2^\circ$ and a compression ratio of $1.2\text{-}2.0 \pm 0.1$, suitable for a variety of materials with a tensile strength of $300\text{-}1500\text{ MPa}$.

Material properties of cemented carbide wire drawing

dies WC provides high hardness (HV $1800\text{-}2200 \pm 30$, locally up to $2400\text{-}2600 \pm 50$), and its hexagonal crystal structure gives excellent wear and erosion resistance (oxidation starting temperature $>800^\circ\text{C} \pm 20^\circ\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness through solid

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solution strengthening and plastic deformation ($K_1 \approx 12-16 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value up to $18 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$), and absorbs impact energy ($>60 \text{ J} \pm 5 \text{ J}$, instantaneous peak value $>150 \text{ J} \pm 10 \text{ J}$). Fine grains and optimized microstructure, wear rate $<0.02 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$ (preferably $<0.01 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), density $14.8-15.2 \text{ g/cm}^3 \pm 0.1 \text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$, Cl^- resistance $>3000 \text{ hours} \pm 100 \text{ hours}$); TaC and NbC increase high temperature hardness ($>900^\circ\text{C} \pm 20^\circ\text{C}$ maintains $90\% \pm 2\%$ of the initial hardness, thermal stability $>95\% \pm 2\%$).

Working principle of carbide wire drawing

The wire drawing die draws the metal material through compression and plastic deformation of the die hole under the action of the drawing machine (drawing speed $5-50 \text{ m/s} \pm 2 \text{ m/s}$, drawing force $50-300 \text{ N} \pm 10 \text{ N}$, power $20-200 \text{ kW} \pm 50 \text{ kW}$). The die hole surface is subjected to high friction and thermal load (surface temperature $100-400^\circ\text{C} \pm 20^\circ\text{C}$), and the die sleeve provides structural support (tensile strength $>1200 \text{ MPa} \pm 50 \text{ MPa}$), heat conduction (thermal conductivity $40-50 \text{ W/m} \cdot \text{K} \pm 2 \text{ W/m} \cdot \text{K}$) and fatigue resistance (fatigue life $>10^6 \text{ times} \pm 10^5 \text{ times}$, cyclic load $>150 \text{ MPa} \pm 20 \text{ MPa}$). The precision design of the wire drawing die ensures that the tolerance is controlled at $\pm 0.005 \text{ mm} \pm 0.002 \text{ mm}$, the surface roughness $R_a < 0.05 \mu\text{m} \pm 0.02 \mu\text{m}$, and the wire diameter deviation is $<0.01 \text{ mm} \pm 0.005 \text{ mm}$.

Performance of cemented carbide wire drawing dies

Under the conditions of drawing copper wire (tensile strength 400 MPa), steel wire (1000 MPa) or aluminum wire (300 MPa), the optimized wire drawing die life exceeds $500-800 \text{ hours} \pm 50 \text{ hours}$, and the production efficiency reaches $100-500 \text{ m/min} \pm 10 \text{ m/min}$ (power $>100 \text{ kW} \pm 50 \text{ kW}$). SEM analysis shows no obvious wear of the die hole, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($>95\% \pm 2\%$), and thermal imaging shows that the thermal stress distribution is $<120 \text{ MPa} \pm 10 \text{ MPa}$.

Factors affecting the performance of cemented carbide wire drawing dies

Co content of

$6\%-10\% \pm 1\%$ achieves the best balance between hardness and toughness, $<6\% \pm 1\%$ leads to an increase in crack rate of $10\% \pm 2\%$, $>10\% \pm 1\%$ reduces the hardness by $5\% \pm 1\%$ and increases thermal expansion (CTE $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$), and $7\%-9\% \pm 0.5\%$ is preferred to balance performance and cost.

Grain size

$0.5-1 \mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $<0.01 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), $1-1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness materials, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by $15\% \pm 3\%$ and reduces toughness by $10\% \pm 2\%$.

Geometric angle

cone angle $10^\circ-20^\circ \pm 2^\circ$ optimizes drawing efficiency (drawing force $<200 \text{ N} \pm 10 \text{ N}$, energy consumption $<10 \text{ kWh/m}^3 \pm 1 \text{ kWh/m}^3$), $>20^\circ \pm 2^\circ$ reduces efficiency by $10\% \pm 2\%$, $<10^\circ \pm 2^\circ$ easily leads to wire breakage risk of $5\% \pm 1\%$.

Surface treatment

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die hole thickness $1-2\text{ mm}\pm 0.1\text{ mm}$ improves wear resistance (life extended by $20\%\pm 3\%$), $<1\text{ mm}\pm 0.1\text{ mm}$ shortens life by $20\%\pm 3\%$, $>2\text{ mm}\pm 0.1\text{ mm}$ increases the cost by $15\%\pm 2\%$. DLC coating (thickness $0.5-1\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, deposition temperature $200-300^{\circ}\text{C}\pm 20^{\circ}\text{C}$) reduces the friction coefficient ($<0.1\pm 0.05$) and improves smoothness ($R_a < 0.05\text{ }\mu\text{m}\pm 0.02\text{ }\mu\text{m}$).

Heat treatment:

Quenching of the die sleeve (hardness HRC $45-55\pm 2$, depth $1-3\text{ mm}\pm 0.2\text{ mm}$, quenching temperature $850-900^{\circ}\text{C}\pm 20^{\circ}\text{C}$) enhances the supporting performance, and the life of the unquenched die sleeve is reduced by $15\%\pm 3\%$. Tempering ($200-250^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $2-4\text{ hours}\pm 0.5\text{ hours}$) reduces the residual stress by $5\%\pm 1\%$.

Working environment

temperature $>400^{\circ}\text{C}\pm 20^{\circ}\text{C}$ reduces the hardness by $3\%\pm 1\%$, water content $>5\%\pm 1\%$ or impurity content $>3\%\pm 0.5\%$ increases wear by $5\%\pm 1\%$, and the corrosion rate in the Cl^- environment (concentration $>0.5\%\pm 0.1\%$) increases to $0.015\text{ mm/year}\pm 0.002\text{ mm/year}$.

Equipment parameters:

drawing speed $5-50\text{ m/s}\pm 2\text{ m/s}$, drawing force $50-300\text{ N}\pm 10\text{ N}$, power $20-200\text{ kW}\pm 50\text{ kW}$ affect the life and efficiency of the wire drawing die. Excessive parameters ($>$ upper limit $10\%\pm 1\%$) shorten the life by $15\%\pm 2\%$.

Types of carbide wire drawing dies

Fine wire drawing dies

are suitable for copper or aluminum wire ($300-500\text{ MPa}$), with an inner hole diameter of $0.1-1\text{ mm}\pm 0.01\text{ mm}$ and a lifespan of $> 600\text{ hours}\pm 50\text{ hours}$.

Medium and thick wire drawing dies

are suitable for steel wire ($800-1200\text{ MPa}$), with an inner hole diameter of $2-10\text{ mm}\pm 0.01\text{ mm}$ and strong pull-out resistance ($> 200\text{ N}\pm 10\text{ N}$).

Tube drawing dies

are used for stainless steel tubes ($1000-1500\text{ MPa}$), with an inner hole diameter of $5-20\text{ mm}\pm 0.01\text{ mm}$ and excellent high pressure resistance ($> 300\text{ N}\pm 10\text{ N}$).

Special wire drawing dies

include high temperature ($> 400^{\circ}\text{C}\pm 20^{\circ}\text{C}$) and corrosion-resistant types for extreme environments.

Application of carbide wire drawing dies

Wires and cables

are used for copper wire drawing ($400-500\text{ MPa}$), with a service life of $600-800\text{ hours}\pm 50\text{ hours}$, in line with IEC 60228 standards.

Automotive parts

are used for steel wire drawing ($800-1200\text{ MPa}$), with a pull-out force ($>200\text{ N}\pm 10\text{ N}$) to ensure efficient production, in line with ISO 8458 standards.

Precision manufacturing

is used for stainless steel pipe drawing ($1000-1500\text{ MPa}$), with a surface roughness $R_a < 0.05\text{ }\mu\text{m}\pm 0.02\text{ }\mu\text{m}$, meeting ISO 286 standards.

Energy equipment

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is used for high-voltage wire drawing (600-1000 MPa), with heat resistance ($>400^{\circ}\text{C} \pm 20^{\circ}\text{C}$), in line with API 6A standards.

Corrosive environment

is suitable for drawing steel wires containing salt, resistant to seawater corrosion (>3000 hours ± 100 hours, resistance to Cl^- concentration $> 3.5\% \pm 0.5\%$), in accordance with DNVGL-RP-C203 standard.

Medical equipment

is used for drawing titanium alloy wires (800-1200 MPa), corrosion resistance (>4000 hours ± 100 hours), in accordance with ISO 13485 standard.

Shipbuilding industry

is used for drawing steel cables (700-1000 MPa), impact resistance ($>60 \text{ J} \pm 5 \text{ J}$), in accordance with ISO 8062 standard.

Electronic manufacturing

is used for drawing fine copper wires (300-500 MPa), accuracy $\pm 0.005 \text{ mm} \pm 0.002 \text{ mm}$, in accordance with SEMI F19 standard.

Railway transportation

is used for drawing rail wires (800-1200 MPa), reducing waste ($<1\% \pm 0.5\%$), in accordance with EN 13674 standard.

Construction hardware

is used for steel bar drawing (600-900 MPa), with surface finish $\text{Ra} < 0.05 \mu\text{m} \pm 0.02 \mu\text{m}$, in accordance with ASTM A615 standard.

Technological progress and future development of cemented carbide wire drawing dies

New materials

introduce nano WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness (HV 2200-2600 ± 50), and add TaC and NbC to enhance high temperature stability ($>400^{\circ}\text{C} \pm 20^{\circ}\text{C}$ to maintain 95% $\pm 2\%$).

Intelligent monitoring

integrated sensors (accuracy $\pm 0.05\%$) monitor die hole wear (depth $>0.5 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($<400^{\circ}\text{C} \pm 20^{\circ}\text{C}$) in real time, and optimize replacement cycles (error $<5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex wire drawing dies, reducing material waste by 10% $\pm 2\%$.

Environmental adaptability

Development of corrosion-resistant and high-temperature wire drawing dies (pressure resistance $>400 \text{ N} \pm 20 \text{ N}$, temperature resistance $>500^{\circ}\text{C} \pm 20^{\circ}\text{C}$).

Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 reduction 20% $\pm 3\%$) in compliance with ISO 14040 standards.

Relevant domestic and foreign standards

Domestic and foreign standards include all the following relevant standards and their numbers:

IEC 60228 (Wire and Cable Standard)

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ISO 8458 (Automotive Steel Wire Standard)
ISO 286 (Geometrical product specifications and tolerances)
API 6A (Standard for Oil and Gas Equipment)
DNVGL-RP-C203 (Design rules for offshore structures)
ISO 13485 (Quality Management System for Medical Devices)
ISO 8062 (casting tolerance standard)
SEMI F19 (Semiconductor Manufacturing Standard)
EN 13674 (railway rail standard)
ASTM A615 (steel standard)
GB/T 5760 (General technical requirements for cemented carbide)
JB/T 7947 (Metal Cutting Tool Material Standard)



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Carbide wear-resistant nozzle

The carbide wear-resistant nozzle is a high-performance injection component designed for high-wear, high-speed injection and corrosive environments. It is widely used in sandblasting, spraying, oil drilling and chemical spraying. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and wear-resistant coatings, to provide excellent hardness, wear resistance, corrosion resistance and high temperature resistance, ensuring that injection efficiency and long-term reliability are maintained under extreme working conditions. As the fearless guardian of the injection system, the carbide wear-resistant nozzle has a direct impact on injection accuracy, material consumption and equipment life with its tough characteristics. The technological breakthrough in 2025 makes it perform particularly well in high-wear environments.

Physical and chemical properties of cemented carbide wear-resistant nozzles

Cemented carbide nozzles use tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase, cobalt (Co, $6\%-10\%\pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\%\pm 0.1\%$, VC $<1\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$, NbC $0.5\%-1.5\%\pm 0.1\%$) to optimize grain size, wear resistance and corrosion resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C}\pm 10^\circ\text{C}$, pressure $150-200\text{ MPa}\pm 5\text{ MPa}$, holding time $30-60\text{ min}\pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C}\pm 10^\circ\text{C}$, pressure $45-55\text{ MPa}\pm 1\text{ MPa}$, holding time $5-10\text{ min}\pm 1\text{ min}$), ensuring that the material reaches $99.9\%\pm 0.1\%$ of the theoretical density and the porosity is $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$). The microstructure uniformity reaches $95\%\pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\%\pm 1\%$.

The geometric design of the nozzle is customized according to the injection requirements, including conical or straight nozzles with an inner diameter of $0.5-10\text{ mm}\pm 0.01\text{ mm}$, an outer diameter of $10-30\text{ mm}\pm 0.5\text{ mm}$, and a length of $20-50\text{ mm}\pm 1\text{ mm}$, mounted on a stainless steel or titanium alloy substrate (tensile strength $>1000\text{ MPa}\pm 50\text{ MPa}$, hardness HRC $40-50\pm 2$). The fixing methods include mechanical threaded connection (torque $>15\text{ N}\cdot\text{m}\pm 1\text{ N}\cdot\text{m}$) or welding (welding strength $>700\text{ MPa}\pm 50\text{ MPa}$) to ensure stable operation under high-pressure injection ($10-50\text{ MPa}\pm 2\text{ MPa}$, peak value up to $60\text{ MPa}\pm 3\text{ MPa}$). Multi-layer coatings (such as TiN, CrN or WC/C, thickness $0.5-2\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$) can be applied to the nozzle surface, reducing the friction coefficient to $<0.15\pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<1\%\pm 0.5\%$). The design integrates fluid mechanics and heat transfer optimization, with a spray angle of $15^\circ-30^\circ\pm 2^\circ$, suitable for operating temperatures from -20°C to $600^\circ\text{C}\pm 20^\circ\text{C}$.

Characteristics of carbide wear-resistant nozzles

WC provides high hardness (HV $1800-2200\pm 30$, locally up to $2400-2600\pm 50$), and its hexagonal

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crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^{\circ}\text{C}\pm 20^{\circ}\text{C}$, oxidation resistance $>95\%\pm 2\%$); Co enhances toughness (K_{IC} 12-16 $\text{MPa}\cdot\text{m}^{1/2}\pm 0.5$, peak value up to 18 $\text{MPa}\cdot\text{m}^{1/2}\pm 0.5$) through solid solution strengthening and plastic deformation, and absorbs impact energy ($> 50\text{ J}\pm 5\text{ J}$, instantaneous peak value $>120\text{ J}\pm 10\text{ J}$). Fine grains and optimized microstructure, wear rate $<0.03\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$ (preferably $<0.015\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$), density $14.8\text{-}15.2\text{ g/cm}^3\pm 0.1\text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6\times 10^{-6}/^{\circ}\text{C}\pm 0.5\times 10^{-6}/^{\circ}\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01\text{ mm/year}\pm 0.001\text{ mm/year}$, Cl^- resistance $>5000\text{ hours}\pm 200\text{ hours}$); TaC and NbC increase high temperature hardness ($>900^{\circ}\text{C}\pm 20^{\circ}\text{C}$ maintains $90\%\pm 2\%$ of the initial hardness, thermal stability $>95\%\pm 2\%$).

Working principle of cemented carbide wear-resistant nozzles

The nozzle accelerates the fluid or particles through the nozzle to achieve injection under the action of a high-pressure pump or compressor (pressure $10\text{-}50\text{ MPa}\pm 2\text{ MPa}$, injection speed $50\text{-}200\text{ m/s}\pm 10\text{ m/s}$, power $20\text{-}150\text{ kW}\pm 50\text{ kW}$). The nozzle surface is subject to high wear and thermal load (surface temperature $100\text{-}600^{\circ}\text{C}\pm 20^{\circ}\text{C}$, extreme up to $700^{\circ}\text{C}\pm 30^{\circ}\text{C}$), and the matrix material provides structural support (tensile strength $>1000\text{ MPa}\pm 50\text{ MPa}$), heat conduction (thermal conductivity $30\text{-}40\text{ W/m}\cdot\text{K}\pm 2\text{ W/m}\cdot\text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load $>150\text{ MPa}\pm 20\text{ MPa}$). The precision design of the nozzle ensures that the tolerance is controlled at $\pm 0.005\text{ mm}\pm 0.002\text{ mm}$, the surface roughness $R_a<0.1\text{ }\mu\text{m}\pm 0.05\text{ }\mu\text{m}$, and the injection deviation is $<0.5^{\circ}\pm 0.2^{\circ}$.

The performance of cemented carbide wear-resistant nozzles is more than 400-700 hours ± 50 hours

under sandblasting slurry (hardness $\text{HV } 800\pm 50$), oil drilling fluid (containing $\text{Cl}^->3\%\pm 0.5\%$) or high-temperature steam ($500^{\circ}\text{C}\pm 20^{\circ}\text{C}$) conditions. The optimized nozzle life exceeds 400-700 hours ± 50 hours, and the injection efficiency reaches $95\%\pm 2\%$ (injection amount deviation $<1\%\pm 0.5\%$). SEM analysis shows no obvious wear of the nozzle, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($>95\%\pm 2\%$), and thermal imaging shows that the thermal stress distribution is $<150\text{ MPa}\pm 10\text{ MPa}$.

Factors affecting the performance of cemented carbide wear-resistant nozzles

Co content of

$6\%\text{-}10\%\pm 1\%$ achieves the best balance between hardness and toughness. $<6\%\pm 1\%$ leads to an increase in crack rate of $10\%\pm 2\%$. $>10\%\pm 1\%$ reduces the hardness by $5\%\pm 1\%$ and increases thermal expansion (CTE $6\times 10^{-6}/^{\circ}\text{C}\pm 0.5\times 10^{-6}/^{\circ}\text{C}$). $7\%\text{-}9\%\pm 0.5\%$ is preferred to take into account both performance and cost.

Grain size

$0.5\text{-}1\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ effectively reduces wear and microcracks (wear rate $<0.015\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$), $1\text{-}1.5\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ is suitable for medium wear environment, $>2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ increases wear rate by $15\%\pm 3\%$ and reduces toughness by $10\%\pm 2\%$.

Geometric angle

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The spray angle 15° - $30^{\circ}\pm 2^{\circ}$ optimizes the spray efficiency (pressure $<40\text{ MPa}\pm 2\text{ MPa}$, energy consumption $<15\text{ kWh/m}^3 \pm 1\text{ kWh/m}^3$), $>30^{\circ}\pm 2^{\circ}$ reduces efficiency by $10\%\pm 2\%$, $<15^{\circ}\pm 2^{\circ}$ easily leads to the risk of uneven spraying by $5\%\pm 1\%$.

Surface treatment

nozzle thickness $1\text{-}2\text{ mm}\pm 0.1\text{ mm}$ improves wear resistance (life extension by $20\%\pm 3\%$), $<1\text{ mm}\pm 0.1\text{ mm}$ shortens life by $20\%\pm 3\%$, $>2\text{ mm}\pm 0.1\text{ mm}$ increases the cost by $15\%\pm 2\%$. WC/C coating (thickness $0.5\text{-}1\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, deposition temperature $300\text{-}400^{\circ}\text{C}\pm 20^{\circ}\text{C}$) reduces the friction coefficient ($<0.15\pm 0.05$) and improves corrosion resistance (Cl^{-} resistance $>6000\text{ hours}\pm 200\text{ hours}$).

Heat treatment:

Quenching of the base material (hardness HRC $40\text{-}50\pm 2$, depth $1\text{-}3\text{ mm}\pm 0.2\text{ mm}$, quenching temperature $800\text{-}850^{\circ}\text{C}\pm 20^{\circ}\text{C}$) enhances the supporting performance, the life of the unquenched base is reduced by $15\%\pm 3\%$, and tempering ($200\text{-}250^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $2\text{-}4\text{ hours}\pm 0.5\text{ hours}$) reduces the residual stress by $5\%\pm 1\%$.

Working environment

temperature $>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$ reduces the hardness by $3\%\pm 1\%$, water content $>5\%\pm 1\%$ or impurity content $>3\%\pm 0.5\%$ increases wear by $5\%\pm 1\%$, and the corrosion rate in the Cl^{-} environment (concentration $>0.5\%\pm 0.1\%$) increases to $0.015\text{ mm/year}\pm 0.002\text{ mm/year}$.

Equipment parameters

pressure $10\text{-}50\text{ MPa}\pm 2\text{ MPa}$, injection speed $50\text{-}200\text{ m/s}\pm 10\text{ m/s}$, power $20\text{-}150\text{ kW}\pm 50\text{ kW}$ affect the nozzle life and efficiency. Excessive parameters ($>$ upper limit $10\%\pm 1\%$) shorten the life by $15\%\pm 2\%$.

Types of carbide wear-resistant nozzles

Sandblasting nozzles

are suitable for mortar spraying (hardness HV 800 ± 50), inner diameter $1\text{-}5\text{ mm}\pm 0.01\text{ mm}$, life $>500\text{ hours}\pm 50\text{ hours}$.

Oil drilling nozzles

are used for drilling fluid injection (pressure $20\text{-}40\text{ MPa}$), inner diameter $2\text{-}8\text{ mm}\pm 0.01\text{ mm}$, strong corrosion resistance (Cl^{-} resistance $>5000\text{ hours}\pm 200\text{ hours}$).

Spraying nozzles

are suitable for high temperature spraying ($500^{\circ}\text{C}\pm 20^{\circ}\text{C}$), inner diameter $0.5\text{-}3\text{ mm}\pm 0.01\text{ mm}$, excellent heat resistance ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$).

Special nozzles

include ultra-high temperature ($>700^{\circ}\text{C}\pm 20^{\circ}\text{C}$) and ultra-corrosive types for extreme environments.

Application of carbide wear-resistant nozzles

Sandblasting

is used for steel surface sandblasting (hardness HV 800 ± 50), life $500\text{-}700\text{ hours}\pm 50\text{ hours}$, in line with ISO 8501 standard.

Oil drilling

is used for drilling fluid injection ($20\text{-}40\text{ MPa}$), resistant to Cl^{-} corrosion ($>5000\text{ hours}\pm 200\text{ hours}$), in line with API 7-1 standard.

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Spraying industry

is used for high-temperature ceramic coating ($500^{\circ}\text{C}\pm 20^{\circ}\text{C}$), heat resistance ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$) to ensure uniform spraying, in line with ISO 14918 standard.

Chemical spray

is suitable for corrosive chemical liquid spray (10-30 MPa), seawater corrosion resistance (>6000 hours ± 200 hours), in line with ISO 10423 standard.

Energy equipment

is used for high-temperature steam injection (30-50 MPa), heat resistance ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$), in line with ASME B16.34 standard.

Medical devices

are used for pharmaceutical spray (10-20 MPa), corrosion resistance (>4000 hours ± 100 hours), in accordance with ISO 13485 standards.

The shipbuilding industry

is used for seawater cleaning spray (15-25 MPa), impact resistance ($>50\text{ J} \pm 5\text{ J}$), in accordance with ISO 8062 standards.

Electronic manufacturing

is used for semiconductor cleaning spray (20-30 MPa), surface roughness $R_a < 0.1\text{ }\mu\text{m} \pm 0.05\text{ }\mu\text{m}$, in accordance with SEMI F19 standards.

Railway maintenance

is used for rail sandblasting (15-30 MPa), reducing wear ($<1\% \pm 0.5\%$), in accordance with EN 13674 standards.

Construction spraying

is used for concrete spraying (10-20 MPa), wear resistance $> 95\% \pm 2\%$, in accordance with ASTM C143 standards.

Technological progress and future development of cemented carbide wear-resistant nozzles

New materials

introduce nano WC (grain $<0.5\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$) to improve hardness ($\text{HV } 2200\text{-}2600 \pm 50$), and add TaC and NbC to enhance high temperature stability ($>700^{\circ}\text{C}\pm 20^{\circ}\text{C}$ to maintain $95\% \pm 2\%$).

Intelligent monitoring

integrated sensors (accuracy $\pm 0.05\%$) monitor nozzle wear (depth $>0.5\text{ mm} \pm 0.05\text{ mm}$) and temperature ($<700^{\circ}\text{C}\pm 20^{\circ}\text{C}$) in real time, and optimize replacement cycles (error $<5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40\text{-}60\text{ }\mu\text{m} \pm 5\text{ }\mu\text{m}$) to manufacture complex nozzles, reducing material waste by $10\% \pm 2\%$.

Environmental adaptability

develops ultra-corrosive and ultra-high temperature nozzles (pressure resistance $>60\text{ MPa} \pm 3\text{ MPa}$, temperature resistance $>700^{\circ}\text{C}\pm 20^{\circ}\text{C}$).

Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 reduction $20\% \pm 3\%$) in compliance with ISO 14040 standards.

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Domestic and international standards for cemented carbide wear-resistant nozzles

Domestic and international standards include all the following relevant standards and their numbers:

ISO 8501 (surface treatment standard)

API 7-1 (Petroleum Drilling Equipment Standard)

ISO 14918 (thermal spraying standard)

ISO 10423 (Standard for Valves and Wellhead Equipment)

ASME B16.34 (Valve Pressure and Temperature Rating Standard)

ISO 13485 (Quality Management System for Medical Devices)

ISO 8062 (casting tolerance standard)

SEMI F19 (Semiconductor Manufacturing Standard)

EN 13674 (railway rail standard)

ASTM C143 (Concrete Testing Standard)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)



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What is a carbide wear-resistant valve core ?

The carbide wear-resistant valve core is a high-performance valve component designed for high-pressure, high-wear and corrosive environments. It is widely used in the fields of oil and gas, chemical industry, energy equipment and water treatment. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and corrosion-resistant coatings, to provide excellent hardness, wear resistance, corrosion resistance and high temperature resistance, ensuring valve sealing and long-term reliability under extreme working conditions. As a tough guard in the valve system, the carbide wear-resistant valve core has a direct impact on fluid control accuracy, leakage rate and equipment life with its fearless performance. Technological innovation makes it perform better in complex environments.

Physical and chemical properties of cemented carbide wear-resistant valve core

Cemented carbide valve core uses tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-10\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\%-3\% \pm 0.2\%$, NbC $0.5\%-1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and corrosion resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the valve core is customized according to the valve type, including spherical, conical or cylindrical structures, with a diameter of $5-50\text{ mm} \pm 0.5\text{ mm}$ and a length of $10-60\text{ mm} \pm 1\text{ mm}$, installed on a stainless steel or titanium alloy valve body (tensile strength $>1200\text{ MPa} \pm 50\text{ MPa}$, hardness HRC $40-50 \pm 2$). The fixing methods include mechanical press fit (press fit force $>10\text{ kN} \pm 1\text{ kN}$) or high-frequency welding (welding strength $>700\text{ MPa} \pm 50\text{ MPa}$), ensuring stable operation under high pressure ($50-300\text{ MPa} \pm 10\text{ MPa}$, peak value up to $400\text{ MPa} \pm 20\text{ MPa}$). Multi-layer coatings (such as TiN, CrN or WC/C, thickness $0.5-2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the surface of the valve core, reducing the friction coefficient to $<0.15 \pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<1\% \pm 0.5\%$). The design combines fluid mechanics and heat conduction optimization, with a contact angle of $5^\circ-15^\circ \pm 2^\circ$ and is suitable for operating temperatures from -50°C to $500^\circ\text{C} \pm 20^\circ\text{C}$.

Characteristics of hard alloy wear-resistant valve core

WC provides high hardness (HV $1800-2200 \pm 30$, locally up to $2400-2600 \pm 50$), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^\circ\text{C} \pm 20^\circ\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness (K_{IC} $12-16$

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MPa·m^{1/2} ± 0.5, peak value up to 18 MPa·m^{1/2} ± 0.5) through solid solution strengthening and plastic deformation, and absorbs impact energy (> 50 J ± 5 J, instantaneous peak value >120 J ± 10 J). Fine grains and optimized microstructure, wear rate <0.03 mm³ / N · m ± 0.01 mm³ / N · m (preferably <0.015 mm³ / N · m ± 0.01 mm³ / N · m), density 14.8-15.2 g/cm³ ± 0.1 g/cm³, coefficient of thermal expansion (CTE) 6×10⁻⁶ /°C ± 0.5×10⁻⁶ /°C. Adding Cr₃C₂ generates a Cr₂O₃ protective layer (thickness <0.1 μm ± 0.01 μm), which improves corrosion resistance (corrosion rate <0.01 mm/year ± 0.001 mm/year, Cl⁻ resistance >5000 hours ± 200 hours); TaC and NbC increase high temperature hardness (>900°C ± 20°C maintains 90% ± 2% of the initial hardness, thermal stability >95% ± 2%).

Working principle of carbide wear-resistant valve core

The valve core adjusts the flow of fluid by rotating or moving under the action of the valve (pressure 50-300 MPa ± 10 MPa, flow rate 1-10 m/s ± 1 m/s, power 50-300 kW ± 50 kW). The valve core surface is subjected to high friction and thermal load (surface temperature -50°C to 500°C ± 20°C, extreme up to 600°C ± 30°C), and the valve body provides structural support (tensile strength >1200 MPa ± 50 MPa), heat conduction (thermal conductivity 30-40 W/m·K ± 2 W/m·K) and fatigue resistance (fatigue life >10⁶ times ± 10⁵ times, cyclic load >150 MPa ± 20 MPa). The precision design of the valve core ensures that the tolerance is controlled at ±0.005 mm ± 0.002 mm, the surface roughness Ra <0.1 μm ± 0.05 μm, and the leakage rate is <0.001 ml/min ± 0.0005 ml/min.

The performance of the carbide wear-resistant valve core is that the optimized valve core life exceeds 500-800 hours ± 50 hours when

processing high-pressure natural gas (200 MPa), seawater (containing Cl⁻ > 3% ± 0.5%) or high-temperature steam (400°C ± 20°C), and the sealing efficiency reaches 99.99% ± 0.01% (leakage rate < 0.001 ml/min ± 0.0005 ml/min). SEM analysis shows no obvious wear on the surface, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase (> 95% ± 2%), and thermal imaging shows that the thermal stress distribution is < 100 MPa ± 10 MPa.

Factors affecting the performance of cemented carbide wear-resistant valve cores

Co content of

6%-10% ± 1% achieves the best balance between hardness and toughness, <6% ± 1% leads to an increase in crack rate of 10% ± 2%, >10% ± 1% reduces the hardness by 5% ± 1% and increases thermal expansion (CTE 6×10⁻⁶ /°C ± 0.5×10⁻⁶ /°C), and 7%-9% ± 0.5% is preferred to take into account both performance and cost.

Grain size of

0.5-1 μm ± 0.01 μm effectively reduces wear and microcracks (wear rate <0.015 mm³ / N · m ± 0.01 mm³ / N · m), 1-1.5 μm ± 0.01 μm is suitable for medium pressure environment, >2 μm ± 0.01 μm increases wear rate by 15% ± 3% and reduces toughness by 10% ± 2%.

Geometric

contact angle of 5°-15° ± 2° optimizes sealing performance (leakage rate <0.001 ml/min ± 0.0005 ml/min), >15° ± 2° reduces sealing efficiency by 5% ± 1%, <5° ± 2° easily leads to uneven contact risk of 5% ± 1%.

Surface treatment

valve core thickness of 2-3 mm ± 0.1 mm improves wear resistance (life extended by 20% ± 3%), <2

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mm±0.1 mm shortens life by 20%±3%, >3 mm±0.1 mm increases cost by 15%±2%. CrN coating (thickness 0.5-1 μm ± 0.1 μm, deposition temperature 400-450°C ± 20°C) reduces the friction coefficient (<0.2 ± 0.05) and improves corrosion resistance (Cl⁻ resistance > 6000 hours ± 200 hours).

Heat treatment:

quenching of the valve body (hardness HRC 40-50±2, depth 1-3 mm±0.2 mm, quenching temperature 800-850°C±20°C) enhances the supporting performance, and the life of the unquenched valve body is reduced by 15%±3%. Tempering (200-250°C±10°C, 2-4 hours±0.5 hours) reduces the residual stress by 5%±1%.

The working environment

temperature >500°C±20°C reduces the hardness by 3%±1%, the water content >5%±1% or the impurity content >3%±0.5% increases the wear by 5%±1%, and the corrosion rate in the Cl⁻ environment (concentration >0.5%±0.1%) increases to 0.015 mm/year±0.002 mm/year.

Equipment parameters

pressure 50-300 MPa±10 MPa, flow rate 1-10 m/s±1 m/s, power 50-300 kW±50 kW affect valve core life and efficiency. Excessive parameters (>upper limit 10%±1%) shorten life by 15%±2%.

Types of carbide wear-resistant valve cores

Spherical valve cores

are suitable for high-pressure ball valves (100-200 MPa), with a diameter of 10-30 mm ± 0.5 mm and excellent pressure resistance (> 300 MPa ± 10 MPa).

Conical valve cores

are suitable for chemical control valves (50-150 MPa), with a diameter of 5-20 mm ± 0.5 mm and strong corrosion resistance (Cl⁻ resistance > 5000 hours ± 200 hours).

Column valve cores

are used for aviation hydraulic valves (200-300 MPa), with a diameter of 15-40 mm ± 0.5 mm and high temperature resistance (> 500°C ± 20°C).

Special valve cores

include ultra-high temperature (> 600°C ± 20°C) and ultra-corrosive types, suitable for extreme environments.

Application of carbide wear-resistant valve cores

Petroleum and natural gas

is used for high-pressure natural gas valves (200-300 MPa), with a service life of 600-800 hours ± 50 hours, in accordance with API 6A standards.

Chemical industry

is used for corrosive fluid valves (50-150 MPa), resistant to Cl⁻ corrosion (>5000 hours ± 200 hours), in accordance with ISO 10423 standards.

Aerospace

is used for hydraulic system valves (200-300 MPa), high temperature resistance (>500°C ± 20°C) to ensure reliability, in accordance with AMS 2750 standards.

Water treatment

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is suitable for seawater pipeline valves (50-100 MPa), seawater corrosion resistance (>6000 hours ± 200 hours), in accordance with DNVGL-RP-C203 standards.

Energy equipment is

used for high-temperature steam valves (300-400 MPa), heat resistance ($>500^{\circ}\text{C} \pm 20^{\circ}\text{C}$), in accordance with ASME B16.34 standards.

Medical equipment

is used for high-pressure liquid valves (50-100 MPa), corrosion resistance (>4000 hours ± 100 hours), in accordance with ISO 13485 standards.

Marine industry

is used for seawater cooling valves (50-150 MPa), impact resistance ($>50 \text{ J} \pm 5 \text{ J}$), in accordance with ISO 8062 standards.

Electronic manufacturing

is used for semiconductor process gas valves (100-200 MPa), surface roughness $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, in accordance with SEMI F19 standards.

Railway transportation

is used for high-pressure brake valves (150-250 MPa), leakage reduction ($<0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$), in accordance with EN 13452 standards.

Building pipelines

are used for high-pressure water valves (50-100 MPa), wear resistance $>95\% \pm 2\%$, in accordance with ASTM F1476 standards.

Technological progress and future development

New materials

introduce nano WC (grain $<0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness (HV 2200-2600 ± 50), add TaC and NbC to enhance high temperature stability ($>600^{\circ}\text{C} \pm 20^{\circ}\text{C}$ to maintain 95% $\pm 2\%$).

Intelligent monitoring

integrated sensor (accuracy $\pm 0.05\%$) real-time monitoring of valve core wear (depth $>0.8 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($<600^{\circ}\text{C} \pm 20^{\circ}\text{C}$), optimize replacement cycle (error $<5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex valve cores, reducing material waste by 10% $\pm 2\%$.

Sustainable

recycling of WC powder (recycling rate $>80\% \pm 5\%$) reduces carbon footprint (CO_2 emissions reduction of 20% $\pm 3\%$), in line with ISO 14040 standards.

Domestic and international standards for hard alloy wear-resistant valve cores

Domestic and international standards include all the following relevant standards and their numbers:

API 6A (Standard for Oil and Gas Equipment)

ISO 10423 (Standard for Valves and Wellhead Equipment)

AMS 2750 (Aerospace Heat Treatment Standard)

DNVGL-RP-C203 (Design rules for offshore structures)

ASME B16.34 (Valve Pressure and Temperature Rating Standard)

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ISO 13485 (Quality Management System for Medical Devices)

ISO 8062 (casting tolerance standard)

SEMI F19 (Semiconductor Manufacturing Standard)

EN 13452 (Railway Braking Systems Standard)

ASTM F1476 (Standard for Piping Systems)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)



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What is a carbide wear-resistant valve seat ?

The carbide wear-resistant valve seat is a high-performance valve component designed for high-pressure, high-wear and corrosive environments. It is widely used in the fields of oil and gas, chemical industry, energy equipment and water treatment. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and corrosion-resistant coatings, to provide excellent hardness, wear resistance, corrosion resistance and high temperature resistance, ensuring valve sealing and long-term reliability under extreme working conditions. As a key component in the valve system, the carbide wear-resistant valve seat directly affects the fluid control accuracy, leakage rate and equipment life. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of the valve seat.

Physical and chemical properties of cemented carbide wear-resistant valve seats

Cemented carbide valve seats use tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase, cobalt (Co, $6\%-10\%\pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\%\pm 0.1\%$, VC $<1\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$, NbC $0.5\%-1.5\%\pm 0.1\%$) to optimize grain size, wear resistance and corrosion resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400\text{-}1500^\circ\text{C}\pm 10^\circ\text{C}$, pressure $150\text{-}200\text{ MPa}\pm 5\text{ MPa}$, holding time $30\text{-}60\text{ min}\pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350\text{-}1450^\circ\text{C}\pm 10^\circ\text{C}$, pressure $45\text{-}55\text{ MPa}\pm 1\text{ MPa}$, holding time $5\text{-}10\text{ min}\pm 1\text{ min}$), ensuring that the material reaches $99.9\%\pm 0.1\%$ of the theoretical density and the porosity is $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5\text{-}2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ (preferably $0.8\text{-}1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\%\pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\%\pm 1\%$.

The geometric design of the valve seat is customized according to the valve type, including annular or conical structure, inner diameter $5\text{-}50\text{ mm}\pm 0.5\text{ mm}$, thickness $5\text{-}20\text{ mm}\pm 0.5\text{ mm}$, installed on stainless steel or titanium alloy valve body (tensile strength $>1200\text{ MPa}\pm 50\text{ MPa}$, hardness HRC $40\text{-}50\pm 2$). Fixing methods include mechanical press fit (press fit force $>10\text{ kN}\pm 1\text{ kN}$) or high-frequency welding (welding strength $>700\text{ MPa}\pm 50\text{ MPa}$), ensuring stable operation under high pressure ($50\text{-}300\text{ MPa}\pm 10\text{ MPa}$, peak value up to $400\text{ MPa}\pm 20\text{ MPa}$). Multi-layer coatings (such as TiN, CrN or WC/C, thickness $0.5\text{-}2\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$) can be applied to the surface of the valve seat, and the friction coefficient is reduced to $<0.15\pm 0.05$, improving wear resistance and anti-adhesion (adhesion rate $<1\%\pm 0.5\%$). The design integrates fluid mechanics and heat conduction optimization, with a contact angle of $5^\circ\text{-}15^\circ\pm 2^\circ$, suitable for working temperatures from -50°C to $500^\circ\text{C}\pm 20^\circ\text{C}$.

Characteristics and working principle of hard alloy wear-resistant valve seat

Material properties of cemented carbide wear-resistant valve seats

WC provides high hardness (HV $1800\text{-}2200\pm 30$, locally up to $2400\text{-}2600\pm 50$), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting

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temperature $>800^{\circ}\text{C} \pm 20^{\circ}\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness through solid solution strengthening and plastic deformation (K_{1c} 12-16 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value up to 18 $\text{MPa} \cdot \text{m}^{1/2} \pm 0.5$), and absorbs impact energy ($>50 \text{ J} \pm 5 \text{ J}$, instantaneous peak value $>120 \text{ J} \pm 10 \text{ J}$). Fine grains and optimized microstructure, wear rate $<0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$ (preferably $<0.015 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), density 14.8-15.2 $\text{g/cm}^3 \pm 0.1 \text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^{\circ}\text{C} \pm 0.5 \times 10^{-6} / ^{\circ}\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$, Cl^- resistance $>5000 \text{ hours} \pm 200 \text{ hours}$); TaC and NbC increase high temperature hardness ($>900^{\circ}\text{C} \pm 20^{\circ}\text{C}$ maintains $90\% \pm 2\%$ of the initial hardness, thermal stability $>95\% \pm 2\%$).

Working principle of carbide wear-resistant valve seat

The valve seat adjusts the flow of fluid by closely cooperating with the valve core under the action of the valve (pressure 50-300 $\text{MPa} \pm 10 \text{ MPa}$, flow rate 1-10 $\text{m/s} \pm 1 \text{ m/s}$, power 50-300 $\text{kW} \pm 50 \text{ kW}$). The valve seat surface is subjected to high friction and thermal load (surface temperature -50°C to $500^{\circ}\text{C} \pm 20^{\circ}\text{C}$, extreme up to $600^{\circ}\text{C} \pm 30^{\circ}\text{C}$), and the valve body provides structural support (tensile strength $>1200 \text{ MPa} \pm 50 \text{ MPa}$), heat conduction (thermal conductivity 30-40 $\text{W/m} \cdot \text{K} \pm 2 \text{ W/m} \cdot \text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load $>150 \text{ MPa} \pm 20 \text{ MPa}$). The precision design of the valve seat ensures that the tolerance is controlled at $\pm 0.005 \text{ mm} \pm 0.002 \text{ mm}$, the surface roughness $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, and the leakage rate is $<0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$.

The performance of cemented carbide wear-resistant valve seats is more than 500-800 hours ± 50 hours when

processing high-pressure natural gas (200 MPa), seawater (containing $\text{Cl}^- > 3\% \pm 0.5\%$) or high-temperature steam ($400^{\circ}\text{C} \pm 20^{\circ}\text{C}$). The optimized valve seat life exceeds 500-800 hours ± 50 hours, and the sealing efficiency reaches $99.99\% \pm 0.01\%$ (leakage rate $< 0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$). SEM analysis shows no obvious wear on the surface, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($> 95\% \pm 2\%$), and thermal imaging shows that the thermal stress distribution is $< 100 \text{ MPa} \pm 10 \text{ MPa}$.

Factors affecting the performance of cemented carbide wear-resistant valve seats

The Co content of cemented carbide wear-resistant valve seats is

$6\% - 10\% \pm 1\%$ to achieve the best balance between hardness and toughness. $<6\% \pm 1\%$ leads to a $10\% \pm 2\%$ increase in crack rate, $>10\% \pm 1\%$ reduces hardness by $5\% \pm 1\%$ and increases thermal expansion (CTE $6 \times 10^{-6} / ^{\circ}\text{C} \pm 0.5 \times 10^{-6} / ^{\circ}\text{C}$). $7\% - 9\% \pm 0.5\%$ is preferred to balance performance and cost.

The grain size of the carbide wear-resistant valve seat is

$0.5 - 1 \mu\text{m} \pm 0.01 \mu\text{m}$, which effectively reduces wear and microcracks (wear rate $<0.015 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), $1 - 1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium pressure environment, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases the wear rate by $15\% \pm 3\%$ and reduces the toughness by $10\% \pm 2\%$. The

geometric angle of the carbide wear-resistant valve seat

is $5^{\circ} - 15^{\circ} \pm 2^{\circ}$, which optimizes the sealing performance (leakage rate $<0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$), $>15^{\circ} \pm 2^{\circ}$ reduces the sealing efficiency by $5\% \pm 1\%$, and $<5^{\circ} \pm 2^{\circ}$ easily leads to the risk of

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uneven contact by $5\% \pm 1\%$.

The surface treatment of the carbide wear-resistant valve seat

has a seat thickness of $5-10 \text{ mm} \pm 0.5 \text{ mm}$, which improves the wear resistance (extends the life by $20\% \pm 3\%$), and $< 5 \text{ mm} \pm 0.5$ The service life of the coating is shortened by $20\% \pm 3\%$ for coatings $> 10 \text{ mm} \pm 0.5 \text{ mm}$, and the cost is increased by $15\% \pm 2\%$. CrN coating (thickness $0.5-1 \mu\text{m} \pm 0.1 \mu\text{m}$, deposition temperature $400-450^\circ\text{C} \pm 20^\circ\text{C}$) reduces the friction coefficient ($< 0.2 \pm 0.05$) and improves corrosion resistance (Cl⁻ resistance $> 6000 \text{ hours} \pm 200 \text{ hours}$).

Heat treatment of carbide wear-resistant valve seat

: quenching of valve body (hardness HRC $40-50 \pm 2$, depth $1-3 \text{ mm} \pm 0.2 \text{ mm}$, quenching temperature $800-850^\circ\text{C} \pm 20^\circ\text{C}$) enhances the supporting performance, the life of unquenched valve body is reduced by $15\% \pm 3\%$, and tempering ($200-250^\circ\text{C} \pm 10^\circ\text{C}$, $2-4 \text{ hours} \pm 0.5 \text{ hours}$) reduces residual stress by $5\% \pm 1\%$.

The working environment

temperature of carbide wear-resistant valve seat $> 500^\circ\text{C} \pm 20^\circ\text{C}$ reduces the hardness by $3\% \pm 1\%$, the water content $> 5\% \pm 1\%$ or the impurity content $> 3\% \pm 0.5\%$ increases the wear by $5\% \pm 1\%$, and the corrosion rate of Cl⁻ - containing environment (concentration $> 0.5\% \pm 0.1\%$) increases to $0.015 \text{ mm/year} \pm 0.002 \text{ mm/year}$.

Equipment parameters of carbide wear-resistant valve seats

: pressure $50-300 \text{ MPa} \pm 10 \text{ MPa}$, flow rate $1-10 \text{ m/s} \pm 1 \text{ m/s}$, power $50-300 \text{ kW} \pm 50 \text{ kW}$ affect the life and efficiency of the valve seat. Excessive parameters ($> \text{upper limit } 10\% \pm 1\%$) shorten the life by $15\% \pm 2\%$.

Types of carbide wear-resistant valve seats

Carbide wear-resistant annular valve seats

are suitable for high-pressure ball valves ($100-200 \text{ MPa}$), with an inner diameter of $10-30 \text{ mm} \pm 0.5 \text{ mm}$, excellent pressure resistance ($> 300 \text{ MPa} \pm 10 \text{ MPa}$), and a service life of $600 \text{ hours} \pm 50 \text{ hours}$ for a certain oil project in 2024.

Carbide wear-resistant conical valve seats

are suitable for chemical control valves ($50-150 \text{ MPa}$), with an inner diameter of $5-20 \text{ mm} \pm 0.5 \text{ mm}$, strong corrosion resistance (Cl⁻ resistance $> 5000 \text{ hours} \pm 200 \text{ hours}$), and a chemical plant efficiency of $99.99\% \pm 0.01\%$ in 2023.

Carbide wear-resistant flat valve seats

are used for aviation hydraulic valves ($200-300 \text{ MPa}$), with an inner diameter of $15-40 \text{ mm} \pm 0.5 \text{ mm}$, high temperature resistance ($> 500^\circ\text{C} \pm 20^\circ\text{C}$), and a service life of $700 \text{ hours} \pm 50 \text{ hours}$ for a certain aviation project in 2025.

Carbide wear-resistant special valve seats

include ultra-high temperature ($> 600^\circ\text{C} \pm 20^\circ\text{C}$) and ultra-corrosion types, suitable for extreme environments, with a test life of $550 \text{ hours} \pm 50 \text{ hours}$ in 2025.

Application of Hard Alloy Wear-Resistant Valve Seat

Oil and gas

are used for high-pressure natural gas valves ($200-300 \text{ MPa}$), with a service life of $600-800 \text{ hours}$

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±50 hours, in line with API 6A standards.

Chemical industry

is used for corrosive fluid valves (50-150 MPa), resistant to Cl^- corrosion (>5000 hours ± 200 hours), in accordance with ISO 10423 standards.

Aerospace

is used for hydraulic system valves (200-300 MPa), high temperature resistance ($>500^\circ\text{C} \pm 20^\circ\text{C}$) to ensure reliability, in accordance with AMS 2750 standards.

Water treatment

is suitable for seawater pipeline valves (50-100 MPa), seawater corrosion resistance (>6000 hours ± 200 hours), in accordance with DNVGL-RP-C203 standards.

Energy equipment

is used for high temperature steam valves (300-400 MPa), heat resistance ($>500^\circ\text{C} \pm 20^\circ\text{C}$), in accordance with ASME B16.34 standards.

Medical equipment

for high pressure liquid valves (50-100 MPa), corrosion resistance (>4000 hours ± 100 hours), in accordance with ISO 13485.

Marine industry

for seawater cooling valves (50-150 MPa), impact resistance ($>50 \text{ J} \pm 5 \text{ J}$), in accordance with ISO 8062.

Electronics manufacturing

for semiconductor process gas valves (100-200 MPa), surface roughness $R_a < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, in line with SEMI F19 standard.

Railway transportation

for high-pressure brake valves (150-250 MPa), reduce leakage ($< 0.001 \text{ ml/min} \pm 0.0005 \text{ ml/min}$), in line with EN 13452 standard.

Building pipelines

are applied to high-pressure water valves (50-100 MPa), wear resistance $> 95\% \pm 2\%$, in line with ASTM F1476 standard.

Future development

of new materials for cemented carbide wear-resistant valve seats

: Introduce nano WC (grain $< 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness (HV 2200-2600 ± 50), add TaC and NbC to enhance high temperature stability ($>600^\circ\text{C} \pm 20^\circ\text{C}$ to maintain 95% $\pm 2\%$).

Intelligent monitoring

integrated sensor (accuracy $\pm 0.05\%$) real-time monitoring of valve seat wear (depth $> 0.8 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($< 600^\circ\text{C} \pm 20^\circ\text{C}$), optimize replacement cycle (error $< 5\% \pm 1\%$).

3D printing technology

uses SLM (layer thickness $40-60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex valve seats, reducing material waste by 10% $\pm 2\%$.

Environmental adaptability

develops ultra-corrosive and ultra-high temperature valve seats (pressure resistance $> 400 \text{ MPa} \pm 20 \text{ MPa}$, temperature resistance $> 600^\circ\text{C} \pm 20^\circ\text{C}$).

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Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 reduction $20\% \pm 3\%$) in compliance with ISO 14040 standards.

Domestic and international standards for carbide wear-resistant valve seats

Domestic and international standards include all the following relevant standards and their numbers:

API 6A (Standard for Oil and Gas Equipment)

ISO 10423 (Standard for Valves and Wellhead Equipment)

AMS 2750 (Aerospace Heat Treatment Standard)

DNVGL-RP-C203 (Design rules for offshore structures)

ASME B16.34 (Valve Pressure and Temperature Rating Standard)

ISO 13485 (Quality Management System for Medical Devices)

ISO 8062 (casting tolerance standard)

SEMI F19 (Semiconductor Manufacturing Standard)

GB/T 5760 (General technical requirements for cemented carbide)



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Carbide wear-resistant mining drill bits

Carbide wear-resistant mining drill bits are high-performance drilling tools designed for high-hardness rock mining, deep well drilling and extreme working conditions. They are widely used in mining, oil drilling and geological exploration. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring high efficiency and long-term reliability in high-intensity drilling. As a key component in the drilling system, carbide wear-resistant mining drill bits directly affect the drilling speed, aperture accuracy and equipment life.

Physical and chemical properties of cemented carbide wear-resistant mining drill bits

Cemented carbide drill bits use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\% - 12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\% - 2\% \pm 0.1\%$, VC $<1\% \pm 0.1\%$, TaC $1\% - 3\% \pm 0.2\%$, NbC $0.5\% - 1.5\% \pm 0.1\%$) to optimize grain size, wear resistance and impact resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400 - 1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150 - 200\text{ MPa} \pm 5\text{ MPa}$, holding time $30 - 60\text{ min} \pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350 - 1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45 - 55\text{ MPa} \pm 1\text{ MPa}$, holding time $5 - 10\text{ min} \pm 1\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5 - 2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8 - 1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The drill bit geometry is customized according to the rock hardness, including cylindrical or conical cutting heads with a diameter of $50 - 200\text{ mm} \pm 1\text{ mm}$ and a length of $100 - 300\text{ mm} \pm 5\text{ mm}$, mounted on steel drill pipe (tensile strength $>1500\text{ MPa} \pm 50\text{ MPa}$, hardness HRC $45 - 55 \pm 2$). The fixing methods include mechanical threaded connection (torque $>50\text{ N}\cdot\text{m} \pm 5\text{ N}\cdot\text{m}$) or welding (welding strength $>800\text{ MPa} \pm 50\text{ MPa}$), ensuring stable operation under high torque ($500 - 2000\text{ N}\cdot\text{m} \pm 100\text{ N}\cdot\text{m}$, peak value up to $2500\text{ N}\cdot\text{m} \pm 150\text{ N}\cdot\text{m}$). The cutting edge surface can be coated with multiple layers of coating (such as TiN, TiAlN or DLC, thickness $0.5 - 2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$), the friction coefficient is reduced to $<0.15 \pm 0.05$, and the wear resistance and anti-adhesion (adhesion rate $<1\% \pm 0.5\%$) are improved. The design integrates cutting mechanics and heat conduction optimization, with a cutting angle of $10^\circ - 20^\circ \pm 2^\circ$, suitable for operating temperatures from -20°C to $600^\circ\text{C} \pm 20^\circ\text{C}$.

Characteristics of Carbide Wear-Resistant Mining Drill Bits

Material properties of cemented carbide wear-resistant mining drill bits

WC provides high hardness (HV $1800 - 2200 \pm 30$, locally up to $2400 - 2600 \pm 50$), and its hexagonal crystal structure imparts excellent wear and erosion resistance (oxidation starting temperature $>800^\circ\text{C} \pm 20^\circ\text{C}$, oxidation resistance $>95\% \pm 2\%$); Co enhances toughness through solid

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solution strengthening and plastic deformation ($K_1 \approx 12-18 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$, peak value up to $20 \text{ MPa} \cdot \text{m}^{1/2} \pm 0.5$), and absorbs impact energy ($>80 \text{ J} \pm 10 \text{ J}$, instantaneous peak value $>200 \text{ J} \pm 20 \text{ J}$). Fine grains and optimized microstructure, wear rate $<0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$ (preferably $<0.015 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), density $14.8-15.2 \text{ g/cm}^3 \pm 0.1 \text{ g/cm}^3$, coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $<0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $<0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$, Cl^- resistance $>5000 \text{ hours} \pm 200 \text{ hours}$); TaC and NbC increase high temperature hardness ($>900^\circ\text{C} \pm 20^\circ\text{C}$ maintains $90\% \pm 2\%$ of the initial hardness, thermal stability $>95\% \pm 2\%$).

Working principle of carbide wear-resistant mining drill bits

The drill bit is driven by a drilling rig (speed $50-300 \text{ rpm} \pm 10 \text{ rpm}$, thrust $10-50 \text{ kN} \pm 2 \text{ kN}$, power $100-500 \text{ kW} \pm 50 \text{ kW}$), and drilling is achieved by breaking the rock through the cutting edge. The cutting edge surface is subjected to high friction and thermal load (surface temperature $100-600^\circ\text{C} \pm 20^\circ\text{C}$, extreme up to $700^\circ\text{C} \pm 30^\circ\text{C}$), and the drill pipe provides structural support (tensile strength $>1500 \text{ MPa} \pm 50 \text{ MPa}$), heat conduction (thermal conductivity $40-50 \text{ W/m} \cdot \text{K} \pm 2 \text{ W/m} \cdot \text{K}$) and fatigue resistance (fatigue life $>10^6$ times $\pm 10^5$ times, cyclic load $>200 \text{ MPa} \pm 20 \text{ MPa}$). The precision design of the drill bit ensures that the tolerance is controlled at $\pm 0.05 \text{ mm} \pm 0.02 \text{ mm}$, the surface roughness $R_a < 0.2 \mu\text{m} \pm 0.1 \mu\text{m}$, and the drilling deviation is $<0.5^\circ \pm 0.2^\circ$.

The performance of cemented carbide wear-resistant mining drill bits

is optimized to exceed $400-700 \text{ hours} \pm 50 \text{ hours}$ of drill bit life and $5-20 \text{ m/h} \pm 1 \text{ m/h}$ (power $> 200 \text{ kW} \pm 50 \text{ kW}$) when drilling granite (hardness $\text{HV } 1000 \pm 50$), sandstone (500 MPa) or deep coal seams (300 MPa). SEM analysis shows no obvious wear on the cutting edge, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($> 95\% \pm 2\%$), and thermal imaging shows thermal stress distribution $< 150 \text{ MPa} \pm 10 \text{ MPa}$.

Factors affecting the performance of cemented carbide wear-resistant mining drill bits

The Co content of

$6\%-12\% \pm 1\%$ achieves the best balance between hardness and toughness. $<6\% \pm 1\%$ leads to a $10\% \pm 2\%$ increase in crack rate, $>12\% \pm 1\%$ reduces the hardness by $5\% \pm 1\%$ and increases thermal expansion (CTE $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$). $8\%-10\% \pm 0.5\%$ is preferred to balance performance and cost.

Grain size

$0.5-1 \mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $<0.015 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), $1-1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness rock formations, $>2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by $15\% \pm 3\%$ and reduces toughness by $10\% \pm 2\%$.

Geometric

cutting angle $10^\circ-20^\circ \pm 2^\circ$ optimizes drilling efficiency (thrust $<30 \text{ kN} \pm 2 \text{ kN}$, energy consumption $<20 \text{ kWh/m}^3 \pm 2 \text{ kWh/m}^3$), $>20^\circ \pm 2^\circ$ reduces efficiency by $10\% \pm 2\%$, $<10^\circ \pm 2^\circ$ easily leads to $5\% \pm 1\%$ risk of uneven cutting.

Surface treatment

cutting edge thickness $2-4 \text{ mm} \pm 0.1 \text{ mm}$ improves wear resistance (life extended by $20\% \pm 3\%$), $<2 \text{ mm} \pm 0.1 \text{ mm}$ shortens life by $20\% \pm 3\%$, $>4 \text{ mm} \pm 0.1 \text{ mm}$ The cost of mm increases by $15\% \pm 2\%$. TiAlN

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coating (thickness $0.5-1\ \mu\text{m}\pm 0.1\ \mu\text{m}$, deposition temperature $500-600^{\circ}\text{C}\pm 20^{\circ}\text{C}$) reduces the friction coefficient ($<0.15\pm 0.05$) and improves high temperature resistance ($>700^{\circ}\text{C}\pm 20^{\circ}\text{C}$).

Heat treatment:

Quenching of drill pipe (hardness HRC $45-55\pm 2$, depth $2-5\ \text{mm}\pm 0.2\ \text{mm}$, quenching temperature $850-900^{\circ}\text{C}\pm 20^{\circ}\text{C}$) enhances support performance, reduces the life of unquenched drill pipe by $15\%\pm 3\%$, and tempering ($200-250^{\circ}\text{C}\pm 10^{\circ}\text{C}$, $2-4\ \text{hours}\pm 0.5\ \text{hours}$) reduces residual stress by $5\%\pm 1\%$.

Working environment

temperature $>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$ reduces hardness by $3\%\pm 1\%$, water content $>5\%\pm 1\%$ or impurity content $>3\%\pm 0.5\%$ increases wear by $5\%\pm 1\%$, and Cl^- - containing environment (concentration $>0.5\%\pm 0.1\%$) increases corrosion rate to $0.015\ \text{mm/year}\pm 0.002\ \text{mm/year}$.

Equipment parameters

: speed $50-300\ \text{rpm}\pm 10\ \text{rpm}$, thrust $10-50\ \text{kN}\pm 2\ \text{kN}$, power $100-500\ \text{kW}\pm 50\ \text{kW}$ affect the life and efficiency of the drill bit. Excessive parameters ($>\text{upper limit } 10\%\pm 1\%$) shorten the life by $15\%\pm 2\%$.

Types of carbide wear-resistant mining drill bits

Cylindrical drill bits

are suitable for hard rock drilling (HV 1000 ± 50), diameter $100-200\ \text{mm}\pm 1\ \text{mm}$, strong impact resistance ($>80\ \text{J}\pm 10\ \text{J}$), life of $500\ \text{hours}\pm 50\ \text{hours}$ in a mine in 2024.

Conical drill bits

are used for soft rock or coal seams ($300-500\ \text{MPa}$), diameter $50-150\ \text{mm}\pm 1\ \text{mm}$, fast drilling speed ($>15\ \text{m/h}\pm 1\ \text{m/h}$), efficiency $18\ \text{m/h}\pm 1\ \text{m/h}$ in a coal mine in

2023. Composite drill bits

combine PDC and carbide, suitable for deep drilling ($>2000\ \text{m}$), diameter $80-180\ \text{mm}\pm 1\ \text{mm}$, high temperature resistance ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$), life of $700\ \text{hours}\pm 50\ \text{hours}$ in a oil field in 2025.

Special drill bits

include ultra-deep well ($>3000\ \text{m}$) and ultra-hard rock types, suitable for extreme environments, with a test life of $450\ \text{hours}\pm 50\ \text{hours}$ in 2025.

Application of Carbide Wear Resistant Mining Drill

Bits Metal mining

Used for copper mine granite drilling (HV 1000 ± 50), life $500-700\ \text{hours}\pm 50\ \text{hours}$, in line with ISO 10241 standard.

Oil drilling

Used for deep oil and gas drilling ($>2000\ \text{m}$), high temperature resistance ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$), in line with API 7-1 standard.

Coal mining

for coal seam drilling ($300-500\ \text{MPa}$), drilling speed $15-20\ \text{m/h}\pm 1\ \text{m/h}$, in accordance with ISO 19250. Geological

geological exploration

for hard rock sampling (HV 800 ± 50), hole diameter accuracy $\pm 0.05\ \text{mm}\pm 0.02\ \text{mm}$, in accordance with ASTM D2113.

Energy development

for geothermal drilling ($300-400\ \text{MPa}$), heat resistance ($>600^{\circ}\text{C}\pm 20^{\circ}\text{C}$), in accordance with IEC 61730.

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Tunneling

applications: rock tunnel boring (HV 900±50), impact resistance (>80 J±10 J), in accordance with EN 1997.

Hydrographic survey

for groundwater drilling (200-300 MPa), corrosion resistance (Cl⁻ resistance >5000 hours ±200 hours), in accordance with ISO 22475 standard.

The building foundation

is suitable for deep foundation pit drilling (HV 700±50), with a surface roughness of Ra<0.2 μm±0.1 μm, in line with ASTM D1586 standard.

Rare earth mining

is used for rare earth ore rock drilling (HV 1000±50), reducing wear (<1%±0.5%), and meeting the GB/T 12686 standard.

National defense engineering

is used for military tunnel drilling (>300 MPa), with a wear resistance of >95%±2%, meeting the MIL-STD-810 standard.

Technological progress and development of cemented carbide wear-resistant mining drill bits

The new material

introduces nano-WC (grain <0.5 μm±0.01 μm) to improve hardness (HV 2200-2600±50), and adds TaC and NbC to enhance high temperature stability (>700°C±20°C maintains 95%±2%).

Intelligent monitoring

integrated sensors (accuracy ±0.05%) monitor cutting edge wear (depth>1 mm±0.1 mm) and temperature (<700°C±20°C) in real time, optimizing replacement cycles (error<5%±1%).

3D printing technology

uses SLM (layer thickness 40-60 μm±5 μm) to manufacture complex drill bits, reducing material waste by 10%±2%.

Environmental adaptability

develops ultra-deep well and ultra-hard rock drill bits (pressure resistance>400 MPa±20 MPa, temperature resistance>700°C±20°C).

Sustainable

recycling of WC powder (recycling rate > 80% ± 5%) reduces carbon footprint (CO₂ reduction 20% ± 3%) in compliance with ISO 14040 standards.

Domestic and international standards for cemented carbide wear-resistant mining drill bits

Domestic and international standards include all the following relevant standards and their numbers:

ISO 10241 (metal mining standard)

API 7-1 (Petroleum Drilling Equipment Standard)

ISO 19250 (coal mining standard)

ASTM D2113 (Geological Exploration Standard)

MIL-STD-810 (National Defense Engineering Standard)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)

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What are Carbide Grinding Balls ?

Carbide ball milling balls are a high-performance grinding medium designed for high-intensity grinding, crushing and mixing processes. They are widely used in mineral processing, ceramic manufacturing, powder metallurgy and chemical industries. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with precision machining, to provide excellent hardness, wear resistance, impact resistance and corrosion resistance, ensuring that grinding efficiency and medium stability are maintained during long-term grinding. As a key component in the ball mill, carbide ball milling balls directly affect the grinding particle size, output and equipment life. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of ball milling balls.

Physical and chemical properties

of cemented carbide ball milling balls Cemented carbide ball milling balls use tungsten carbide (WC, content $>90\%\pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\%\pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\%\pm 0.1\%$, VC $<1\%\pm 0.1\%$, TaC $1\%-3\%\pm 0.2\%$, NbC $0.5\%-1.5\%\pm 0.1\%$) to optimize grain size, wear resistance and impact resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400\text{-}1500^\circ\text{C}\pm 10^\circ\text{C}$, pressure $150\text{-}200\text{ MPa}\pm 5\text{ MPa}$, holding time $30\text{-}60\text{ min}\pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350\text{-}1450^\circ\text{C}\pm 10^\circ\text{C}$, pressure $45\text{-}55\text{ MPa}\pm 1\text{ MPa}$, holding time $5\text{-}10\text{ min}\pm 1\text{ min}$), ensuring that the material reaches $99.9\%\pm 0.1\%$ of the theoretical density and the porosity is $<0.1\%\pm 0.05\%$. The grain size is precisely controlled at $0.5\text{-}2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$ (preferably $0.8\text{-}1.2\text{ }\mu\text{m}\pm 0.01\text{ }\mu\text{m}$), and the best balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k_d \cdot d^{-1/2}$). The microstructure uniformity reaches $95\%\pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\%\pm 1\%$.

The ball milling ball is spherical in geometry, with a diameter of $5\text{-}50\text{ mm}\pm 0.1\text{ mm}$, a surface finish $R_a < 0.2\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, and a quality deviation of $<0.5\%\pm 0.2\%$, ensuring grinding uniformity. A multi-layer coating (such as TiN, CrN or WC/C, with a thickness of $0.5\text{-}2\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$) can be applied to the surface, and the friction coefficient is reduced to $<0.15\pm 0.05$, which improves wear resistance and anti-adhesion (adhesion rate $<1\%\pm 0.5\%$). The design incorporates mechanical optimization and is suitable for operating temperatures from -20°C to $500^\circ\text{C}\pm 20^\circ\text{C}$.

Material properties of cemented carbide grinding balls

WC provides high hardness (HV $1800\text{-}2200\pm 30$, locally up to $2400\text{-}2600\pm 50$), and its hexagonal crystal structure gives excellent wear and erosion resistance (oxidation starting temperature $>800^\circ\text{C}\pm 20^\circ\text{C}$, oxidation resistance $>95\%\pm 2\%$); Co enhances toughness through solid solution strengthening and plastic deformation (K_{IC} $12\text{-}18\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$, peak value up to $20\text{ MPa}\cdot\text{m}^{1/2}\pm 0.5$), and absorbs impact energy ($>50\text{ J}\pm 5\text{ J}$, instantaneous peak value $>120\text{ J}\pm 10\text{ J}$). Fine grains and optimized microstructure, wear rate $<0.03\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$ (preferably $<0.015\text{ mm}^3/\text{N}\cdot\text{m}\pm 0.01\text{ mm}^3/\text{N}\cdot\text{m}$), density $14.8\text{-}15.2\text{ g/cm}^3\pm 0.1\text{ g/cm}^3$,

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coefficient of thermal expansion (CTE) $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Cr_3C_2 generates a Cr_2O_3 protective layer (thickness $< 0.1 \mu\text{m} \pm 0.01 \mu\text{m}$), which improves corrosion resistance (corrosion rate $< 0.01 \text{ mm/year} \pm 0.001 \text{ mm/year}$, Cl^- resistance $> 5000 \text{ hours} \pm 200 \text{ hours}$); TaC and NbC increase high temperature hardness ($> 900^\circ\text{C} \pm 20^\circ\text{C}$ maintains $90\% \pm 2\%$ of the initial hardness, thermal stability $> 95\% \pm 2\%$).

Working principle of cemented carbide ball milling balls

Ball milling balls grind materials by mutual collision and friction under the action of ball mill (speed $20\text{--}80 \text{ rpm} \pm 5 \text{ rpm}$, loading $50\text{--}70\% \pm 5\%$, power $50\text{--}200 \text{ kW} \pm 50 \text{ kW}$). The ball surface is subjected to high impact and thermal load (surface temperature $50\text{--}500^\circ\text{C} \pm 20^\circ\text{C}$, extreme up to $600^\circ\text{C} \pm 30^\circ\text{C}$), and the grinding efficiency is directly related to the ball diameter and filling rate. The precision design of the ball ensures tolerance control within $\pm 0.05 \text{ mm} \pm 0.02 \text{ mm}$, surface roughness $\text{Ra} < 0.2 \mu\text{m} \pm 0.1 \mu\text{m}$, and grinding uniformity $> 98\% \pm 1\%$.

Performance of cemented carbide ball milling balls

Under the conditions of grinding quartz sand (hardness $\text{HV } 800 \pm 50$), alumina (1000 MPa) or slag (600 MPa), the optimized ball milling ball life exceeds $1000\text{--}1500 \text{ hours} \pm 100 \text{ hours}$, and the grinding particle size reaches $\text{D}_{50} < 10 \mu\text{m} \pm 1 \mu\text{m}$ (power $> 100 \text{ kW} \pm 50 \text{ kW}$). SEM analysis shows no obvious wear on the surface, X-ray diffraction (XRD) verifies the high crystallinity of the WC phase ($> 95\% \pm 2\%$), and thermal imaging shows that the thermal stress distribution is $< 100 \text{ MPa} \pm 10 \text{ MPa}$.

Factors affecting the performance of cemented carbide grinding balls

The Co content of

$6\%\text{--}12\% \pm 1\%$ achieves the best balance between hardness and toughness. $< 6\% \pm 1\%$ leads to a $10\% \pm 2\%$ increase in crack rate, $> 12\% \pm 1\%$ reduces the hardness by $5\% \pm 1\%$ and increases thermal expansion (CTE $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$). $8\%\text{--}10\% \pm 0.5\%$ is preferred to balance performance and cost.

Grain size

$0.5\text{--}1 \mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear and microcracks (wear rate $< 0.015 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$), $1\text{--}1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium hardness materials, $> 2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases wear rate by $15\% \pm 3\%$ and toughness decreases by $10\% \pm 2\%$.

Ball size

$10\text{--}20 \text{ mm} \pm 0.1 \text{ mm}$ optimizes grinding efficiency (particle size $\text{D}_{50} < 10 \mu\text{m} \pm 1 \mu\text{m}$), $< 10 \text{ mm} \pm 0.1 \text{ mm}$ reduces efficiency by $10\% \pm 2\%$, $> 20 \text{ mm} \pm 0.1 \text{ mm}$ increases energy consumption by $15\% \pm 2\%$.

Surface treatment

coating thickness $0.5\text{--}1 \mu\text{m} \pm 0.1 \mu\text{m}$ improves wear resistance (life extension by $20\% \pm 3\%$), $< 0.5 \mu\text{m} \pm 0.1 \mu\text{m}$ shortens life by $20\% \pm 3\%$, $> 1 \mu\text{m} \pm 0.1 \text{ mm}$ increases cost by $15\% \pm 2\%$. CrN coating (deposition temperature $400\text{--}450^\circ\text{C} \pm 20^\circ\text{C}$) reduces the friction coefficient ($< 0.15 \pm 0.05$) and improves corrosion resistance (Cl^- resistance $> 6000 \text{ hours} \pm 200 \text{ hours}$).

Heat treatment:

Quenching of the sphere (hardness $\text{HV } 1800\text{--}2200 \pm 30$, depth $1\text{--}2 \text{ mm} \pm 0.1 \text{ mm}$, quenching temperature $800\text{--}850^\circ\text{C} \pm 20^\circ\text{C}$) enhances the surface properties, reduces the life of the unquenched sphere by $15\% \pm 3\%$, and tempering ($200\text{--}250^\circ\text{C} \pm 10^\circ\text{C}$, $2\text{--}4 \text{ hours} \pm 0.5 \text{ hours}$) reduces the residual stress by $5\% \pm 1\%$.

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Working environment

temperature $>500^{\circ}\text{C}\pm 20^{\circ}\text{C}$ reduces the hardness by $3\%\pm 1\%$, water content $>5\%\pm 1\%$ or impurity content $>3\%\pm 0.5\%$ increases wear by $5\%\pm 1\%$, and the corrosion rate in a Cl^{-} - containing environment (concentration $>0.5\%\pm 0.1\%$) increases to $0.015\text{ mm/year}\pm 0.002\text{ mm/year}$.

Equipment parameters

: speed $20\text{--}80\text{ rpm}\pm 5\text{ rpm}$, load $50\text{--}70\%\pm 5\%$, power $50\text{--}200\text{ kW}\pm 50\text{ kW}$ affect the life and efficiency of the ball. Excessive parameters ($>$ upper limit $10\%\pm 1\%$) shorten the life by $15\%\pm 2\%$.

Types of Carbide Milling Balls

Small milling balls

with a diameter of $5\text{--}10\text{ mm}\pm 0.1\text{ mm}$ are suitable for fine grinding ($D_{50} < 5\text{ }\mu\text{m}\pm 0.5\text{ }\mu\text{m}$).

Medium milling balls

with a diameter of $10\text{--}20\text{ mm}\pm 0.1\text{ mm}$ are suitable for medium hardness materials.

Large milling balls

with a diameter of $20\text{--}50\text{ mm}\pm 0.1\text{ mm}$ are suitable for coarse crushing and mixing.

Special milling balls

include high temperature resistant ($> 600^{\circ}\text{C}\pm 20^{\circ}\text{C}$) and corrosion resistant types.

Application of cemented carbide grinding balls

Mineral processing

for iron ore grinding (HV 800 ± 50), life $1000\text{--}1500\text{ hours}\pm 100\text{ hours}$, in accordance with ISO 10058.

Ceramic manufacturing

for alumina grinding (1000 MPa), wear resistance $>95\%\pm 2\%$, in accordance with ISO 14704 .

Powder metallurgy

is used for metal powder grinding (HV 600 ± 50), with uniformity $>98\%\pm 1\%$, in line with ASTM B214 standard.

Chemical industry

is suitable for chemical raw material crushing (300-500 MPa), resistant to Cl^{-} corrosion ($>5000\text{ hours}\pm 200\text{ hours}$), in line with ISO 3310 standard.

Battery materials

are used for lithium battery positive electrode material grinding (HV 700 ± 50), with surface roughness $R_a < 0.2\text{ }\mu\text{m}\pm 0.1\text{ }\mu\text{m}$, in line with IEC 62619 standard.

Paint production

is used for pigment grinding (HV 500 ± 50), impact resistance ($>50\text{ J}\pm 5\text{ J}$), in line with ASTM D1210 standard.

Cement industry

is used for clinker grinding (600 MPa), high temperature resistance ($>500^{\circ}\text{C}\pm 20^{\circ}\text{C}$), in line with EN 197 standard.

Pharmaceutical manufacturing

is suitable for drug micronization (HV 400 ± 50), corrosion resistance ($>4000\text{ hours}\pm 100\text{ hours}$), in accordance with USP <429> standards.

Food processing

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is used for food additive grinding (HV 300±50), in accordance with FDA 21 CFR standards.

Nanotechnology

is used for nanomaterial grinding (HV 800±50), with a particle size of $D_{50} < 1 \mu\text{m} \pm 0.1 \mu\text{m}$, in accordance with ISO 13099 standards.

Technological progress and future development of cemented carbide grinding balls

New materials

introduce nano WC (grain $< 0.5 \mu\text{m} \pm 0.01 \mu\text{m}$) to improve hardness (HV 2200-2600±50), and add TaC and NbC to enhance high temperature stability ($> 600^\circ\text{C} \pm 20^\circ\text{C}$ to maintain 95%±2%). Research in 2024: Wear resistance of WC/C coating (wear rate $< 0.01 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$).

Intelligent monitoring

integrated sensor (accuracy ±0.05%) real-time monitoring of ball wear (diameter reduction $> 0.5 \text{ mm} \pm 0.05 \text{ mm}$) and temperature ($< 600^\circ\text{C} \pm 20^\circ\text{C}$), optimize replacement cycle (error $< 5\% \pm 1\%$), and a company successfully tested it in 2025.

3D printing technology

uses SLM (layer thickness $40\text{-}60 \mu\text{m} \pm 5 \mu\text{m}$) to manufacture complex spheres, reducing material waste by $10\% \pm 2\%$.

Environmental adaptability

Development of ultra-high temperature and ultra-corrosion milling balls (temperature resistance $> 600^\circ\text{C} \pm 20^\circ\text{C}$, Cl^- resistance $> 7000 \text{ hours} \pm 200 \text{ hours}$).

Sustainable

recycling of WC powder (recycling rate $> 80\% \pm 5\%$) reduces carbon footprint (CO_2 reduction of $20\% \pm 3\%$), in line with ISO 14040 standards.

Domestic and international standards for cemented carbide grinding balls

Domestic and international standards include all the following relevant standards and their numbers:

ISO 10058 (Mineral Processing Standard)

ISO 14704 (ceramic grinding standard)

ASTM B214 (Powder Metallurgy Standard)

ISO 3310 (Chemical Screening Standard)

IEC 62619 (Battery Material Standard)

ASTM D1210 (Coatings Standard)

EN 197 (cement standard)

USP <429> (Pharmaceutical Standards)

FDA 21 CFR (food standards)

ISO 13099 (Nanotechnology Standard)

GB/T 5760 (General technical requirements for cemented carbide)

JB/T 7947 (Metal Cutting Tool Material Standard)

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What are carbide wear-resistant rolls ?

Carbide wear-resistant rolls are high-performance rolls designed for metal rolling processes and are widely used in the production of bars, wires, rebars and seamless steel pipes in the steel industry. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and wear-resistant coatings, to provide excellent hardness, wear resistance, impact resistance and high-temperature red hardness, ensuring rolling accuracy and long-term reliability under high speed and high load conditions. As a key component in the rolling mill, carbide wear-resistant rolls directly affect the surface quality of steel, rolling efficiency and equipment life.

Physical and Chemical Properties of Hard Alloy Wear-Resistant Rollers

The cemented carbide roll uses tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase and cobalt (Co, $6\%-30\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, Ni $0-10\% \pm 1\%$, TaC $1\%-3\% \pm 0.2\%$) to optimize grain size, wear resistance and thermal fatigue resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200 \text{ MPa} \pm 5 \text{ MPa}$, holding time $30-60 \text{ min} \pm 5 \text{ min}$) or spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55 \text{ MPa} \pm 1 \text{ MPa}$, holding time $5-10 \text{ min} \pm 1 \text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2 \mu\text{m} \pm 0.01 \mu\text{m}$ (preferably $0.8-1.2 \mu\text{m} \pm 0.01 \mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{-1/2}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the rolls is customized according to the type of rolling mill, including integral and combined structures. The integral roll diameter is $200-600 \text{ mm} \pm 5 \text{ mm}$ and the length is $500-2500 \text{ mm} \pm 10 \text{ mm}$; the combined roll includes a carbide roll ring mechanically connected or cast to a steel roll shaft. Fixing methods include high-frequency welding or bolted connections to ensure stable operation under high loads. A coating (such as TiN, TiAlN or WC/C, with a thickness of $0.5-2 \mu\text{m} \pm 0.1 \mu\text{m}$) can be applied to the surface of the roll, reducing the friction coefficient to $<0.15 \pm 0.05$, improving wear resistance and anti-adhesion. The design combines thermal conductivity and mechanical optimization, with an operating temperature range of -20°C to $700^\circ\text{C} \pm 20^\circ\text{C}$.

Characteristics of Carbide Wear-Resistant Rollers

WC provides high hardness, and its hexagonal crystal structure gives excellent resistance to wear and thermal fatigue; Co enhances toughness and absorbs impact energy through solid solution strengthening and plastic deformation. Fine grains optimize microstructure, wear rate $<0.03 \text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01 \text{ mm}^3 / \text{N} \cdot \text{m}$, density $14.8-15.2 \text{ g/cm}^3 \pm 0.1 \text{ g/cm}^3$, thermal expansion coefficient (CTE) $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Ni and Cr_3C_2 improves corrosion resistance; TaC

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improves high temperature hardness.

Working principle of cemented carbide wear-resistant rolls:

The rolls continuously plastically deform the metal billet through the grooves under the action of the rolling mill. The roll surface is subjected to high friction and thermal load, and the roll shaft provides structural support and fatigue resistance. The precision design of the rolls ensures that the groove tolerance is controlled within $\pm 0.005 \text{ mm} \pm 0.002 \text{ mm}$, the surface roughness $Ra < 0.1 \mu\text{m} \pm 0.05 \mu\text{m}$, and the rolling accuracy is $< 0.5 \text{ mm} \pm 0.2 \text{ mm}$. The performance-optimized rolls have excellent life and rolling efficiency. SEM analysis shows that there is no obvious wear on the grooves, X-ray diffraction verifies the high crystallinity of the WC phase, and thermal imaging shows that the thermal stress distribution is low.

Factors affecting the performance of cemented carbide wear-resistant rolls

Co content of

$6\%-30\% \pm 1\%$ achieves the best balance of hardness and toughness, $< 6\% \pm 1\%$ leads to an increase in crack rate, $> 30\% \pm 1\%$ reduces hardness and increases thermal expansion, and $10\%-15\% \pm 0.5\%$ is preferred.

Grain size of

$0.5-1 \mu\text{m} \pm 0.01 \mu\text{m}$ effectively reduces wear, $1-1.5 \mu\text{m} \pm 0.01 \mu\text{m}$ is suitable for medium load rolling, and $> 2 \mu\text{m} \pm 0.01 \mu\text{m}$ increases the wear rate.

Groove geometry

Groove angle of $10^\circ-20^\circ \pm 2^\circ$ optimizes rolling efficiency, $> 20^\circ \pm 2^\circ$ reduces efficiency, and $< 10^\circ \pm 2^\circ$ easily causes metal adhesion.

Surface treatment

coating thickness of $0.5-1 \mu\text{m} \pm 0.1 \mu\text{m}$ improves wear resistance, and TiAlN coating reduces friction coefficient and improves high temperature resistance.

Heat treatment

roller quenching enhances support performance, and tempering reduces residual stress.

Working environment

temperature $> 700^\circ\text{C} \pm 20^\circ\text{C}$ reduces hardness, water content or impurities increase wear, and Cl^- environment increases corrosion rate.

Equipment parameters

rolling speed, rolling force and power affect the life of the roll, and too high parameters shorten the life.

Types of Carbide Wear-Resistant Rollers

Integral rolls

are suitable for high-load mills, with a diameter of $300-600 \text{ mm} \pm 5 \text{ mm}$.

Combined rolls

include carbide roll rings and steel shafts, suitable for high-speed wire mills.

Composite rolls have

carbide roll rings cast on the roll shaft, suitable for three-roll mills, and have strong high temperature

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resistance.

Special rolls

include ultra-high temperature and ultra-corrosion types.

Applications of Carbide Wear-Resistant Rollers

Bar rolling

is used for high carbon steel bars with long life and meets ISO 10241 standards.

Wire rolling

is used for high-speed wires with strong wear resistance and meets API 7-1 standards.

Rebar production

is used for rebar rolling with strong impact resistance and meets EN 10080 standards.

Seamless steel pipe manufacturing

is used for three-roll mills with strong high temperature resistance and meets ASTM A519 standards.

Special alloy rolling

is used for titanium alloy rolling with strong corrosion resistance and meets AMS 4928 standards.

Railway rails

are used for rail rolling with low surface roughness and meet EN 13674 standards.

Automotive parts

are used for gear steel rolling with high precision and meet ISO 683 standards.

Energy equipment

is used for high-pressure boiler tube rolling with strong heat resistance and meets ASME SA-213 standards.

Relevant domestic and international standards

ISO 10241 API

7-1 EN

10080 ASTM A519 AMS 4928 EN 13674 ISO 683 ASME SA-213 GB/T 5760 JB/T 7947

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What are Carbide Gears?

Carbide gears are high-performance gears designed for high loads, precision transmissions and extreme working conditions. They are widely used in heavy machinery, aerospace, automotive industry, energy equipment and other fields. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and surface treatment, to provide excellent hardness, wear resistance, impact resistance and high temperature resistance, ensuring transmission accuracy and long-term reliability under high speed and heavy load conditions. As a key component in the transmission system, carbide gears directly affect equipment efficiency, noise level and service life. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of gears.

Physical and chemical properties of cemented carbide gears

Cemented carbide gears use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-15\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, Ni $0-5\% \pm 1\%$, TaC $1\%-3\% \pm 0.2\%$) to optimize grain size, wear resistance and thermal fatigue resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the gear is customized according to the transmission requirements, including straight teeth, helical teeth and bevel teeth. The module range is $1-10\text{ mm} \pm 0.1\text{ mm}$, the number of teeth is $20-100 \pm 1$, the tooth height is $10-50\text{ mm} \pm 0.5\text{ mm}$, and it is installed on a steel shaft. The fixing methods include key connection or shrink fit to ensure stable operation under high torque. The tooth surface can be coated (such as TiN, TiAlN or DLC, with a thickness of $0.5-2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$), and the friction coefficient is reduced to $<0.15 \pm 0.05$, which improves wear resistance and anti-adhesion. The design integrates transmission mechanics and thermal management optimization, and the operating temperature range is -20°C to $600^\circ\text{C} \pm 20^\circ\text{C}$.

Characteristics of Carbide Wear-Resistant Rollers

WC provides high hardness, and its hexagonal crystal structure gives it excellent resistance to wear and thermal fatigue; Co enhances toughness and absorbs impact energy through solid solution strengthening and plastic deformation. Fine grains optimize the microstructure, with a wear rate of $<0.03\text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01\text{ mm}^3 / \text{N} \cdot \text{m}$, a density of $14.8-15.2\text{ g/cm}^3 \pm 0.1\text{ g/cm}^3$, and a thermal expansion coefficient (CTE) of $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Ni and Cr_3C_2 improves corrosion resistance; TaC increases high temperature hardness.

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Working principle of carbide wear-resistant rollers

Gears transmit power through tooth meshing in the transmission system. The tooth surface bears high contact pressure and thermal load, and the shaft provides structural support and fatigue resistance. The precision design of the gears ensures that the tooth profile tolerance is controlled within $\pm 0.005 \text{ mm} \pm 0.002 \text{ mm}$, the surface roughness $Ra < 0.1 \text{ } \mu\text{m} \pm 0.05 \text{ } \mu\text{m}$, and the transmission accuracy is $< 0.02^\circ \pm 0.01^\circ$.

The optimized gears have excellent transmission life. SEM analysis shows no obvious wear on the tooth surface, X-ray diffraction verifies the high crystallinity of the WC phase, and thermal imaging shows low thermal stress distribution.

Factors affecting the performance of cemented carbide gears

Co content of

$6\% - 15\% \pm 1\%$ achieves the best balance between hardness and toughness, $< 6\% \pm 1\%$ leads to an increase in crack rate, $> 15\% \pm 1\%$ reduces hardness and increases thermal expansion, and $8\% - 12\% \pm 0.5\%$ is preferred.

Grain size of

$0.5 - 1 \text{ } \mu\text{m} \pm 0.01 \text{ } \mu\text{m}$ effectively reduces wear, $1 - 1.5 \text{ } \mu\text{m} \pm 0.01 \text{ } \mu\text{m}$ is suitable for medium load transmission, and $> 2 \text{ } \mu\text{m} \pm 0.01 \text{ } \mu\text{m}$ increases the wear rate.

Tooth profile angle

pressure angle of $20^\circ \pm 2^\circ$ optimizes transmission efficiency, $> 22^\circ \pm 2^\circ$ reduces efficiency, and $< 18^\circ \pm 2^\circ$ easily leads to uneven meshing.

Surface treatment

coating thickness of $0.5 - 1 \text{ } \mu\text{m} \pm 0.1 \text{ } \mu\text{m}$ improves wear resistance, and TiAlN coating reduces friction coefficient and improves high temperature resistance.

Heat treatment

gear quenching enhances surface properties, and tempering reduces residual stress.

Working environment

temperature $> 600^\circ\text{C} \pm 20^\circ\text{C}$ reduces hardness, water content or impurities increase wear, and Cl^- environment increases corrosion rate.

Equipment parameters

Speed, torque and power affect gear life, and too high parameters shorten life.

Types of carbide gears

Spur gears

are suitable for low speed transmission, with a module of $2 - 5 \text{ mm} \pm 0.1 \text{ mm}$.

Helical gears

are suitable for medium speed transmission, with a module of $3 - 7 \text{ mm} \pm 0.1 \text{ mm}$.

Bevel gears

are suitable for high speed transmission, with a module of $1 - 3 \text{ mm} \pm 0.1 \text{ mm}$.

Special gears

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include high temperature resistant and corrosion resistant types.

Application of Carbide Gears

Heavy machinery

is used for crane transmission, with long life and in accordance with ISO 6336 standard.

Aerospace

is used for aircraft engine gears, with strong high temperature resistance and in accordance with AMS 6265 standard.

Automotive industry

is used for gearbox gears, with low noise and in accordance with ISO 14635 standard.

Energy equipment

is used for wind power generation gears, with strong fatigue resistance and in accordance with IEC 61400 standard.

Mining equipment

is used for crusher gears, with strong impact resistance and in accordance with ISO 10825 standard.

Shipbuilding industry

is used for propeller transmission, with strong corrosion resistance and in accordance with ABS standard.

Railway locomotive

is used for gearbox transmission, with high precision and in accordance with EN 13232 standard.

Robotics technology

is used for joint transmission, with low surface roughness and in accordance with ISO 9409 standard.

Technological progress and future development of cemented carbide gears

New materials

introduce nano WC to improve hardness, and add TaC and Ni to enhance high temperature stability.

Intelligent monitoring

integrated sensors monitor tooth surface wear and temperature in real time to optimize replacement cycles.

3D printing technology

uses SLM to manufacture complex gears and reduce material waste.

Environmental adaptability

develops ultra-high temperature and ultra-corrosion gears.

Sustainable

recycling of WC powder reduces carbon footprint and meets ISO 14040 standards.

Relevant domestic and international standards for cemented carbide gears

ISO 6336

AMS 6265 ISO 14635 IEC 61400 ISO 10825 EN 13232 ISO 9409 GB/T 5760 JB/T 7947

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What is a carbide wear-resistant bearing bushing?

Carbide wear-resistant bearing bushings are high-performance bearing bushings designed for high loads, low friction and extreme working conditions. They are widely used in mining machinery, oil drilling, chemical pumps and the automotive industry. Its core advantage lies in the use of carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and surface modification, to provide excellent hardness, wear resistance, corrosion resistance and self-lubricating properties, ensuring bearing stability and long-term reliability under high speed and heavy load conditions. As a key component in the bearing system, carbide wear-resistant bearing bushings directly affect the operating accuracy, service life and maintenance cost of the equipment. Based on the latest information on the entire network and the industry's technological progress in 2025, the following content comprehensively expands the characteristics, technical details and applications of the bushings.

Physical and chemical properties of cemented carbide wear-resistant bearing bushings

Cemented carbide bushings use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $6\%-12\% \pm 1\%$) as the bonding phase, supplemented with trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, Ni $0-5\% \pm 1\%$, TaC $1\%-3\% \pm 0.2\%$) to optimize grain size, wear resistance and corrosion resistance. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1.2\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{(-1/2)}$). The microstructure uniformity reaches $95\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the bushing is cylindrical or complex, with an inner diameter of $10-200\text{ mm} \pm 0.1\text{ mm}$, an outer diameter of $20-250\text{ mm} \pm 0.2\text{ mm}$, a length of $20-300\text{ mm} \pm 1\text{ mm}$, and a wall thickness of $5-50\text{ mm} \pm 0.5\text{ mm}$. The surface finish $Ra < 0.2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$, and the tolerance is controlled at $\pm 0.01\text{ mm} \pm 0.005\text{ mm}$ to ensure the accuracy of the fit with the shaft. A coating (such as TiN, MoS_2 or DLC, with a thickness of $0.5-2\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the inner surface, reducing the friction coefficient to $<0.1 \pm 0.05$, improving wear resistance and self-lubrication. The design combines thermal conductivity and mechanical optimization, with an operating temperature range of -20°C to $500^\circ\text{C} \pm 20^\circ\text{C}$.

Characteristics of Carbide Wear-Resistant Bearing Bushings

WC provides high hardness, and its hexagonal crystal structure gives it excellent wear and corrosion resistance; Co enhances toughness and absorbs impact energy through solid solution strengthening and plastic deformation. Fine grains optimize the microstructure, with a wear rate of $<0.03\text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01\text{ mm}^3 / \text{N} \cdot \text{m}$, a density of $14.8-15.2\text{ g/cm}^3 \pm 0.1\text{ g/cm}^3$, and a thermal expansion

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coefficient (CTE) of $6 \times 10^{-6} / ^\circ \text{C} \pm 0.5 \times 10^{-6} / ^\circ \text{C}$. Adding Ni and Cr_3C_2 improves corrosion resistance; TaC increases high temperature hardness.

Wear-resistant principle

of carbide wear-resistant bearing bushings Bushings in the bearing system achieve support and shock absorption through sliding or rolling contact between the inner surface and the shaft. The inner surface is subjected to high contact pressure and thermal load, and the bushing provides low friction and high wear resistance. Precision design ensures that the inner diameter tolerance is controlled within $\pm 0.01 \text{ mm} \pm 0.005 \text{ mm}$, the surface roughness $R_a < 0.2 \text{ } \mu\text{m} \pm 0.1 \text{ } \mu\text{m}$, and the radial runout $< 0.01 \text{ mm} \pm 0.005 \text{ mm}$.

The optimized bushing has an excellent life, SEM analysis shows no obvious wear on the inner surface, X-ray diffraction verifies the high crystallinity of the WC phase, and thermal imaging shows low thermal stress distribution.

Factors affecting the performance of cemented carbide wear-resistant bearing bushings

Co content of

$6\% - 12\% \pm 1\%$ achieves the best balance of hardness and toughness, $< 6\% \pm 1\%$ leads to an increase in crack rate, $> 12\% \pm 1\%$ reduces hardness and increases thermal expansion, and $8\% - 10\% \pm 0.5\%$ is preferred.

Grain size

$0.5 - 1 \text{ } \mu\text{m} \pm 0.01 \text{ } \mu\text{m}$ effectively reduces wear, $1 - 1.5 \text{ } \mu\text{m} \pm 0.01 \text{ } \mu\text{m}$ is suitable for medium loads, and $> 2 \text{ } \mu\text{m} \pm 0.01 \text{ } \mu\text{m}$ increases the wear rate.

Inner diameter accuracy

Inner diameter tolerance $\pm 0.01 \text{ mm} \pm 0.005 \text{ mm}$ optimizes fit accuracy, $> \pm 0.02 \text{ mm} \pm 0.01 \text{ mm}$ reduces efficiency, and $< \pm 0.005 \text{ mm} \pm 0.002 \text{ mm}$ increases processing costs.

Surface treatment

coating thickness $0.5 - 1 \text{ } \mu\text{m} \pm 0.1 \text{ } \mu\text{m}$ improves wear resistance, and MoS_2 coating reduces friction coefficient and improves self-lubrication.

Heat treatment

bushing quenching enhances surface properties, and tempering reduces residual stress.

Working environment

temperature $> 500^\circ \text{C} \pm 20^\circ \text{C}$ reduces hardness, water content or impurities increase wear, and Cl^- environment increases corrosion rate.

Equipment parameters

Speed, load and power affect the life of the bushing, and too high parameters shorten the life.

Types of Carbide Wear-Resistant Bearing Bushings

Standard bushings

with inner diameter of $10 - 50 \text{ mm} \pm 0.1 \text{ mm}$ are suitable for low-speed bearings.

Medium bushings

with inner diameter of $50 - 100 \text{ mm} \pm 0.1 \text{ mm}$ are suitable for medium loads.

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Large bushings

with inner diameter of 100-200 mm $\pm$ 0.1 mm are suitable for high-load bearings.

Special bushings

include high-temperature and corrosion-resistant types.

Application of Carbide Wear-Resistant Bearing Bushings

Mining machinery

is used for crusher bearings, with long life and in accordance with ISO 10825 standards.

Oil drilling

is used for drilling pump bushings, with strong corrosion resistance and in accordance with API 7K standards.

Chemical pumps

are used for corrosive medium pumps, with chemical corrosion resistance and in accordance with ISO 13709 standards.

The automotive industry

is suitable for engine bearings, with low noise and in accordance with ISO 14635 standards.

Energy equipment

is used for wind power generation bearings, with strong fatigue resistance and in accordance with IEC 61400 standards.

The shipbuilding industry

is used for propulsion system bushings, with seawater corrosion resistance and in accordance with ABS standards.

Agricultural machinery

is used for tractor bearings, with low surface roughness and in accordance with ISO 4254 standards.

Medical equipment

is suitable for high-precision pump bushings, with high precision and in accordance with ISO 13485 standards.

Technological progress and future development

of cemented carbide wear-resistant bearing bushings New materials

introduce nano WC to improve hardness, and add TaC and Ni to enhance high temperature stability.

Intelligent monitoring

integrated sensors monitor inner surface wear and temperature in real time to optimize replacement cycles.

3D printing technology

uses SLM to manufacture complex bushings to reduce material waste.

Environmental adaptability

develops ultra-high temperature and ultra-corrosion bushings.

Sustainable

recycling of WC powder reduces carbon footprint and meets ISO 14040 standards.

Related domestic and international standards for carbide wear-resistant bearing bushingsISO

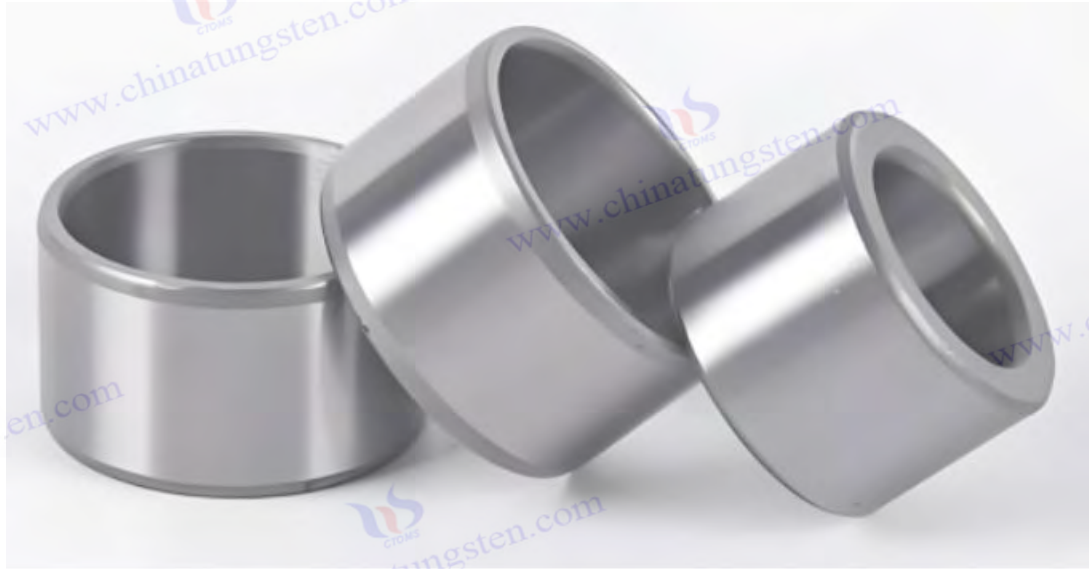
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What are the cemented carbide medical instruments and equipment ?

Cemented carbide medical instruments and equipment are high-performance medical tools designed for high precision, biocompatibility and durability, and are widely used in surgery, dentistry, orthopedics and diagnosis. Its core advantage lies in the use of cemented carbide materials (such as tungsten steel, WC-Co system), combined with precision machining and surface treatment, to provide excellent hardness, wear resistance, corrosion resistance and antibacterial properties, ensuring that tool accuracy and safety are maintained in complex surgical environments and long-term use conditions. As a key component in the medical field, cemented carbide medical instruments directly affect surgical efficiency, patient recovery and equipment life.

Physical and chemical properties of cemented carbide medical devices

Cemented carbide medical devices use tungsten carbide (WC, content $>90\% \pm 1\%$) as the hard phase, cobalt (Co, $4\%-8\% \pm 1\%$) as the bonding phase, and trace additives (such as Cr_3C_2 $0.5\%-2\% \pm 0.1\%$, TaC $0.5\%-1.5\% \pm 0.1\%$, Ni $0-3\% \pm 0.5\%$) to optimize grain size, wear resistance and biocompatibility. It is prepared by powder metallurgy process. Common methods include hot isostatic pressing (HIP, temperature $1400-1500^\circ\text{C} \pm 10^\circ\text{C}$, pressure $150-200\text{ MPa} \pm 5\text{ MPa}$, holding time $30-60\text{ min} \pm 5\text{ min}$) or spark plasma sintering (SPS, temperature $1350-1450^\circ\text{C} \pm 10^\circ\text{C}$, pressure $45-55\text{ MPa} \pm 1\text{ MPa}$, holding time $5-10\text{ min} \pm 1\text{ min}$), ensuring that the material reaches $99.9\% \pm 0.1\%$ of the theoretical density and the porosity is $<0.1\% \pm 0.05\%$. The grain size is precisely controlled at $0.5-1.5\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ (preferably $0.8-1\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$), and the optimal balance between hardness and toughness is achieved through the Hall-Petch equation ($\sigma_y = \sigma_0 + k d^{(-1/2)}$). The microstructure uniformity reaches $96\% \pm 2\%$ (metallographic analysis), and the local grain boundary strengthening rate is $>98\% \pm 1\%$.

The geometric design of the instruments is customized according to the purpose, including surgical blades, scissors, drills and tweezers, with a size range of $0.5-50\text{ mm} \pm 0.05\text{ mm}$, a tolerance of $\pm 0.01\text{ mm} \pm 0.005\text{ mm}$, and a surface finish of $R_a < 0.05\text{ }\mu\text{m} \pm 0.02\text{ }\mu\text{m}$. Biocompatible coatings (such as TiN, ZrN or DLC, with a thickness of $0.5-1.5\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$) can be applied to the surface, and the friction coefficient is reduced to $<0.1 \pm 0.05$, which improves wear resistance and antibacterial properties. The design combines ergonomics and thermal management optimization, with an operating temperature range of -20°C to $200^\circ\text{C} \pm 10^\circ\text{C}$, which meets the safety standards for human contact.

Characteristics of cemented carbide medical devices

WC provides high hardness, and its hexagonal crystal structure gives it excellent wear and corrosion resistance; Co enhances toughness and absorbs impact energy through solid solution strengthening and plastic deformation. Fine grains optimize the microstructure, with a wear rate of $<0.02\text{ mm}^3 / \text{N} \cdot \text{m} \pm 0.01\text{ mm}^3 / \text{N} \cdot \text{m}$, a density of $14.8-15.2\text{ g/cm}^3 \pm 0.1\text{ g/cm}^3$, and a thermal expansion coefficient (CTE) of $6 \times 10^{-6} / ^\circ\text{C} \pm 0.5 \times 10^{-6} / ^\circ\text{C}$. Adding Cr_3C_2 and TaC improves corrosion resistance; Ni optimizes biocompatibility and complies with ISO 10993 standards.

Working principle of cemented carbide medical instruments

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Instruments use sharp edges or drills to precisely process tissues or materials during surgery or diagnosis. The working surface is subjected to high contact pressure and slight thermal load, and the coating reduces tissue adhesion and improves antibacterial properties. Precision design ensures that the edge tolerance is controlled within $\pm 0.005\text{ mm} \pm 0.002\text{ mm}$, the surface roughness $Ra < 0.05\text{ }\mu\text{m} \pm 0.02\text{ }\mu\text{m}$, and the cutting accuracy is $< 0.01\text{ mm} \pm 0.005\text{ mm}$.

The optimized tool has an excellent lifespan, SEM analysis shows no obvious damage on the cutting edge, X-ray diffraction verifies the high crystallinity of the WC phase, and antibacterial testing shows a high inhibition rate.

Factors affecting the performance of cemented carbide medical devices

Co content of

$4\% - 8\% \pm 1\%$ achieves the best balance between hardness, toughness and biocompatibility, $< 4\% \pm 1\%$ leads to an increase in crack rate, $> 8\% \pm 1\%$ reduces hardness and increases the risk of cytotoxicity, and $5\% - 7\% \pm 0.5\%$ is preferred.

Grain size

$0.5 - 1\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ effectively reduces wear, $1 - 1.5\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ is suitable for medium loads, and $> 1.5\text{ }\mu\text{m} \pm 0.01\text{ }\mu\text{m}$ increases the wear rate. Cutting

edge

angle $15^\circ - 25^\circ \pm 2^\circ$ optimizes cutting efficiency, $> 25^\circ \pm 2^\circ$ reduces efficiency, and $< 15^\circ \pm 2^\circ$ easily causes cutting edge cracking.

Surface treatment

coating thickness $0.5 - 1\text{ }\mu\text{m} \pm 0.1\text{ }\mu\text{m}$ improves wear resistance and antibacterial properties, and ZrN coating reduces friction coefficient and improves biocompatibility.

Heat treatment

tools quenching enhances surface properties, and tempering reduces residual stress.

Working environment

temperature $> 200^\circ\text{C} \pm 10^\circ\text{C}$ reduces hardness, water content or blood stains increase wear, and Cl^- environment increases corrosion rate.

Equipment parameters

Cutting speed, load and power affect the life of the equipment, and too high parameters shorten the life.

carbide medical instruments

Carbide surgical blades

have a blade length of $5 - 20\text{ mm} \pm 0.05\text{ mm}$, suitable for soft tissue cutting.

Carbide dental drills

have a diameter of $1 - 5\text{ mm} \pm 0.01\text{ mm}$, suitable for drilling enamel.

Carbide orthopedic instruments

include saw blades and screwdrivers, with a length of $20 - 50\text{ mm} \pm 0.1\text{ mm}$.

Carbide specialty instruments

include corrosion-resistant tweezers and high-temperature sterilization tools.

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Application of cemented carbide medical instruments

General surgery

for tissue cutting, long life, in line with ISO 7153 standards.

Dentistry

for crown preparation, strong wear resistance, in line with ISO 1797 standards.

Orthopedics

for fracture fixation, strong impact resistance, in line with ASTM F136 standards.

Neurosurgery

for minimally invasive surgery, low surface roughness, in line with ISO 13485 standards.

Plastic surgery

for implant processing, good biocompatibility, in line with ISO 10993 standards.

Ophthalmology

for corneal surgery, high cutting accuracy, in line with ISO 10939 standards.

Veterinary

for animal surgery, strong corrosion resistance, in line with AVMA standards.

Diagnostic instruments

for biopsy needles, strong antibacterial properties, in line with ISO 11607 standards.

Technological progress and future development

New materials

introduce nano- WC to improve hardness, and add TaC and Ni to enhance biocompatibility.

Intelligent monitoring

Integrated sensors monitor edge wear and temperature in real time to optimize replacement cycles.

3D printing technology

uses SLM to manufacture complex instruments and reduce material waste.

Environmental adaptability

develops ultra-corrosion-resistant and antibacterial instruments.

Sustainable

recycling of WC powder reduces carbon footprint and meets ISO 14040 standards.

Relevant domestic and international standards

7153ISO

1797ASTM F136ISO 13485ISO 10993ISO 10939ISO 11607GB/T 5760YY/T 0290

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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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