Tungsten Cemented Carbide

Comprehensive Exploration of Physical & Chemical Properties, Processes, & Applications (XI)

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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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.

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Part 4: Classification and application fields of cemented carbide

Chapter 11 Carbide Cutting Tools and Processing

11.0 Carbide Cutting Tools and Processing

11.0.1 What is cutting?

Cutting is a core process in machining, which is a process of using tools to cut off excess parts from the workpiece material to obtain the desired shape, size and surface quality. Cutting relies on the sharpness of the tool and the plastic or brittle deformation of the material, and gradually removes the material layer by using forces such as shear, extrusion and friction. The cutting process usually involves high-speed rotation or feed motion, which produces chips and exhibits different physical properties in metal cutting (such as steel, cast iron) or non-metal cutting (such as composite materials). The efficiency and quality of cutting are directly affected by the tool material, geometric parameters, cutting parameters (such as speed, feed rate, depth of cut) and the hardness and toughness of the workpiece material. As a key tool in cutting processing, cemented carbide cutting tools have significantly improved cutting accuracy, efficiency and tool life with their excellent performance, and have become an indispensable part of modern manufacturing.

1.0.2 What are carbide cutting tools?

Cemented carbide cutting tools are cutting tools made of cemented carbide as the base material. They are widely used in metal cutting, non-metallic processing, and composite material processing. With their excellent mechanical properties and durability, they have become an indispensable core equipment in modern manufacturing. Cemented carbide is a composite material made of carbide (such as tungsten carbide WC, titanium carbide TiC , tantalum carbide TaC) as a hard phase and metal (such as cobalt Co, nickel Ni) as a bonding phase through advanced powder metallurgy processes (including mixing, pressing, sintering and post-processing). Its preparation process involves precise proportioning of high-purity raw materials, high-temperature sintering (1400-1600°C) under vacuum or inert atmosphere, and precision machining or coating treatment to ensure material uniformity and performance stability. Its excellent performance is mainly reflected in the following key aspects:

Excellent performance of cemented carbide cutting tools - high hardness
The hardness range is HV 1600-2500 (±30), which is much higher than traditional high-speed steel (HV 800-900) or tool steel (HV 600-700). This feature enables it to effectively cut a variety of high-hardness materials, including steels (such as carbon steel Q235 HV 150-250±10, alloy steel 40Cr HV 200-400±10), cast irons (such as gray cast iron HT200 HV 150-220±10, ductile iron QT500 HV 200-250±10), as well as difficult-to-machine materials (such as titanium alloy TC4 HV 300-400±10, nickel-based alloy Inconel 718 HV 400-500±10) and superhard materials (such as polycrystalline diamond PCD HV >5000±50). This high hardness maintains cutting edge stability during high-

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speed cutting, avoids geometric misalignment due to wear, and significantly extends tool life (up to hundreds of hours under suitable working conditions), making it particularly suitable for high-precision and continuous cutting tasks.

Excellent performance of cemented carbide cutting tools - excellent toughness

The fracture toughness ($K_{1}c$) is 10-20 MPa·$m^{1/2}$ (±0.5), and a dynamic balance between hardness and toughness is achieved by adjusting the cobalt content of the binder phase (usually 6 %-20%) or adding trace rare earth elements (such as Ce, La). This toughness property enables it to withstand high-frequency impact, vibration and thermal stress during the cutting process, especially in intermittent cutting (such as machining cast iron or workpieces with gaps), heavy-load machining (such as deep hole drilling) or intermittent loading conditions. In addition, by optimizing the grain size (0.5-2 μm) or introducing nano-scale carbides, the material's resistance to crack propagation is further improved, ensuring the structural integrity of the tool under complex working conditions.

Excellent performance of cemented carbide cutting tools - wear resistance

The wear rate is less than 0.05 mm^3 / N · m (±0.01 mm^3 / N · m) . Thanks to the high hardness of carbides and the lubrication of the binder phase, the tool can maintain its cutting performance after long-term cutting (lifespan >10 hours±1 hour, up to 50-100 hours depending on the working conditions). Especially under conditions of high speed (1000-2000 m/min±10 m/min) or containing hard particles (such as grinding wheel abrasives, ceramic powder), cemented carbide tools show excellent wear resistance. This wear resistance comes from the synergistic effect of the dense structure inside the material (density >98% theoretical value) and the surface coating (such as TiN , Al_2O_3 , TiAlN , thickness 5-25 μm), and is widely used in high-load processing scenarios such as high-speed milling, drilling and turning .

Excellent performance of cemented carbide cutting tools - other performance advantages

In addition to the above core characteristics, cemented carbide cutting tools also have excellent resistance to high-temperature oxidation (resistant to 800-1000°C), low thermal expansion coefficient (about $4.5\text{-}6.0\times10^{-6}$ /°C), and good chemical stability (acid and alkali corrosion resistance). These characteristics enable it to adapt to a variety of processing environments from room temperature to high temperature (300-800°C), and are particularly suitable for aerospace (such as titanium alloy processing), energy industry (such as high-temperature alloy blades) and electronics industry (such as high-precision micromachining). In addition, through modern manufacturing technologies (such as hot isostatic pressing HIP and laser surface treatment), the internal defects of the tool (such as pores and cracks) are effectively reduced, further improving its service life and reliability.

Application and development of cemented carbide cutting tools

The application range of cemented carbide cutting tools covers a variety of workpieces such as steel, cast iron, difficult-to-process materials, non-ferrous metals, composite materials and superhard materials. They are widely used in automobile manufacturing (such as engine parts), aerospace (such as turbine discs), mold processing (such as stamping dies) and electronics industry (such as

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circuit board drilling). With the advancement of Industry 4.0 and intelligent manufacturing, cemented carbide tools are moving towards high performance (such as nano coatings, gradient materials) and intelligence, such as integrated sensors to monitor wear status or optimize cutting parameters through AI to meet higher efficiency and more complex needs.

11.0.3 What are the cemented carbide cutting tools?

Carbide cutting tools are cutting tools made of cemented carbide as the base material. With their excellent hardness, wear resistance and toughness, they are widely used in metal cutting and non-metal processing. These tools meet the diverse needs from general processing to high-precision and complex working conditions through precision design, advanced surface treatment processes and geometric optimization. The following are the main types of carbide cutting tools and their characteristics, application scenarios and optimization technologies, which are comprehensively and detailedly explained in combination with industry practices and the latest technological developments.

(1) Carbide turning tools
are the core tools in lathe processing. Through the rotation of the workpiece and the axial or radial feeding of the tool, the cutting of the outer circle, inner hole, end face, step, thread and complex contour is completed. Carbide turning tools are usually made of high-hardness materials (such as YG6, YG8, YT15, YT30). The tool body includes solid carbide, welded carbide blades or replaceable blade structures to meet different processing requirements. The tool rake angle (5°-15°±0.5°) and back angle (6°-12°) are precisely geometrically optimized to reduce cutting force and chip resistance and improve cutting efficiency; the secondary back angle (1°-3°) and cutting edge chamfer (0.1-0.2 mm) further enhance the ability to resist chipping . Surface coating technology is widely used, such as PVD coating (TiN , TiCN , thickness 2-5 μm) and CVD coating (Al_2O_3 , TiAlN , thickness 5-25 μm±0.1 μm) , which significantly improves heat resistance (up to 1000°C), wear resistance and oxidation resistance. During the cutting process, the turning tool needs to withstand the stable load of continuous cutting or the impact of intermittent cutting. The service life is generally 10-20 hours (±1 hour), and the accuracy can reach <0.01 mm (±0.001 mm), which is suitable for high-precision parts processing. Its technical characteristics include cutting speed 100-500 m/min (±10 m/min), hardness HV 1800-2200, fracture toughness 12-18 MPa·$m^{1/2}$, wear rate <0.05 mm^3 / N · m . It is widely used in the automotive industry to process crankshafts, camshafts and connecting rods, mold manufacturing precision turning mold cavities and stamping dies, and aviation parts processing titanium alloy outer circles and aluminum alloy parts.

(2) Carbide milling cutters: Milling cutters are used for high-speed cutting with multiple
blades on a milling machine . They are suitable for machining planes, slots, steps, sides and complex curved surfaces. They are the core tools of multi-axis machining centers. Carbide milling cutters include end mills, face mills, ball-end mills and profile mills. Commonly used grades include YG10 (high toughness, suitable for intermittent cutting), YT30 (high heat resistance, suitable for high temperature conditions) and YW2 (excellent overall performance). End mills are mostly solid

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carbide structures with 2-4 blades and a diameter of 3-20 mm. They are suitable for small-diameter holes and slots and fine machining. Face mills have larger diameters (50-200 mm) and use replaceable blades or integral designs. They have 4-12 blades and are suitable for large-area plane milling. Ball-end mills and profile mills are used for complex curved surfaces and mold machining. Geometric optimization includes helix angle (30°-45°±1°) to improve chip discharge, positive rake angle (5°-10°) to reduce cutting force, and R angle (0.5-2 mm) to enhance edge strength. CVD coating (such as TiAlN , Al_2O_3 , thickness 10-25 μm) or PVD coating (such as CrN , thickness 2-5 μm) provides temperature resistance (up to 1100°C) and wear protection. Cutting speed 200-1000 m/min, life 5-15 hours, accuracy <0.02 mm, its technical characteristics are hardness HV 1700-2100, fracture toughness 14-20 $MPa·m^{1/2}$, strong impact resistance, the main application scenarios include aerospace processing of aluminum alloy skins and titanium alloy components, mold industry milling of complex surfaces and stamping dies, and machining of slot parts and gear profiles.

(3) Carbide drills

Carbide drills are used for drilling, replacing traditional high-speed steel drills, and are suitable for drilling deep holes, small diameter holes, and multi-layer materials. Twist drills are general-purpose, using YG6X (nanocrystalline structure , hardness HV 1900-2000), with a helix angle of 25°-35°±1°, and can drill holes with a diameter of 5-50 mm, suitable for general-purpose drilling; deep hole drills (such as gun drills) use YW1, with a length-to-diameter ratio of up to 100:1, equipped with internal cooling channels to reduce heat accumulation and chip removal, suitable for deep hole processing (such as >100 mm); step drills use a multi-layer blade design, which can process step holes of different diameters at one time, and are widely used in molds and mechanical parts. PVD coating (such as TiN , TiCN , thickness 10-15 μm) or CVD coating (diamond, thickness 5-10 μm) enhances wear resistance and high temperature resistance, cutting speed 50-300 m/min, life 10-30 hours, precision <0.01 mm. Its technical characteristics include hardness HV 1800-2200, wear resistance <0.03 $mm^3/N·m$, good high temperature resistance (up to 900°C), widely used in automotive parts drilling (such as cylinder blocks, connecting rods), electronic component PCB board processing, and deep hole drilling of aviation structural parts (such as wing joints). The key to optimization is to add self-lubricating coating (such as MoS_2) to reduce friction and optimize the chip groove design to prevent clogging.

(4) Carbide Boring Tools

Boring tools are used to expand or fine-tune existing hole diameters. Carbide boring tools are mostly adjustable, integral or replaceable. Rough boring tools use YG8 (high toughness, HV 1700-1900), with a cutting depth of 1-5 mm, suitable for rapid roughing, and a tool diameter range of 20-150 mm; fine boring tools use YT5 (hardness HV 1750-1850), with a cutting depth of 0.1-0.5 mm and an accuracy of <0.005 mm, suitable for high-precision hole processing. The tool geometry includes a rake angle of 5°-10° (negative rake angle can be used for rough boring), a secondary back angle of 2°-5° and a cutting edge relaxation angle (0.2°-0.5°). CVD coating (such as Al_2O_3 , thickness 10-20 μm) or PVD coating (such as TiAlN) enhances heat resistance and surface finish. The cutting speed is 100-400 m/min, the service life is 15-25 hours, and the technical characteristics are fracture toughness of 12-16 $MPa·m^{1/2}$ and surface roughness Ra <0.4 μm . The main application scenarios

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include engine cylinder block fine boring (cylinder diameter accuracy <0.01 mm), hydraulic parts internal hole processing (such as pump body), and mold precision boring (such as punching die).

(5) Carbide reamers (Reamers)

Reamers are used for finishing the hole diameter, improving the roundness, tolerance and surface finish, and are suitable for mass production and high-precision requirements. Machine reamers use YG6 (hardness HV 1800-2000), with a diameter range of 5-50 mm, 4-8 blades, and a blade length of 1.5-2 times the diameter; adjustable reamers use YT15 , with an adjustment range of ±0.02 mm, which is suitable for fine-tuning the hole diameter and multi-specification processing. The geometric design includes straight or spiral blades (helix angle 5°-10°), rake angle 5°-8°, PVD coating (such as TiCN , thickness 10-15 µm) or CVD coating (such as Al_2O_3) to improve wear resistance and anti-sticking. Cutting speed 20-100 m/min, life 20-40 hours, accuracy <0.002 mm, its technical characteristics include hardness HV 1800-2100, wear resistance <0.02 mm^3 / N · m , widely used in bearing hole finishing (roundness <0.005 mm), automobile transmission shaft holes, and precision instrument parts (such as measuring tool holes).

(6) Carbide broaches :

Broaches are used for broaching and are suitable for mass production of keyways, tooth shapes, racks and complex contours. Circular broaches use YW2 (strong heat resistance, HV 1750-2000), with a diameter of 10-100 mm, 10-20 teeth, and progressive tooth height (0.1-0.5 mm/tooth); flat broaches use YG10, with a width of 20-100 mm and 15-30 teeth, suitable for plane broaching. Geometric optimization includes rake angle of 5°-10°, chip groove depth of 2-5 mm, CVD coating (such as TiAlN , thickness of 15-20 µm) or PVD coating (such as CrN) to enhance impact resistance and heat resistance. The cutting speed is 10-50 m/min, the service life is 10-20 hours, and the accuracy is <0.01 mm. Its technical characteristics are fracture toughness of 14-18 MPa·$m^{1/2}$ and excellent impact resistance. The main application scenarios include gear keyway broaching (module 1-5), aviation structural parts tooth drawing (such as fuselage connectors), and mold drawing (such as punching dies).

(7) Carbide forming tools:

Forming tools are used to process specific shapes, such as tooth profiles, curved surfaces or special contours, and are widely used in multi-axis CNC machining. The tooth profile cutter uses YT30 (good heat resistance, HV 1600-1800), which processes gears with a module of 1-10, and the tool diameter is 50-200 mm; the curved surface cutter uses YW1A, and complex curved surface processing requires 5-axis linkage, and the tool radius is 5-50 mm. The geometric design includes forming blades (R 0.1-2 mm), relaxation angles (0.1°-0.5°) and multi-blade structures (3-6 blades). PVD coatings (such as CrN , thickness 15-25 µm) or CVD coatings (such as TiAlN) provide wear resistance and high temperature resistance protection. Cutting speed is 50-200 m/min, life is 5-15 hours, precision is <0.02 mm, its technical characteristics include hardness HV 1700-2000, wear resistance <0.04 mm^3 / N · m , widely used in automotive gear forming (module 2-8), precision part surface processing (such as mobile phone housing), and aviation blade manufacturing (such as turbine blades).

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(8) Special carbide cutting tools

Special carbide cutting tools are designed for specific working conditions, including composite tools, superhard material tools and micro tools. Composite tools use YG6X (nanocrystalline, HV 1900-2100), low heat design is required for processing CFRP, tool diameter is 6-20 mm, number of blades is 2-4; superhard material tools cut PCD, use CVD coating (such as diamond, thickness 5-10 μm), tool diameter is 3-15 mm; micro tool diameter is <1 mm, nano carbide (grain <0.5 μm) is used , and accuracy is <0.005 mm. Cutting speed is 100-500 m/min, life span is 5-10 hours, its technical characteristics include hardness HV 1800-2200, excellent high temperature resistance (up to 1000°C), wear resistance <0.03 mm^3 / N · m , and it is widely used in aviation composite material processing (such as wing skins), electronic microcircuit boards (such as chip substrates), and medical device micro-hole drilling (such as orthopedic implants).

(8.1) Nano-carbide cutting tools

Nano-carbide cutting tools use nano-grade carbide (such as YG6X, YW1) with a grain size of less than 0.5 μm , and use nano-powder sintering technology to improve the material density and hardness. The tool geometry design includes a rake angle of 5°-10° and a helix angle of 30°-40° . The PVD coating (such as TiN , TiAlN , thickness 5-10 μm) enhances wear resistance and high temperature resistance. The cutting speed is 200-600 m/min, the service life is 8-15 hours, and the accuracy is <0.01 mm. Its technical characteristics include hardness HV 2000-2300, fracture toughness 15-20 MPa·m $^{1/2}$, and wear resistance <0.02 mm^3 / N · m . It is widely used in high-precision mold processing, automotive parts finishing, and fine-tuning of aviation structural parts.

(8.2) Carbide composite tools

Carbide composite tools are designed for machining carbon fiber reinforced plastics (CFRP, HV 200-300) and glass fiber reinforced plastics (GFRP). They are made of YG6X (nanocrystalline structure , HV 1900-2100) or composite materials doped with SiC particles. The tool diameter is 6-20 mm and the number of blades is 2-4. The geometric optimization includes negative rake angle (-5° to 0°) and serrated cutting edge . CVD coating (such as diamond, thickness 5-15 μm) provides low-heat cutting capability, cutting speed 100-300 m/min, life 5-10 hours, and accuracy <0.02 mm. Its technical characteristics include excellent high temperature resistance (up to 900°C) and wear resistance <0.03 mm^3 / N · m . It is widely used in aviation composite processing (such as wing skins), wind turbine blade manufacturing, and sports equipment molding.

(8.3) Cemented carbide superhard material tools

Cemented carbide superhard material tools are designed for cutting polycrystalline diamond (PCD, HV >5000) and cubic boron nitride (CBN, HV 4000-5000). They use YG6X as the substrate, with CVD coating (such as diamond, thickness 5-10 μm) or CBN particles to enhance the cutting edge. The tool diameter is 3-15 mm and the number of blades is 1-3. The geometric design includes a rake angle of 0°-5° and a relaxation angle (0.1°-0.3°), a cutting speed of 50-200 m/min, a life of 5-12 hours, and an accuracy of <0.005 mm. Its technical characteristics include hardness HV 2200-2500, wear resistance <0.01 mm^3 / N · m , and strong high temperature resistance (up to 1100°C). It is

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widely used in the finishing of cemented carbide molds, cutting of ceramic products, and gemstone processing.

(8.4) Carbide micro-tools

Carbide micro-tools are suitable for micron-level machining. They are made of nano-carbide (grain <0.5 µm), with a tool diameter <1 mm, a blade length of 1-5 mm, and 1-2 blades. Geometric optimization includes rake angle 5°-15° and micro helix angle (20°-30°). PVD coating (such as CrN , thickness 2-5 µm) improves wear resistance and anti-adhesion. Cutting speed 100-500 m/min, life 5-10 hours, accuracy <0.005 mm. Its technical characteristics include hardness HV 2000-2300, fracture toughness 12-15 $MPa \cdot m^{1/2}$, wear resistance <0.02 mm^3 / N · m . It is widely used in electronic micro-circuit board processing (such as chip substrates), medical device micro-hole drilling (such as orthopedic implants) and micro-electromechanical system (MEMS) manufacturing.

(8.5) PCD cutting with superhard material tools

PCD cutting with superhard material tools is a special application of cemented carbide superhard material tools. It uses a YG6X substrate and applies a CVD diamond coating (thickness 5-10 µm), a tool diameter of 3-12 mm, and 1-2 blades . The geometric design includes zero rake angle (0°) and polished cutting edge, cutting speed of 50-150 m/min, life of 5-10 hours, and accuracy of <0.005 mm. Its technical characteristics include hardness HV 2200-2500, wear resistance <0.01 mm^3 / N · m , and excellent high temperature resistance (up to 1200°C). It is widely used in the regrinding of PCD tools, the dressing of cemented carbide molds, and the manufacture of high-precision cutting tools.

(8.6) Carbide coated cutting tools Carbide coated cutting tools

are coated with various coatings (such as TiN , TiCN , Al_2O_3 , TiAlN , thickness 5-25 µm) through PVD or CVD technology . They are suitable for processing a variety of materials. Tool types include turning tools, milling cutters and drills. The coating selection is adjusted according to the workpiece material. For example , TiAlN is suitable for high-temperature steel, Al_2O_3 is suitable for cast iron, cutting speed is 100-800 m/min, life is 10-30 hours, and accuracy is <0.01 mm. Its technical characteristics include hardness HV 1800-2300, wear resistance < 0.03 mm^3 / N · m , and oxidation resistance temperature up to 1000°C. It is widely used in mass processing of automotive parts, aviation titanium alloy cutting, and mold finishing.

(8.7) Carbide cutting tools for machining aviation composite materials (such as wing skins)

This tool is designed specifically for aviation composite materials (such as CFRP, HV 200-300). It uses a YG6X matrix, doped with diamond particles, a tool diameter of 6-15 mm, and 2-4 blades . The geometric design includes serrated edges and negative rake angles (-5° to 0°), CVD diamond coating (thickness 10-15 µm) to reduce thermal damage, cutting speed 100-300 m/min, life 5-10 hours, and accuracy <0.02 mm. Its technical characteristics include high temperature resistance (up to 900°C) and wear resistance <0.03 mm^3 / N · m . It is widely used in precision cutting of wing skins, fuselage panels, and aviation structural parts.

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(8.8) Cemented carbide electronic microcircuit board (such as chip substrate) cutting tool

This microcutting tool is made of nano-cemented carbide, with a tool diameter of 0.2-1 mm, a blade length of 1-3 mm, and 1-2 blades. The geometric design includes a rake angle of 5°-10° and a micro-helix angle (20°-30°). The PVD coating (such as CrN , thickness 2-5 μm) improves wear resistance. The cutting speed is 100-400 m/min, the service life is 5-10 hours, and the accuracy is <0.005 mm. Its technical characteristics include hardness HV 2000-2300 and wear resistance <0.02 mm^3 / N · m . It is widely used in chip substrate micro-hole processing, circuit board drilling, and fine manufacturing of electronic components.

(8.9) Tools for micro-hole drilling of medical devices (e.g. orthopedic implants)

This tool is made of nano-carbide, with a tool diameter of 0.5-2 mm, a blade length of 2-5 mm, and 1-2 blades. The geometric design includes a rake angle of 10°-15° and a polished edge. The PVD coating (e.g. TiN , thickness 2-5 μm) ensures biocompatibility, a cutting speed of 50-200 m/min, a life of 5-15 hours, and an accuracy of <0.005 mm. Its technical characteristics include hardness HV 2000-2200, fracture toughness 12-15 MPa·m $^{1/2}$, and wear resistance <0.02 mm^3 / N · m . It is widely used in micro-hole drilling of orthopedic implants, dental tool processing, and medical device finishing.

(8.10) Carbide medical surgical tools

Carbide medical surgical tools are made of ultrafine nano-carbide (such as YG6X), with a tool length of 30-50 mm, a blade thickness of 0.1-0.3 mm, and one blade. The geometric design includes an ultra-thin blade edge (R <0.01 mm) and a rake angle of 15°-20°. The PVD coating (such as TiN , thickness 1-3 μm) provides corrosion resistance and biocompatibility. The cutting speed is 10-50 m/min (manual or low-speed mechanical), the life span is 20-50 operations, and the accuracy is <0.01 mm. Its technical characteristics include hardness HV 2000-2300 and wear resistance <0.01 mm^3 / N · m . It is widely used in soft tissue cutting, bone plastic surgery, and minimally invasive surgical tool manufacturing.

Carbide cutting tools are widely used in automobile manufacturing, aerospace, mold processing and electronic industries due to their diversity and high performance. Different types of tools are selected according to the workpiece material (such as steel, cast iron, titanium alloy) and processing requirements (such as precision, speed) with appropriate grades (such as YG, YT, YW series), and the life is extended through coatings (such as TiN , Al_2O_3), geometric optimization (such as helix angle, rake angle) and cooling technology (such as internal cooling channels).

table of cemented carbide cutting tools

Knives type	Typical grades	Hardness (HV)	Fracture toughness (MPa·m $^{1/2}$)	Cutting speed (m/min)	Accuracy (mm)	life (Hour)	Main application scenarios
turning tool	YG6, YT15	1800-2200	12-18	100-500	<0.01	10-20	Automotive shafts, mold finishing

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Knives type	Typical grades	Hardness (HV)	Fracture toughness (MPa·m¹/²)	Cutting speed (m/min)	Accuracy (mm)	life (Hour)	Main application scenarios
Milling cutter	YG10, YT30	1700-2100	14-20	200-1000	<0.02	5-15	Aerospace skin, mold surface
drill	YG6X, YW1	1800-2200	12-16	50-300	<0.01	10-30	Automotive hole processing , PCB drilling
Boring tool	YG8, YT5	1700-1850	12-16	100-400	<0.005	15-25	Cylinder boring , hydraulic parts processing
Reamer	YG6, YT15	1800-2100	12-16	20-100	<0.002	20-40	Bearing hole, transmission shaft processing
Broach	YW2, YG10	1750-2000	14-18	10-50	<0.01	10-20	Gear keyway, aviation gear
Forming tools	YT30, YW1A	1600-2000	14-18	50-200	<0.02	5-15	Automobile gears, aviation blades
Special tools	YG6X	1900-2100	12-16	100-500	<0.005	5-10	Composite materials, Micromachining

11.0.4 What are the processing objects suitable for cemented carbide cutting tools?

With their excellent hardness, wear resistance and toughness, cemented carbide cutting tools can efficiently process a variety of processing objects, covering metal and non-metal materials, especially showing significant advantages in the fields of high hardness, difficult processing and ultra-precision processing. These tools have a wide range of applications and strong adaptability, and can meet processing needs from ordinary materials to extreme conditions. The following is a detailed description of the processing objects suitable for cemented carbide cutting tools, which is comprehensively explained in combination with the physical properties of the materials, specific processing requirements and actual application scenarios in different industries.

(1) Steels

Steel is the most common processing object of carbide cutting tools, including carbon steel, alloy steel and stainless steel. Carbon steel (such as Q235, hardness HV 150-250) has good machinability and is suitable for general rough machining and finishing; alloy steel (such as 40Cr, hardness HV 200-300) contains alloy elements such as chromium and nickel, has a higher hardness, and requires higher heat resistance when cutting; stainless steel (such as 304, hardness HV 150-250) is prone to chip adhesion due to its high toughness and viscosity, which increases the difficulty of cutting. For this reason, machining usually adopts cutting speed of 100-400 m/min, feed rate of 0.1-0.3 mm/r and cutting depth of 1-5 mm, and anti-adhesion and heat-resistant coatings (such as TiAlN) are used to reduce adhesion and heat accumulation. YT15 and YT30 grades are ideal choices due to their excellent heat resistance and oxidation resistance. They are widely used in the automotive industry to process crankshafts and gears, shaft components in mechanical manufacturing, and steel structures in the construction field. However, built- up edge and heat accumulation are prone to occur during the cutting process, and these challenges need to be effectively addressed by optimizing the use of coolant and adjusting the tool geometry.

(2) Cast Irons

Cast iron is another important machining object, including gray cast iron (such as HT200, hardness HV 150-220), ductile cast iron (such as QT500, hardness HV 200-250) and malleable cast iron. These materials are known for their brittle characteristics, and chips are easy to break during cutting. With their high hardness, cemented carbide tools can effectively cope with the machining needs of cast iron surface roughness and internal defects (such as sand holes or pores). Usually, the parameters of cutting speed 150-500 m/min, feed rate 0.2-0.5 mm/r and cutting depth 2-6 mm are used. Especially in intermittent cutting, it is necessary to ensure that the tool has high toughness. YG6 and YG8 grades are favored for their good balance of toughness and hardness and excellent impact resistance. They are widely used in the machining and manufacturing of engine cylinder blocks, brake discs and pump body castings. However, sand holes and hard spots in castings may cause tool edge breakage , which needs to be reduced by adjusting cutting parameters and optimizing machining strategies.

(3) Difficult -to-Machine Materials

Difficult-to-machine materials mainly include titanium alloys (such as TC4, hardness HV 300-400), nickel-based alloys (such as Inconel 718, hardness HV 400-500) and high-temperature alloys. These materials are widely used in the aerospace field. Their high strength, high toughness and low thermal conductivity make it easy to generate high temperatures during cutting and cause adhesion on the workpiece surface, increasing the difficulty of processing. For this reason, the processing usually adopts the parameters of cutting speed 20-100 m/min, feed rate 0.05-0.2 mm/r and cutting depth 0.5-2 mm. It is necessary to be equipped with an efficient cooling system and select low-speed and high- torque cutting conditions. YW1 and YW2 grades have enhanced heat resistance due to the presence of tantalum carbide (TaC). Combined with PVD coatings (such as TiN), the performance is further improved. They are widely used in the precision processing of aircraft engine blades, turbine disks and aerospace structural parts. However, heat concentration during cutting may cause deformation of the workpiece, and special tools and optimized processing technology are required to ensure quality.

(4) Non-Ferrous Metals

Nonferrous metals include aluminum alloys (such as 6061, hardness HV 80-120), copper alloys (such as H62, hardness HV 100-150) and magnesium alloys. These materials are soft materials and are prone to tool adhesion during cutting, but they have good thermal conductivity. When processing these materials with carbide tools, special attention should be paid to preventing the formation of built-up edge and ensuring that the surface of the workpiece remains smooth after processing. The parameters of cutting speed 300-1000 m/min, feed rate 0.1-0.4 mm/r and cutting depth 1-4 mm are usually used. High rake angle tools are selected to reduce cutting resistance. YG6X (ultrafine grain structure, high hardness) and YG10 (good toughness) are ideal choices and are widely used in the

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processing of electronic equipment housings, lightweight automotive parts and decorative parts. However, tool adhesion and surface scratches are the main problems, which can be improved by polishing and low-friction coating.

(5) Composite Materials

Composite materials include carbon fiber reinforced plastic (CFRP, hardness HV 200-300) and glass fiber reinforced plastic (GFRP). These materials are anisotropic, high hardness and low toughness. They are prone to delamination or tearing during cutting, and require high wear resistance and cutting stability of the tool. For this reason, the processing usually adopts the parameters of cutting speed 100-300 m/min, feed rate 0.05-0.15 mm/r and cutting depth 0.2-1 mm. Low heat design is required to reduce thermal damage. YG6X (nanocrystalline structure) and tools with PCD coating are the first choice and are widely used in the manufacture of aviation structural parts, wind turbine blades and sports equipment. However, fiber pull-out and thermal damage are key issues, which can be effectively alleviated by oscillating cutting technology.

(6) Ultra-Hard Materials

Superhard materials include polycrystalline diamond (PCD, hardness HV >5000) and cubic boron nitride (CBN, hardness HV 4000-5000), which are mainly used for the processing of high-precision and super-hard workpieces. The extremely high hardness of these materials requires carbide tools with diamond or CBN coatings to achieve effective cutting. The processing usually adopts cutting speeds of 50-200 m/min, feed rates of 0.01-0.1 mm/r and cutting depths of 0.1-0.5 mm. High-rigidity machine tools are required to ensure processing stability. YG6X is used as a substrate support, combined with CVD diamond coating to enhance cutting ability, which is commonly used in carbide molds, ceramic products and precision cutting of gemstones. However, the tool wears quickly and the coating life is limited, so it needs to be replaced regularly or the cutting strategy optimized.

(7) Heat-Treated Materials

Heat-treated materials include hardened steel (such as HRC 50-60, hardness HV 500-700) and case-hardened steel. These materials have high surface hardness, but retain a certain toughness inside. When cutting, special attention should be paid to overcoming the resistance of the hardened layer. For this reason, the processing usually adopts the parameters of cutting speed 50-200 m/min, feed rate 0.05-0.2 mm/r and cutting depth 0.5-2 mm. Heat-resistant coating is required to cope with high temperature. YT5 and YW1 grades are suitable for the processing of such materials because of their characteristics of both heat resistance and hardness. They are widely used in bearing rings, gear shafts and finishing after heat treatment of tools. However, the hardened layer has high requirements on cutting force, which requires high-precision control to avoid premature failure of the tool.

Application Summary

Carbide cutting tools are suitable for steel, cast iron, difficult-to-machine materials, non-ferrous metals, composite materials, super-hard materials and heat-treated materials, covering a wide range of needs from rough machining to finishing. By selecting the appropriate grade (such as YG, YT, YW series) according to the characteristics of the workpiece material and optimizing cutting

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parameters (such as speed, feed rate and cutting depth), the tool can effectively adapt to various materials with hardness ranging from HV 80 to 5000+. In addition, combined with advanced geometric design and coating technology, the performance and service life of the tool in different processing objects are further improved.

List summary comparison

Processing object	Hardness range (HV)	Cutting speed (m/min)	Feed rate (mm/r)	Cutting depth(mm)	Applicable grades	Main application scenarios	challenge
Steel	150-700	100-400	0.1-0.3	1-5	YT15, YT30	Auto parts, Mechanical shafts	Built-up edge , heat build-up
cast iron	150-250	150-500	0.2-0.5	2-6	YG6, YG8	Engine block, Brake disc	Sand hole, chipping
Difficult-to-process materials	300-500	20-100	0.05-0.2	0.5-2	YW1, YW2	Aircraft blades, turbine disks	Heat concentration, deformation
Non-ferrous metals	80-150	300-1000	0.1-0.4	1-4	YG6X, YG10	Electronic housing, automotive lightweight	Sticky knife , scratch
Composite Materials	200-300	100-300	0.05-0.15	0.2-1	YG6X, PCD	Aviation structural parts, wind turbine blades	Delamination, thermal damage
Superhard materials	4000-5000+	50-200	0.01-0.1	0.1-0.5	YG6X, CVD	Carbide molds, ceramics	Fast wear, coating life
Heat treatment materials	500-700	50-200	0.05-0.2	0.5-2	YT5, YW1	Bearing ring, gear shaft	Hardened layer with high cutting force

This chapter will start from four aspects: cutting performance, processing objects, failure analysis and improvement of cemented carbide tools, and systematically analyze its application characteristics, technical advantages and optimization directions in cutting processing, in order to provide theoretical guidance and practical reference for industrial production.

11.1 Geometric parameters of cemented carbide tools

Cemented carbide tools achieve efficient cutting (speed>1000 m/min±10 m/min) and long life (>10 hours±1 hour) by optimizing geometric parameters (front angle , back angle, cutting edge inclination) and coatings (TiAlN , Al_2O_3). Composition (WC>80%±1%, Co 6%12%±1%), grain (0.52 μm±0.01 μm) and process (sintering 1450°C±10°C) directly affect performance (hardness HV 1600 - 2200±30). This section starts with the performance of geometric parameters and cutting edge optimization and coated tools.

11.1.1 Geometric parameters and cutting edge optimization

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Basic principles and technical overview

Tool geometry parameters include rake angle (5°15°±0.5°), back angle (6°12°±0.5°), inclination angle (5°5°±0.5°), cutting edge radius (10 - 50 μm±1 μm) and cutting edge width (0.1 - 0.5 mm±0.01 mm), which optimizes performance by reducing cutting forces (<1000 N±10 N) and improving surface quality (Ra<0.2 μm±0.01 μm). Cutting edge optimization is achieved by grinding (grinding wheel grit <10 μm±1 μm) or laser treatment (power 100 - 200 W±10 W).

The tests include cutting force (dynamometer, accuracy ±1 N), surface roughness (profilometer, accuracy ±0.01 μm) and cutting edge morphology (SEM, resolution <0.1 μm±0.01 μm). For example, a P10 tool (front angle 10°±0.5°) has a cutting force of 800 N±10 N and Ra 0.15 μm±0.01 μm .

Mechanism and performance analysis:

The rake angle (5°15°±0.5°) reduces cutting resistance (friction coefficient <0.3±0.05), and the back angle (6°12°±0.5°) reduces back tool wear (wear bandwidth <0.1 mm±0.01 mm). The cutting edge radius (1050 μm±1 μm) balances sharpness and strength, and the radius <20 μm±1 μm is suitable for finishing (Ra<0.1 μm±0.01 μm). SEM shows that the optimized cutting edge has no microcracks (<0.01 mm±0.001 mm), and EDS confirms that the WC/Co distribution is uniform (deviation <0.1%±0.02%). Cutting tests show that the cutting force of the tool with a rake angle of 10°±0.5° is reduced by 15%±2% compared with 5°±0.5°, and the life is increased by 20%±3%.

Analysis of influencing factors

Rake angle: 10°15°±0.5°, cutting force decreases by 15%±2%; <5°±0.5°, wear increases by 10%±2%.
Back angle: 6°12°±0.5°, wear band width <0.1 mm±0.01 mm; >15°±0.5°, strength reduction by 10%±2%.
Cutting edge radius: 1020 μm±1 μm , excellent finishing; >50 μm±1 μm , cutting force increased by 10%±2%.
Material hardness: HV 18002000±30, high edge stability; <1600±30, edge chipping rate increases by 10%±2%.
Processing speed: 10001500 m/min±10 m/min, balanced performance; >2000 m/min±10 m/min, thermal wear increases by 15%±3%.

For example, the wear band width of a tool with a rake angle of 5°±0.5° (speed 1500 m/min±10 m/min) increases to 0.15 mm±0.01 mm.

The optimization strategy

is to achieve cutting force <1000 N±10 N, Ra<0.2 μm±0.01 μm . The following are recommended:
Geometric optimization: rake angle 10°15°±0.5°, back angle 6°12°±0.5°, cutting edge radius 1020 μm±1 μm .
Edge treatment: laser grinding (power 150 W ± 10 W), micro cracks < 0.01 mm ± 0.001 mm.

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Material selection: WC grain 0.51 μm±0.01 μm , Co 6%10%±1%.
Test specifications: ISO 1832 (geometric parameters), ASTM G99 (friction coefficient).
Verification and optimization: SEM and dynamometer confirm edge quality and cutting forces.

For example, the P10 tool (rake angle 10°±0.5°, cutting edge radius 15 μm±1 μm) has a cutting force of 800 N±10 N and Ra 0.15 μm±0.01 μm .

11.1.2 Performance of coated tools (PVD, CVD)

Basic Principles and Technology Overview

The coated tools are deposited by physical vapor deposition (PVD, TiAlN , 23 μm±0.1 μm) or chemical vapor deposition (CVD, Al_2O_3 , 35 μm±0.1 μm) to improve hardness (HV 25003500±50), wear resistance (wear rate <0.03 mm³/N·m±0.01 mm³/ N·m) and high temperature resistance (>1000°C±10°C). PVD is suitable for high-speed cutting (>1000 m/min±10 m/min), and CVD is suitable for heavy-load cutting (load>1000 N±10 N).

Tests include coating hardness (nanoindentation, accuracy ±50 HV), wear (ASTM G99, accuracy ±0.01 mm³/ N·m) and tool life (ISO 3685, accuracy ±0.01 mm). For example, a PVDTiAlN tool has a hardness of HV 3000±50 and a tool life of 12 hours±1 hour.

Mechanism and performance analysis

PVDTiAlN (Al 50%70%±1%) forms a nano-multilayer structure (layer thickness 510 nm±1 nm), improves hardness (HV 3000±50) and oxidation resistance (oxidation temperature>1000°C±10°C). CVDAl_2O_3 (grain size 0.10.5 μm±0.01 μm) provides a thermal barrier (thermal conductivity <10 W/m·K±0.5 W/ m·K) and reduces crater wear (depth <0.05 mm±0.01 mm). SEM shows that the PVD coating is dense (porosity <0.1%±0.01%) and the CVD coating has regular grains (deviation <0.1%±0.02%). XPS confirms the AlN bond in TiAlN (Al 2p~74 eV±0.1 eV).

Life tests show that the life of PVDTiAlN tools (1000 m/min±10 m/min) is 12 hours±1 hour, and the life of CVDAl_2O_3 (500 m/min±10 m/min) is 15 hours±1 hour.

Analysis of influencing factors

Coating thickness: 25 μm±0.1 μm , service life increases by 30%±5%; >10 μm±0.1 μm , peeling rate increases by 15%±3%.
Deposition temperature: PVD (400-600°C±10°C), low residual stress; CVD (800-1000°C±10°C), adhesion increased by 10%±2%.
Grain size: 0.10.5 μm±0.01 μm , high hardness; >1 μm±0.01 μm , wear resistance decreases by 10%±2%.
Cutting speed: >1000 m/min±10 m/min, PVD is excellent; <500 m/min±10 m/min, CVD is applicable.
Substrate hardness: HV 18002000±30, excellent coating bonding; <1600±30, peeling rate increases by 10%±2%.

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For example, the peeling rate of TiAlN coating (thickness 10 μm ± 0.1 μm) increased to 20% ± 3%.

The optimization strategy
is to achieve hardness HV 25003500±50 and life>10 hours±1 hour. Recommended:
Coating options: PVDTiAlN (high-speed cutting), CVDAl_2O_3 (heavy-load cutting).
Thickness optimization: 25 μm±0.1 μm , porosity <0.1%±0.01%.
Matrix optimization: WC grain 0.51 μm±0.01 μm , Co 6%10%±1%.
Deposition optimization: PVD (500°C ± 10°C), CVD (900°C ± 10°C).
Test specifications: ASTM E384 (nanoindentation), ISO 3685 (lifetime).

For example, PVDTiAlN tool (2 μm±0.1 μm) has a hardness of HV 3000±50 and a life of 12 hours±1 hour.

11.2 Cutting performance

The cutting performance of cemented carbide tools is reflected by high-speed cutting (>1000 m/min±10 m/min) and wear resistance (wear rate <0.05 mm^3/N·m±0.01 mm^3/ N·m), meeting the requirements of high efficiency (processing time <1 min/piece±0.1 min) and long life (>10 hours±1 hour). The performance is closely related to the material (WCCoTiC), coating (TiAlN , Al_2O_3) and working conditions (speed, feed rate).

This section starts with high-speed cutting, wear resistance and tool life.

11.2.1 High-speed cutting (>1000 m/min)

Basic principles and technical overview
High-speed cutting (10002000 m/min±10 m/min) requires tools with high hardness (HV 18002200±30), low friction (coefficient <0.3±0.05) and high temperature resistance (>1000°C±10°C). P10/YT15 tools (TiC 10%15%±1%) combined with PVDTiAlN coating (23 μm±0.1 μm) are suitable for steel (HV 200400±10) and aluminum alloys (>2000 m/min±10 m/min).

The tests include cutting temperature (infrared temperature measurement, accuracy ±5°C), surface quality (Ra<0.2 μm±0.01 μm) and life (ISO 3685, accuracy ±0.01 mm). For example, the YT15 tool (1500 m/min±10 m/min) has a cutting temperature of 800°C±5°C and Ra 0.1 μm±0.01 μm .

Mechanism and performance analysis
High-speed cutting generates high shear stress (>1000 MPa±10 MPa) and heat load (>800°C±5°C), and TiC (10%15%±1%) and TiAlN coatings reduce adhesion (friction coefficient <0.3±0.05). Grain 0.51 μm±0.01 μm improves thermal cracking resistance (crack <0.01 mm±0.001 mm). SEM shows that the YT15 tool wears evenly (depth <0.05 mm±0.01 mm), and EDS confirms the TiC distribution (deviation <0.1%±0.02%). Cutting tests show that the life of YT15 (1500 m/min±10 m/min) is 12

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hours±1 hour, which is better than YG6 (10 hours±1 hour).

Analysis of influencing factors

Cutting speed: 10001500 m/min±10 m/min, life>10 hours±1 hour;>2000 m/min±10 m/min, thermal wear increases by 15%±3%.

Coating: TiAlN (2 μm±0.1 μm), life increased by 30%±5%; without coating, wear rate increased by 20%±3%.

Grain size: 0.51 μm±0.01 μm , excellent resistance to thermal cracking; >2 μm±0.01 μm , crack rate increases by 10%±2%.

Coolant: Oil-based, temperature drops by 10%±2%; water-based, wear rate increases by 10%±2%.

Workpiece hardness: HV 200400±10, balanced performance; >600±10, wear increase of 15%±3%.

For example, the life of a YG6 tool (2000 m/min±10 m/min) is reduced to 8 hours±1 hour.

The optimization strategy

is to achieve a lifespan of >10 hours ±1 hour and Ra <0.2 μm ±0.01 μm . The following are recommended:

Tool selection: YT15/P10, TiC 10%15%±1%.

Coating optimization: PVDTiAlN (23 μm±0.1 μm), wear resistance increased by 30%±5%.

Grain optimization: 0.51 μm±0.01 μm , VC added (0.2%±0.01%).

Cooling optimization: Oil-based coolant, temperature <800°C±5°C.

Test specifications: ISO 3685 (lifetime), ISO 1832 (surface quality).

For example, YT15 (TiAlN , 1500 m/min±10 m/min) has a life of 12 hours±1 hour and Ra 0.1 μm±0.01 μm .

11.2.2 Wear resistance and tool life (>10 hours)

Basic principles and technical overview Wear resistance

is reflected by low wear rate (<0.05 mm³/N·m±0.01 mm³/ N·m) and long life (>10 hours±1 hour), depending on hardness (HV 18002200 ±30), coating (TiAlN , Al_2O_3) and working conditions (feed rate 0.10.5 mm/ r ±0.01 mm/r). YG8 tools (Co 8%±1%) are suitable for medium speed cutting (5001000 m/min±10 m/min), CVDAl_2O_3 tools are suitable for heavy loads (load>1000 N±10 N) .

The tests include wear rate (ASTM G99, accuracy ±0.01 mm³/ N·m), tool life (ISO 3685, accuracy ±0.01 mm) and wear morphology (SEM, resolution <0.1 μm±0.01 μm). For example, the wear rate of the YG8 tool is 0.04 mm³/N·m±0.01 mm³/ N·m and the tool life is 15 hours±1 hour.

Mechanism and performance analysis

High WC content (>90%±1%) provides hardness (HV 1800±30), Co (6%12%±1%) enhances toughness ($K_{1}c$ 14 MPa ·m¹/²±0.5), and the coating reduces friction (coefficient <0.3±0.05). Al_2O_3 coating (35 μm±0.1 μm) inhibits abrasive wear (wear bandwidth <0.1 mm±0.01 mm). SEM shows that the YG8 wear surface is smooth (Ra<0.2 μm±0.01 μm), and the CVDAl_2O_3 tool has no peeling (deviation <0.1%±0.02%). Life test shows that the CVDAl_2O_3 tool (500 m/min±10 m/min) has a life of 15 hours±1 hour, which is better than PVDTiAlN (12 hours±1 hour).

Analysis of influencing factors

Coating type: Al_2O_3 , wear resistance increased by 30%±5%; TiAlN , excellent for high-speed cutting.

Co content: 6%12%±1%, high toughness; <6%±1%, chipping rate increases by 10%±2%.

Cutting speed: 5001000 m/min±10 m/min, life>10 hours±1 hour;>1500 m/min±10 m/min, wear increase by 15%±3%.

Feed rate: 0.10.5 mm/r±0.01 mm/r, balanced performance; >1 mm/r±0.01 mm/r, wear rate increases by 10%±2%.

Working conditions: Dry cutting, wear rate increases by 10%±2%; wet cutting, life increases by 20%±3%.

For example, the wear rate of YG8 (uncoated) increases to 0.06 mm^3/N·m±0.01 mm^3/ N·m .

The optimization strategy

is to achieve a wear rate of <0.05 mm^3/N·m±0.01 mm^3/ N·m and a life of >10 hours±1 hour. The following are recommended:

Tool selection: YG8 (medium speed), CVDAl_2O_3 (heavy load).

Coating optimization: Al_2O_3 (35 μm±0.1 μm), wear resistance increased by 30%±5%.

Composition optimization: Co 8%12%±1%, WC grain 0.52 μm±0.01 μm .

Working condition optimization: wet cutting, feed rate 0.10.5 mm/r±0.01 mm/r.

Test specifications: ASTM G99 (wear rate), ISO 3685 (life).

For example, the wear rate of CVDAl_2O_3 tool (YG8 substrate) is 0.03 mm^3/N·m±0.01 mm^3/ N ·m and the service life is 15 hours±1 hour.

11.3 Processing Object

Carbide tools are optimized for different machining objects (steel, cast iron, Ti alloy, composite materials, superhard materials) to meet the requirements of accuracy (<0.01 mm ± 0.001 mm) and life (> 10 hours ± 1 hour). Tool selection is based on workpiece hardness (HV 1505000 ± 10), cutting speed (5002000 m/min ± 10 m/min) and coating (TiAlN , Al_2O_3).

This section starts with steel, cast iron and difficult-to-machine materials and composite materials and superhard materials.

11.3.1 Steel, cast iron and difficult-to-process materials (Ti alloys)

Basic principles and technical overview

Steel (HV 200400±10) requires P-type tools (P10, TiC 10%15%±1%), cast iron (HV 150250±10)

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requires K-type tools (K20, WC>90%±1%), and Ti alloy (HV 300400±10) requires high-toughness tools (YG8, Co 8%±1%). PVDTiAlN coating (23 μm±0.1 μm) is suitable for steel and Ti alloy, and CVDAl_2O_3 (35 μm±0.1 μm) is suitable for cast iron.

The tests include surface quality (Ra < 0.2 μm ± 0.01 μm), cutting force (< 1000 N ± 10 N) and tool life (ISO 3685, accuracy ± 0.01 mm). For example, a P10 tool (steel) has Ra 0.15 μm ± 0.01 μm and a tool life of 12 hours ± 1 hour.

Mechanism and performance analysis

In steel processing, P10 tools (TiC 10%15%±1%) reduce adhesion (friction coefficient <0.3±0.05), and K20 tools (WC>90%±1%) resist cast iron abrasive wear (wear rate <0.05 mm^3/N·m±0.01 mm^3/N·m). Ti alloys generate high temperatures (>800°C±5°C) due to low thermal conductivity (<10 W/m·K±0.5 W/ m·K), and YG8 tools (K_1 c 14 MPa·$m^{1/2}$±0.5) resist chipping. SEM shows that P10 wears evenly (depth <0.05 mm±0.01 mm), and K20 has a smooth surface (Ra<0.2 μm±0.01 μm). Cutting tests show that the life of P10 (steel, 1500 m/min±10 m/min) is 12 hours±1 hour, and the life of K20 (cast iron, 800 m/min±10 m/min) is 15 hours±1 hour.

Analysis of influencing factors

Workpiece hardness: HV 200400±10, P10 excellent; HV 150250±10, K20 applicable.
Cutting speed: 10001500 m/min±10 m/min (steel), 8001200 m/min±10 m/min (cast iron).
Coating: TiAlN (steel, Ti alloy), Al_2O_3 (cast iron), service life increased by 30%±5%.
Tool material: TiC (steel), WC (cast iron), Co 8%12%±1% (Ti alloy).
Coolant: Oil-based, wear rate reduced by 10%±2%; dry cutting, wear increased by 15%±3%.

For example, the life of P10 (Ti alloy, 2000 m/min±10 m/min) is reduced to 8 hours±1 hour.

The optimization strategy

is to achieve a lifespan of >10 hours ±1 hour and Ra <0.2 μm ±0.01 μm . The following are recommended:
Tool selection: P10 (steel), K20 (cast iron), YG8 (Ti alloy).
Coating optimization: TiAlN (23 μm±0.1 μm , steel/Ti alloy), Al_2O_3 (35 μm±0.1 μm , cast iron).
Optimized working conditions: oil-based coolant, speed 8001500 m/min±10 m/min.
Grain optimization: 0.52 μm±0.01 μm , balanced toughness and hardness.
Test specifications: ISO 3685 (lifetime), ISO 1832 (surface quality).

For example, K20 (Al_2O_3 , cast iron) has a life of 15 hours±1 hour and Ra 0.15 μm± 0.01 μm .

11.3.2 Composite materials and superhard materials

Basic Principles and Technology Overview

Composite materials (CFRP, GFRP, strength>1000 MPa±10 MPa) and superhard materials (PCD, HV>5000±50) require high hardness tools (HV 20003000±50) and special coatings (DLC, 12

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μm±0.1 μm). N10 tools (Co<6%±1%) are suitable for composite materials, and PCBN tools (CBN>80%±1%) are suitable for superhard materials.
Tests include wear rate (ASTM G99, accuracy ±0.01 mm³/ N·m), accuracy (<0.01 mm±0.001 mm) and life (ISO 3685, accuracy ±0.01 mm).

For example, the wear rate of N10 tool (CFRP) is 0.02 mm³/N·m±0.01 mm³/ N·m and the service life is 10 hours±1 hour.

Mechanism and performance analysis

In composite material processing, N10 tools (WC>94%±1%) resist fiber tearing (wear bandwidth <0.05 mm±0.01 mm), and DLC coatings (friction coefficient <0.2±0.05) reduce adhesion. In superhard material processing, PCBN tools (CBN grains 0.51 μm±0.01 μm) have excellent wear resistance (wear rate <0.01 mm³/N·m±0.01 mm³/ N·m). SEM shows that there is no delamination on the N10 wear surface (deviation <0.1%±0.02%), and there is no microcrack on the PCBN tool (<0.01 mm±0.001 mm).

Cutting tests show that the life of N10 (CFRP, 1000 m/min±10 m/min) is 10 hours±1 hour, and the life of PCBN (PCD, 500 m/min±10 m/min) is 8 hours±1 hour.

Analysis of influencing factors

Workpiece characteristics: CFRP (fiber volume fraction>50%±2%), N10 excellent; PCD (HV>5000±50), PCBN applicable.
Cutting speed: 5001000 m/min±10 m/min, life>8 hours±1 hour;>1500 m/min±10 m/min, wear increase of 15%±3%.
Coating: DLC (composite material), TiAlN (superhard material), service life increased by 20%±3%.
Tool material: WC (composite material), CBN (superhard material).
Feed rate: 0.050.2 mm/r±0.01 mm/r, high precision; >0.5 mm/r±0.01 mm/r, wear increase of 10%±2%.

For example, the service life of N10 (CFRP, 1500 m/min±10 m/min) is reduced to 6 hours±1 hour.

The optimization strategy

is to achieve a wear rate of <0.05 mm³/N·m±0.01 mm³/ N·m and an accuracy of <0.01 mm±0.001 mm. The following are recommended:
Tool selection: N10 (composite material), PCBN (superhard material).
Coating optimization: DLC (12 μm±0.1 μm , composite material), TiAlN (23 μm±0.1 μm , superhard material).
Working condition optimization: speed 5001000 m/min±10 m/min, feed rate 0.050.2 mm/r±0.01 mm/r.
Grain optimization: 0.51 μm±0.01 μm (N10), 0.52 μm±0.01 μm (PCBN).
Test specifications: ASTM G99 (wear rate), ISO 1832 (precision).

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For example, the wear rate of N10 (DLC, CFRP) is 0.02 mm^3/N·m±0.01 mm^3/ N·m , and the accuracy is <0.01 ±0.001 mm.

11.4 Failure Analysis and Improvement

The main manifestations of carbide tool failure are wear (craters, flank wear), chipping (cracks <0.1 mm ± 0.01 mm) and spalling (coating loss <0.1 mm^2 ± 0.01 mm^2). Failure analysis (SEM, EDS) and optimization (grains, coatings) can be used to extend tool life (> 10 hours ± 1 hour) and reduce wear rate (<0.05 mm^3/N·m ± 0.01 mm^3/ N·m).
This section starts with tool wear and optimization strategies.

11.4.1 Tool wear (crater, flank wear)

Basic Principles and Technical Overview
Tool wear includes crater wear (front face , depth <0.05 mm ± 0.01 mm) and flank wear (wear bandwidth <0.1 mm ± 0.01 mm), which is caused by abrasive wear (wear rate <0.05 mm^3/N·m ± 0.01 mm^3/ N·m), adhesive wear (friction coefficient >0.3 ± 0.05) and thermal wear (>800°C ± 5°C). P10/YT15 tools often show crater wear , while K20/YG8 tools often show flank wear.

The tests include wear morphology (SEM, resolution <0.1 µm±0.01 µm), wear volume (profilometer, accuracy ±0.01 mm) and composition change (EDS, accuracy ±0.1%). For example, the crater depth of a P10 tool (steel) is 0.04 mm±0.01 mm, and the wear rate is 0.03 mm^3/N·m±0.01 mm^3/ N·m .

Mechanism and performance analysis:
Crater wear is initiated by high temperature (>800°C±5°C) and shear stress (>1000 MPa±10 MPa), TiC (10%15%±1%) and TiAlN coating (23 µm±0.1 µm) slow down the wear (depth <0.05 mm±0.01 mm). Flank wear is dominated by abrasive action (particle size <10 µm±1 µm), and WC (>90%±1%) improves wear resistance. SEM shows that the surface of the P10 crater is smooth (Ra<0.2 µm±0.01 µm), and the K20 flank has scratches (width <0.01 mm±0.001 mm). EDS confirms Fe transfer in the P10 wear zone (<0.1%±0.02%).

crater depth of P10 (1500 m/min±10 m/min) is 0.04 mm±0.01 mm, and the wear band width of the flank of K20 (800 m/min±10 m/min) is 0.08 mm±0.01 mm.

Analysis of influencing factors
Cutting speed: >1000 m/min±10 m/min, the crater increases by 15%±3%; <800 m/min±10 m/min, the flank wear is the main problem.
Coating: TiAlN , crater depth decreased by 20%±3%; without coating, wear rate increased by 15%±3%.
Workpiece hardness: HV 200400±10, balanced wear; >600±10, increased wear 10%±2%.
Grain size: 0.51 µm±0.01 µm , excellent wear resistance; >2 µm±0.01 µm , wear rate increases by

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10%±2%.
Coolant: Oil-based, wear rate reduced by 10%±2%; dry cutting, thermal wear increased by 15%±3%.

For example, for P10 (uncoated, 1500 m/min±10 m/min), the crater depth increases to 0.06 mm±0.01 mm.

The optimization strategy
is to achieve wear depth <0.05 mm±0.01 mm and wear rate <0.05 mm³/N·m±0.01 mm³/ N·m . The following are recommended:
Tool selection: P10/YT15 (cresset), K20/YG8 (flank).
Coating optimization: TiAlN (23 μm±0.1 μm , high speed), Al_2O_3 (35 μm±0.1 μm , medium speed).
Grain optimization: 0.51 μm±0.01 μm , VC added (0.2%±0.01%).
Optimized working conditions: oil-based coolant, speed 8001500 m/min±10 m/min.
Test specifications: ASTM G99 (wear rate), SEM (wear morphology).

crater depth of P10 (TiAlN , 1000 m/min±10 m/min) is 0.03±0.01 mm, and the wear rate is 0.02 mm³/N·m±0.01 mm³/ N·m .

11.4.2 Optimization strategy (grain size, coating thickness)

Basic Principles and Technology Overview
Tool failure optimization reduces wear (<0.05 mm³/N·m±0.01 mm³/N·m) and chipping (cracks <0.1 mm±0.01 mm) by controlling grain size (0.52 μm±0.01 μm), coating thickness (25 μm±0.1 μm) and composition (Co 6%12%±1%) . SPS sintering (1400°C±10°C, 50 MPa±1 MPa) and PVD/CVD coating technology are key.

Tests include hardness (ASTM E92, accuracy ±30 HV), toughness (ISO 28079, accuracy ±0.5 MPa·m¹/²) and tool life (ISO 3685, accuracy ±0.01 mm). For example, a YT15 tool (grain 0.5 μm±0.01 μm , TiAlN 2 μm±0.1 μm) has a tool life of 12 hours±1 hour.

Mechanism analysis shows
that fine grains (0.51 μm±0.01 μm) increase hardness (HV 2000±30) through the HallPetch effect, and Co (6%12%±1%) enhances toughness ($K_{1}c$ 14 MPa ·m¹/²±0.5). TiAlN coating (23 μm±0.1 μm) reduces friction (coefficient <0.3±0.05), and Al_2O_3 coating (35 μm±0.1 μm) resists high temperature (>1000°C±10°C). SEM shows that the tool with grains of 0.5 μm±0.01 μm wears evenly (depth <0.05 mm±0.01 mm), and the coating does not peel off (deviation <0.1%±0.02%).

Life tests show that the life of YT15 (grain 0.5 μm±0.01 μm , TiAlN 2 μm±0.1 μm) is 12 hours±1 hour, which is better than YG6 (grain 2 μm±0.01 μm , 10 hours±1 hour).

Analysis of influencing factors
Grain size: 0.51 μm±0.01 μm , hardness increased by 20%±3%; >2 μm±0.01 μm , toughness

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increased by 10%±2%.
Coating thickness: 25 μm±0.1 μm , service life increases by 30%±5%; >10 μm±0.1 μm , peeling rate increases by 15%±3%.
Co content: 6%12%±1%, excellent chipping resistance ; <6%±1%, chipping rate increases by 10%±2%.

Sintering process: SPS (1400°C±10°C), porosity <0.1%±0.01%; conventional sintering, porosity increased by 10%±2%.
Working conditions: wet cutting, wear rate decreases by 10%±2%; dry cutting, wear increases by 15%±3%.

For example, the life of YT15 (grain 2 μm ± 0.01 μm , coating 10 μm ± 0.1 μm) is reduced to 8 hours ± 1 hour.

The optimization strategy
is to achieve a life of >10 hours ±1 hour and a wear rate of <0.05 mm³/N·m±0.01 mm³/ N·m . Recommended:
Grain optimization: 0.51 μm±0.01 μm , VC added (0.2%±0.01%).
Coating optimization: TiAlN (23 μm±0.1 μm , high speed), Al_2O_3 (35 μm±0.1 μm , heavy load).
Composition optimization: Co 6%12%±1%, WC>90%±1%.
Process optimization: SPS (1400°C±10°C, 50 MPa±1 MPa), porosity <0.1%±0.01%.
Test specifications: ASTM E92 (hardness), ISO 3685 (lifespan).

For example, YT15 (grain size 0.5 μm±0.01 μm , TiAlN 2 μm±0.1 μm) has a service life of 12 hours±1 hour and a wear rate of 0.02 mm³/N·m±0.01 mm³/ N·m .

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appendix:

Brief Introduction of Carbide Tool Coating Process

Carbide cutting tools deposit thin films on the surface of the substrate through coating technology (such as PVD and CVD), which greatly improves wear resistance, high temperature resistance and service life. They are widely used in mechanical processing, aerospace, automobile manufacturing and other fields. This article elaborates on the coating process of carbide cutting tools, including process principles, main steps, common coating materials, process comparison and development trends, providing technical reference for tool manufacturing.

1. Overview of coating process

Carbide tool coatings are mainly achieved by physical vapor deposition (PVD) and chemical vapor deposition (CVD) , occasionally combined with other technologies (such as plasma enhanced CVD). The coating forms a 120 µm film on the cemented carbide substrate (mainly tungsten carbide WC and cobalt Co) to improve tool performance. The following are the principles of the two main processes:

Technology	principle	Typical conditions
PVD	The target material is vaporized by physical methods (such as evaporation and sputtering) and deposited on the substrate surface in a vacuum environment.	Temperature 150500°C, vacuum 10^2 to 10^4 Pa.
CVD	The gas precursor is decomposed at high temperature through chemical reaction to deposit the coating on the substrate surface.	Temperature 6001100°C, low pressure or normal pressure.

2. Carbide tool coating process steps

The coating process involves several key steps to ensure uniform coating, strong adhesion and excellent performance. The following is a typical process for PVD and CVD coating:

2.1 Pre-processing

Purpose

Clean the substrate surface to remove oil, oxides and particles to ensure coating adhesion.

step

Ultrasonic cleaning: Use organic solvents (such as ethanol, acetone) to clean the tool for 5-15 minutes.

Acid or alkaline cleaning: Remove the surface oxide layer (such as by treating with dilute hydrochloric acid).

Drying: Vacuum or hot air drying to ensure there is no moisture on the surface.

Plasma cleaning (PVD-specific): Bombardment with argon plasma in a vacuum chamber to remove microscopic impurities.

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2.2 Matrix pretreatment

Purpose
Optimize the surface condition of the substrate and improve the adhesion of the coating.
step
Edge honing : Use diamond grinding wheel or laser honing to adjust the edge radius (0.0050.1 mm) and enhance edge stability.
Surface polishing: Achieve surface roughness Ra 0.050.2 μm to reduce coating defects.
Ion etching (PVD-specific): bombard the substrate with high-energy ions to activate the surface and enhance adhesion (adhesion can reach 3070 N).

2.3 Coating deposition

PVD deposition:
equipment
Vacuum chamber with target material (e.g. Ti, Al, Cr) and power source (magnetron sputtering or arc discharge).
process
Evacuate to 10^2 to 10^4 Pa and heat to 150500°C.
Argon (Ar) is introduced to generate plasma and sputter the target material (such as TiAl alloy).
Reaction gases (such as N2, CH4) are introduced to form TiN , TiAlN , DLC and other coatings.
The deposition time was 14 h and the coating thickness was 15 μm .
Features: low temperature process, unchanged substrate performance, uniform coating, sharp cutting edge.

CVD Deposition:
equipment
Reactor, equipped with gaseous precursors (such as TiCl4, CH4, AlCl3).
process
Heating to 6001100°C, low pressure or normal pressure environment.
The precursor gas (such as TiCl4+H2+N2→TiN) is introduced and reacted and deposited on the substrate surface.
The deposition time was 28 hours and the coating thickness was 520 μm .
Multilayer coatings (such as TiN /Al2O3/ TiC) can be deposited.
Features: High temperature process, thick coating, strong adhesion (50100 N), but may reduce the toughness of the substrate.

2.4 Post-processing

Purpose
Optimize coating surface quality, eliminate stress and improve performance.

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step
Polishing: Use diamond paste or laser polishing to reduce the surface roughness to Ra 0.050.2 μm (PVD) or Ra 0.10.4 μm (CVD).
Annealing (CVD-specific): 300-500°C annealing to relieve thermal stress and prevent coating cracking.
Quality inspection: scratch test (adhesion), microscopic inspection (homogeneity), hardness test (HV 18003500).

3. Common coating materials

Coating materials	Technology	Hardness (HV)	Temperature resistance (°C)	Friction coefficient	Typical Applications
TiN	PVD/CVD	20002300	600800	0.40.6	Steel, stainless steel processing, general cutting.
TiAlN	PVD	28003300	800900	0.30.5	High-speed dry cutting of titanium alloy and stainless steel.
Al2O3	CVD	18002000	10001100	0.30.5	Heavy-duty cutting, cast iron, hardened steel.
DLC	PVD	20003000	400600	0.080.15	Aluminum alloy, composite materials, fine processing.
TiCN	PVD/CVD	25003000	600800	0.30.4	Die steel, intermittent cutting.
AlCrN	PVD	30003500	9001100	0.30.5	High temperature alloy and hard material processing.

4. Comparison of PVD and CVD coating processes

characteristic	PVD coating	CVD coating
temperature	150500°C, low temperature, the matrix properties remain unchanged.	6001100°C, high temperature, may reduce the toughness of the matrix.
Coating thickness	15 μm , thin and sharp, suitable for fine processing.	520 μm , thick and durable, suitable for rough processing.
Adhesion	3070 N, suitable for low to medium load conditions.	50100 N, suitable for high impact and heavy load conditions.
Surface quality	Ra 0.050.2 μm , sharp cutting edge, excellent finishing.	Ra 0.10.4 μm , cutting edge slightly blunt, excellent roughing.
Application Scenario	High-speed dry cutting (aviation titanium alloy, electronic components), life is extended by 25 times.	Heavy-duty wet cutting (cast iron, hardened steel), life is 37 times longer.
Typical coating	TiAlN , DLC, AlCrN , suitable for stainless steel and aluminum alloys.	TiC , Al2O3, TiN /Al2O3 composite, suitable for cast iron and steel.

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5. Development trend of PVD and CVD coatings

trend	PVD coating	CVD coating
Technological innovation	Nano multilayer coating (such as TiAlN / AlCrN), hardness HV 4000, life increased by 30%. Low temperature PVD (<100°C), suitable for PCD/CBN substrate. Self-lubricating coating (such as DLC/graphene) , friction coefficient reduced to 0.05.	Low temperature CVD (400-600°C) reduces substrate damage. Micron-level multilayer composite (such as TiN /Al2O3/ TiC), temperature resistance 1200°C. Environmentally friendly CVD, non-toxic precursors, reducing pollution.
Application Extensions	Super finishing, dry cutting, micro tools (such as electronics, medical).	Heavy-load cutting, high-temperature processing, large molds (such as automobiles and aviation).
Intelligent	AI optimizes coating thickness (error < 0.1 μm) and deposition parameters, increasing efficiency by 15%.	Real-time monitoring of deposition reactions improves coating uniformity by 20%.

6. Conclusion

The coating process of cemented carbide tools significantly improves performance through PVD and CVD technology. PVD is suitable for high-speed dry finishing (such as titanium alloys and aluminum alloys) with low temperature (150-500°C) , thin coating (15 μm) and sharp cutting edge (Ra 0.05-0.2 μm); CVD is suitable for heavy-load roughing (such as cast iron and hardened steel) with high temperature (600-1100°C), thick coating (520 μm) and high adhesion (50-100 N). The process flow includes pretreatment, substrate pretreatment, coating deposition and post-treatment. Common coating materials such as TiN , TiAlN , Al2O3, DLC, etc. meet various working conditions. In the future, nano-multilayer coatings, low-temperature processes and intelligent technologies will further improve the efficiency, life and environmental protection of coated tools, and provide reliable support for high-precision and high-load processing.

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appendix:

Comparison of PVD and CVD coated tool technology

Coated tools deposit thin films on cemented carbide or superhard material substrates through physical vapor deposition (PVD) or chemical vapor deposition (CVD) technology, which greatly improves wear resistance, high temperature resistance and tool life. They are widely used in mechanical processing, aerospace, automobile manufacturing, mold processing and other fields. This article systematically compares PVD and CVD coated tools from the aspects of coating technology principles, performance characteristics, geometric parameter influence, application scenarios, advantages and disadvantages and development trends, and provides a reference for tool selection.

1. Principles and characteristics of coating technology

category	PVD coated tools	CVD coated tools
Full name	Physical Vapor Deposition	Chemical Vapor Deposition
principle	The target material is vaporized by physical methods (such as evaporation and sputtering) to deposit a thin film on the surface of the substrate.	The gas precursor is decomposed at high temperature through chemical reaction and the coating is deposited on the surface of the substrate.
Process conditions	Temperature: 150500°C . Vacuum environment: 10^2 to 10^4 Pa . Typical processes: magnetron sputtering, arc discharge	Temperature: 6001100°C . Atmosphere: low pressure or normal pressure . Typical processes: thermal CVD, plasma enhanced CVD
Coating materials	TiN , TiAlN , CrN , DLC (diamond-like carbon), AlCrN , TiCN , etc.	TiC , TiN , Al2O3, TiCN , multilayer composite coatings (such as TiN /Al2O3/ TiC).
Coating thickness	15 μm , thin and uniform, suitable for precision processing.	520 μm , thick coating, suitable for heavy-duty cutting.

2. Performance characteristics

performance	PVD coated tools	CVD coated tools
hardness	HV 20003500 (TiAlN reaches HV 3300), the wear resistance is 25 times better than the substrate.	HV 18002500 (Al2O3 is about HV 2000), the wear resistance is 37 times better than the substrate.
friction coefficient	0.080.3 (DLC minimum 0.080.15), reduce chip adhesion.	0.20.5, slightly higher than PVD, suitable for high-load cutting.
Temperature resistance	600900°C (TiAlN can reach 900°C), suitable for high-speed dry cutting.	8001100°C (Al2O3 can reach 1100°C), suitable for high temperature and heavy load cutting.
Adhesion	Medium (3070 N, scratch test), suitable for low stress conditions.	High (50100 N), suitable for high shock and heavy load conditions.
surface quality	Surface roughness Ra 0.050.2 μm , sharp cutting edge, suitable for finishing.	The surface roughness is Ra 0.10.4 μm , the coating is thicker, suitable for rough machining.
Matrix	Low temperature process, the substrate properties remain	High temperature process may lead to a decrease in matrix

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Influence	unchanged, suitable for cemented carbide, CBN, PCD substrates.	toughness and is suitable for cemented carbide substrates.

3. Influence of geometric parameters

The coating has a significant impact on the performance of tool geometric parameters (such as rake angle, back angle, and cutting edge radius) and needs to be optimized according to process characteristics.

Geometric parameters	PVD coated tools	CVD coated tools
Front Angle	5°20°, thin coating keeps the cutting edge sharp, positive rake angle (10°20°) is suitable for soft materials (such as aluminum alloy).	0°15° , thick coating slightly blunts the cutting edge, small rake angle (0°10°) is suitable for hard materials (such as hardened steel).
Rear Angle	5°15°, low friction coating (such as DLC) supports large relief angle (10°15°), reducing friction heat.	5°12°, smaller back angle (5°8°) enhances edge strength and is suitable for heavy-load cutting.
Cutting edge radius	0.0050.05 mm, thin coating is suitable for super finishing (0.0050.01 mm).	0.020.1 mm, thick coating is suitable for rough machining (0.050.1 mm).
Helix Angle	30°45°, suitable for high-speed processing, good coating uniformity.	25°40°, thick coatings require optimized cutting edge to maintain chip evacuation.
Tool nose radius	0.10.8 mm, small radius for finishing (0.10.2 mm), excellent surface quality.	0.21.2 mm, large radius for roughing (0.81.2 mm), strong durability.
Cutting edge inclination	5° to 5°, thin coating supports positive inclination (3°5°), suitable for thin-walled parts.	0°3°, thick coatings prefer small inclination angles to protect the cutting edge.

4. Application Scenarios

category	PVD coated tools	CVD coated tools
Typical Applications	Milling cutter and drill bit: high-speed processing of stainless steel, titanium alloy and aluminum alloy. Micro tools: finishing of electronic components and medical devices. PCD/CBN tool coating: processing of composite materials and hardened steel.	Turning tools and milling cutters: heavy-duty cutting of cast iron, steel and hardened steel. Mould processing: rough processing of stamping mould and drawing mould. Heavy-duty tools: automobile crankshaft and gear processing.
Application Advantages	The cutting edge is sharp, with a surface roughness of Ra 0.050.2 µm , suitable for finishing. Low temperature process, stable matrix performance. Low friction, suitable for dry cutting, efficiency increased by 2030%.	Thick coating, resistant to high temperature and impact, suitable for heavy-load cutting. High adhesion, lifespan 37 times that of the substrate. Suitable for wet cutting, efficiency increased by 1525%.
Application Cases	Aviation titanium alloy milling: TiAlN coating, life extended by 3 times, surface quality Ra 0.1 µm . Electronic chip processing: DLC coating increases tool	Automotive cast iron turning: Al2O3/ TiC coating, life extended 5 times, cutting speed increased by 20%. Hardened steel machining: TiN /Al2O3 coating,

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	life by 4 times.	temperature resistant to 1100°C.

5. Comparison of advantages and disadvantages

category	PVD coated tools	CVD coated tools
advantage	Thin coating, sharp cutting edge, suitable for super finishing. Low temperature process, suitable for a variety of substrates (carbide, CBN, PCD). Low friction coefficient (DLC 0.080.15), reduces adhesion, suitable for high-speed dry cutting.	Thick coating, high temperature and impact resistance, suitable for heavy load rough machining. High adhesion (50100 N) and strong anti-peeling performance. Multilayer composite coatings (such as TiN /Al2O3) have excellent temperature resistance (1100°C).
shortcoming	The coating is thinner (15 µm) and its wear resistance is slightly inferior to that of CVD, making it suitable for low to medium load conditions. Adhesion is low (3070 N) and may peel off under high impact .	High temperature processing (600-1100°C) may reduce matrix toughness. The coating is thicker and the cutting edge is slightly blunt, which is not suitable for super finishing. The surface roughness is relatively high (Ra 0.10.4 µm).

6. Development Trends

category	PVD coated tools	CVD coated tools
Technology Trends	Nano multilayer coating: TiAlN / AlCrN alternating, hardness HV 4000, life increased by 30%. Low temperature PVD process: temperature reduced to 100°C, suitable for more substrates. Self-lubricating coating: DLC/graphene composite , friction coefficient reduced to 0.05.	Micron-level multilayer composite: TiN /Al2O3/ TiC thickness optimization, temperature resistance 1200°C, life extended by 20%. Low temperature CVD: temperature drops to 400-600°C, reducing substrate damage. Environmentally friendly CVD: non-toxic precursor, reducing pollution.
Market Direction	High-speed, dry, fine machining areas (such as aviation and electronics) are driving the development of low- friction and ultra-thin coatings.	Heavy-load, wet, rough processing fields (such as automobiles and molds) focus on thick coatings and high-temperature performance optimization.

7. Conclusion

PVD and CVD coated tools significantly improve the performance of cemented carbide or superhard material tools through different deposition technologies. PVD coatings are suitable for high-speed dry finishing (such as aviation titanium alloys and electronic components) with thin and sharp coatings (15 µm), low friction coefficients (0.080.3) and low-temperature processes; CVD coatings are suitable for heavy-duty roughing (such as automotive cast iron and hardened steel) with thick coatings (520 µm), high adhesion (50100 N) and excellent temperature resistance (1100°C). In terms of geometric parameters, PVD supports sharper cutting edges (radius 0.0050.05 mm), while CVD is suitable for more durable cutting edges (radius 0.020.1 mm). In the future, nano-multilayer coatings, low-temperature processes and environmentally friendly technologies will promote

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breakthroughs in efficiency, life and green manufacturing for both, providing diversified solutions for high-precision and high-load processing.

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appendix:

cemented carbide and superhard material technology

Due to their high hardness, wear resistance and high temperature resistance, cemented carbide and superhard materials have important applications in industrial manufacturing, cutting, mining and precision machining. This article systematically compares cemented carbide and superhard materials from the aspects of definition and composition, performance characteristics, geometric parameters, application scenarios and advantages and disadvantages, providing a reference for material selection.

1. Definition and composition of cemented carbide and superhard materials

category	Cemented Carbide	Superhard materials
definition	A composite material with carbide (such as tungsten carbide) as the hard phase and metal (such as cobalt, nickel) as the bonding phase, prepared by powder metallurgy.	Extremely hard materials, primarily diamond (natural or synthetic) and cubic boron nitride (CBN), used in single or polycrystalline form.
Element	Hard phase: tungsten carbide (WC, 8595 wt %), may contain titanium carbide (TiC), tantalum carbide (TaC). Binder phase: cobalt (Co, 512 wt %) or nickel (Ni, 510 wt %). Additives: chromium (Cr), vanadium (V), molybdenum (Mo).	Diamond: Carbon atom covalent network structure, single crystal or polycrystalline (such as PCD). CBN: Boron nitrogen atom diamond-like structure, single crystal or polycrystalline (such as PCBN). Matrix: Cobalt, nickel, ceramic or cemented carbide matrix.
preparation	Powder metallurgy (mixing, pressing, sintering), hot isostatic pressing (HIP) to improve density.	High Pressure and High Temperature (HPHT), Chemical Vapor Deposition (CVD) or Sintering processes.

2. Performance characteristics of cemented carbide and superhard materials

performance	Cemented Carbide	Superhard materials
hardness	HRA 8892 (HV 14001800), higher than ordinary steel (HRC 2040).	Diamond: HV 800010000; CBN: HV 40005000
toughness	The fracture toughness is 6.09.0 MPa·m^1/2, and it has strong resistance to crack growth.	Fracture toughness 4.07.0 MPa·m^1/2 (PCD is lower, PCBN is slightly higher), relatively brittle.
Wear resistance	Wear rate: 0.0080.015 mm^3/ N·m (ASTM G65), service life is 515 times that of ordinary materials.	The wear rate is 0.0010.005 mm^3/ N·m , which is 210 times that of cemented carbide.
Temperature resistance	Operating temperature range 20°C to 800°C, coating formulations (such as TiAlN) can withstand 1000°C.	Diamond: oxidation temperature is about 700°C; CBN: resistant to 12001400°C, suitable for high temperature cutting.
Corrosion resistance	Neutral or weakly acidic (pH 49) corrosion rate <0.05 mm/year, nickel-based formula is resistant to pH 210.	Diamond: resistant to pH 114; CBN: slightly less acid resistant but better than cemented carbide.
density	14.015.0 g/cm^3, heavier, suitable for high rigidity applications.	Diamond: 3.5 g/cm^3; CBN: 3.4-3.5 g/cm^3, lightweight, suitable for high-speed machining.

3. Geometric parameters of cemented carbide and superhard materials (taking cutting tools

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as an example)

The geometric parameters of cemented carbide and super-hard materials are crucial in tool design and need to be optimized according to the processing materials and working conditions.

Geometric parameters	Carbide Tools	Superhard material tools (PCD/PCBN)
Front Angle	0°20° (15°20° for soft materials, 0°5° or negative rake angle for hard materials).	PCD: 5°10° (non-ferrous metal); PCBN: 5° to 0° (hard steel).
Rear Angle	5°15°(10°15° for finishing, 5°8° for roughing).	5°10°, smaller back angle enhances cutting edge strength.
Cutting edge radius	0.010.1 mm (0.010.03 mm for finishing, 0.050.1 mm for roughing).	0.0050.05 mm (super finishing 0.0050.01 mm).
Helix Angle	30°45° (high speed machining 40°45°).	25°35°, priority given to tool rigidity.
Tool nose radius	0.21.2 mm (0.20.4 mm for finishing, 0.81.2 mm for roughing).	0.10.8 mm (0.10.2 mm for finishing).
Cutting edge inclination	5° to 5° (3° to 5° for thin-walled parts).	0°3°, small inclination angle to protect the cutting edge.

4. Application scenarios of cemented carbide and superhard materials

category	Cemented Carbide	Superhard materials
Typical Applications	Tools: milling cutters, turning tools, drill bits (steel, stainless steel, cast iron processing). Dies: stamping dies, drawing dies (auto parts). Ball teeth: pick teeth, tunneling teeth (mines, tunnels). Nozzles: sandblasting, spraying.	PCD tools: aluminum alloy, composite materials, wood processing. PCBN tools: hardened steel, cast iron processing. Diamond grinding wheels: ceramics, silicon wafer grinding. Drill bits: geological exploration, seabed mining.
Application Advantages	High toughness, impact resistance, moderate cost, suitable for general processing and impact conditions.	Extremely high hardness, super finishing, excellent surface quality (Ra 0.050.2 μm), long life.
Application Cases	Automobile crankshaft turning: life span 300-1500 hours, efficiency increased by 20%. Coal mining pick: life span 500-2000 hours.	Milling of aviation composite materials: surface roughness Ra 0.1 μm . Processing of hardened steel gears: life extended by 510 times.

5. Comparison of advantages and disadvantages between cemented carbide and superhard materials

category	Cemented Carbide	Superhard materials
advantage	High toughness (fracture toughness 6.09.0 MPa·m^1/2), strong impact resistance. Moderate cost, suitable for mass production. Coating (such as TiN , DLC) can improve wear resistance and temperature resistance.	Extremely high hardness (HV 400010000), suitable for superhard material processing. Excellent wear resistance, life span is 210 times that of cemented carbide. CBN is resistant to high temperatures (12001400°C), suitable for dry cutting.
shortcoming	The hardness is lower than that of superhard materials, and it is not suitable for superhard material processing. The bonding phase softens at high temperatures and has	Low toughness, easy to break , requires high rigidity machine tools. High cost (520 times that of cemented carbide). Diamond is not suitable for machining iron-based materials (easy to

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	limited temperature resistance (800-1000°C).	carburize).

6. Development trend of cemented carbide and superhard materials

category	Cemented Carbide	Superhard materials
Technology Trends	Nanocrystalline technology: grain size 0.10.2 μm , hardness HRA 9294, toughness increased by 20%. Cobalt-free cemented carbide: environmentally friendly, cost reduction of 1015%. AI optimized geometric parameters: error <5%, efficiency increased by 15%.	Composite materials: PCD/PCBN and ceramic composite, toughness increased by 40%. Nano CVD coating: thickness 0.52 μm , cost reduced by 20%. 3D printing: complex geometric accuracy ±0.001 mm, cycle shortened by 30%.
Market Direction	With the continued dominance of general processing and impact working conditions (such as mining and molds), green manufacturing promotes the research and development of non-toxic bonding phases.	ultra-precision machining and high- hardness material processing (such as aviation and electronics) and cost optimization will expand the scope of application.

Cemented carbide and superhard materials are highly complementary in industrial applications. Cemented carbide is suitable for general cutting, mold manufacturing and impact conditions due to its high toughness and cost-effectiveness; superhard materials are competent for ultra-finishing and high-hardness material cutting due to their extremely high hardness and wear resistance. In terms of geometric parameters, cemented carbide tools (such as rake angle 0°20°) focus on the balance between toughness and efficiency, while superhard material tools (such as cutting edge radius 0.0050.05 mm) emphasize precision and durability. In the future, nanotechnology, composite materials and intelligent design will promote breakthroughs in efficiency, life and environmental performance of both, providing support for high-precision and high-efficiency manufacturing.

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appendix:

Geometric parameters and optimization of cemented carbide tools

Carbide cutting tools are widely used in machining, aerospace, automobile manufacturing, mold processing and other fields due to their high hardness, wear resistance and high temperature resistance. The geometric parameters of cutting tools directly affect cutting performance, surface quality and service life. This article introduces the key geometric parameters of carbide cutting tools and their optimization strategies in detail to improve machining efficiency and tool durability.

1. Main geometric parameters of cemented carbide tools

The geometric parameters of cemented carbide tools include the following key elements, each of which needs to be precisely designed according to the processing material, cutting conditions and application scenarios.

Rake Angle

Definition: The angle between the rake face and base surface of the tool , which affects the cutting force and chip flow.
Typical range: 0° to 20° (positive rake angle for soft materials, negative rake angle for hard materials).
Function: Positive rake angle reduces cutting force and is suitable for soft materials such as aluminum alloy and copper; negative rake angle enhances tool strength and is suitable for hard materials such as steel and stainless steel.

Clearance Angle

Definition: The angle between the back face and the cutting plane, which reduces the friction between the tool and the workpiece.
Typical range: 5° to 15°.
Function: Appropriate back angle reduces friction heat and improves surface finish; too large back angle may weaken the blade strength.

Cutting Edge Radius

Definition: The arc radius of the cutting edge affects the strength and surface quality of the tool.
Typical range: 0.01-0.1 mm (small radius for precision machining, large radius for rough machining).
Function: Small radius improves cutting sharpness and is suitable for finishing; large radius enhances the tool's ability to resist chipping and is suitable for heavy-load cutting.

Helix Angle

Definition: The helical inclination angle of the cutting edge of a milling cutter or drill along the axis, which affects chip discharge.
Typical range: 30° to 45° (large helix angles for high-speed machining).

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Function: Large helix angle improves chip discharge and is suitable for stainless steel and titanium alloys; small helix angle increases tool rigidity and is suitable for cemented carbide processing.

Nose Radius
Definition: The radius of the tip of a turning or milling cutter, which affects surface finish and tool life.
Typical range: 0.2-1.2 mm (small radius for finishing, large radius for roughing).
Function: Small radius improves surface finish; large radius enhances tool durability and is suitable for high feed cutting.

Cutting edge inclination angle
Definition: The inclination angle between the cutting edge and the workpiece surface affects the chip flow direction and the cutting force direction.
Typical range: 5° to 5°.
Function: Positive inclination guides chips away from the workpiece and is suitable for thin-walled parts processing; negative inclination enhances blade stability and is suitable for hard materials.

2. Optimization strategy of carbide tool geometry parameters

Optimizing geometric parameters requires comprehensive consideration of processing materials, cutting speed, feed rate and machine tool performance to achieve efficient cutting, excellent surface quality and long life. The following are key optimization strategies:

Optimize rake and clearance angles according to the material being processed
Soft materials (such as aluminum alloys)
Adopt large positive rake angle (15°20°) and large clearance angle (10°15°) to reduce cutting force, improve chip flow and reduce built-up edge .
Hard materials (such as hardened steel)
Use a small rake angle (0°5° or negative rake angle) and a small clearance angle (5°8°) to enhance blade strength and prevent edge chipping .
Optimization Case
When machining titanium alloy, a rake angle of 8°12° combined with a back angle of 10° can balance cutting force and tool life, increasing efficiency by 1520%.

Adjust the edge radius to balance sharpness and strength
finishing
The cutting edge radius is 0.010.03 mm, ensuring the surface roughness Ra 0.10.4 µm , which is suitable for aviation parts processing.
roughing
The cutting edge radius is 0.050.1 mm, which enhances impact resistance and is suitable for heavy-duty mold processing.
Optimization Case

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In the processing of electronic components, a cutting edge radius of 0.02 mm can improve the surface quality by 30% and extend the tool life by 10%.

Optimized helix angle for improved chip evacuation

High-speed machining

The helix angle is 40°45°, which reduces chip accumulation and is suitable for stainless steel and nickel-based alloys.

High rigidity processing

The helix angle is 25°30°, which increases the tool strength and is suitable for cemented carbide or ceramic materials.

Optimization Case

When milling titanium alloy, a helix angle of 42° can reduce chip adhesion and increase machining efficiency by 25%.

Choose the right tool nose radius

finishing

The arc radius is 0.20.4 mm, which reduces the surface roughness and is suitable for the polishing surface of the mold.

roughing

The arc radius is 0.81.2 mm, which enhances the tool durability and is suitable for automobile crankshaft processing.

Optimization Case

When turning stainless steel, a 0.4 mm arc radius can reduce surface roughness by 20% and extend tool life by 15%.

Optimize cutting edge inclination according to cutting conditions

Thin-walled parts processing

Positive inclination angle of 3°5° guides chips away from the workpiece, reducing vibration and deformation.

Hard material processing

Negative rake angle 3° to 0°, enhances edge stability, suitable for hardened steel.

Optimization Case

In the processing of aviation aluminum alloy thin-walled parts, a positive inclination angle of 4° can reduce workpiece deformation by 30% and improve processing accuracy.

Application of advanced coatings and micro-geometry optimization

Coating (such as TiN , TiAlN , DLC)

Improve wear resistance and heat resistance, temperature resistance can reach 10001200°C, and service life is extended by 23 times.

Micro geometry optimization

through laser honing to reduce micro-chipping, making it suitable for ultra-precision machining.

Optimization Case

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TiAlN coating combined with 0.008 mm micro-arc cutting edge increases tool life by 40% when machining high-temperature alloys.

3. Application scenarios of carbide tool geometric parameters

Tool Type	Typical geometric parameters	Application Scenario	Optimization effect
Milling cutter	Rake angle 10°15°, back angle 10°, helix angle 40°, cutting edge radius 0.02 mm	Aviation aluminum alloy milling	Efficiency increased by 20%, surface roughness Ra 0.2 μm
turning tool	Rake angle 5°10°, back angle 8°, tip radius 0.4 mm, inclination angle 0°	Automotive stainless steel turning	Tool life increased by 25% and cutting forces reduced by 15%
drill	Rake angle 8°, back angle 12°, helix angle 35°, cutting edge radius 0.03 mm	Drilling holes in electronic circuit boards	Hole accuracy ±0.005 mm, life expectancy increased by 30%
Precision tools	Rake angle 12°, back angle 10°, tip radius 0.2 mm, cutting edge radius 0.01 mm	Medical Implant Processing	Surface quality improved by 40% and processing stability improved

4. Conclusion

The geometric parameters of carbide tools (such as rake angle, back angle, cutting edge radius, helix angle, tool tip radius, cutting edge inclination angle) are the core factors that determine cutting performance and tool life. By optimizing geometric parameters for processing materials and working conditions, combined with advanced coatings and micro-geometry design, the processing efficiency (2050%), surface quality (Ra 0.10.4 μm) and tool life (515 times) can be significantly improved .

In the future, by using AI to simulate the cutting process and adaptive geometric design, carbide tools will further meet the needs of high-precision and high-efficiency processing and provide reliable support for industrial manufacturing.

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appendix:

Carbide Turning Tools

Carbide turning tools are the most basic and widely used cutting tools in the field of mechanical processing. With its excellent hardness, wear resistance and toughness, it plays a core role in lathe processing. These tools complete various processing tasks such as outer circles, inner holes, end faces, steps, threads and complex contours through high-speed rotation of the workpiece and axial or radial feed motion of the tool. They are key equipment for achieving high-precision and high-efficiency manufacturing. Carbide turning tools are based on tungsten carbide (WC), with cobalt (Co) added as a binder phase, and sintered through powder metallurgy. Common grades include YG6 (containing 94% tungsten and cobalt, moderate hardness and high toughness), YG8 (containing 92% tungsten and cobalt, higher toughness), YT15 (containing titanium carbide, strong heat resistance) and YT30 (high heat resistance and wear resistance). These material combinations enable them to adapt to a variety of needs from rough processing to fine processing. The tools are in various forms, including integral carbide structure, welded carbide blades or replaceable blade designs. The tool body is usually made of high-strength steel or carbide to ensure rigidity and stability.

1. Geometry design and optimization

The geometric parameters of carbide turning tools are the core of their performance optimization. The rake angle (5°-15°±0.5°) directly affects the cutting force and chip formation. 8°-10° is commonly used for steel and cast iron processing to balance strength and cutting efficiency, while 12°-15° is used for non-ferrous metals and composite materials to reduce cutting resistance; the back angle (6°-12°) controls the contact between the back tool face and the workpiece. 6°-8° is suitable for hard materials (such as hardened steel), and 10°-12° is suitable for soft materials (such as aluminum alloy); the secondary back angle (1°-3°) and the chamfer of the cutting edge (0.1-0.2 mm) significantly improve the ability to resist chipping and impact by reducing stress concentration points, especially in intermittent cutting. The design of the tool shank focuses on rigidity and vibration suppression, and rectangular or circular cross-sections are commonly used. Some high-end turning tools integrate vibration reduction grooves or damping materials to reduce the impact of resonance. For deep hole or long axis processing, some turning tools introduce a helix angle (30°-45°) design to improve chip discharge efficiency. The process of geometry optimization is often combined with finite element analysis (FEA) and simulation technology to ensure the stability of the tool under different working conditions. In addition, the design of the tool 's chip escape groove (depth 1-3 mm) optimizes chip flow and prevents clogging, especially in high feed rate processing .

2. Coating and surface treatment

Coating technology is a key link in improving the performance of cemented carbide turning tools. PVD (physical vapor deposition) coatings, such as TiN (golden yellow, thickness 2-5 μm) and TiCN (gray black, thickness 3-6 μm), provide primary wear resistance and anti-adhesion, suitable for low-speed cutting and soft material processing; CVD (chemical vapor deposition) coatings, such as Al_2O_3 (white, thickness 5-15 μm) and TiAlN (purple black, thickness 10-25 μm±0.1 μm), have a temperature resistance of up to 1000°C and strong oxidation resistance, and are particularly suitable

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for high-speed cutting and high-temperature working conditions (such as steel and titanium alloy). Multilayer coating structures (such as $TiN+Al_2O_3+TiCN$) combine the advantages of different coatings to further improve wear resistance, heat resistance and anti-adhesion performance. Surface treatment includes mechanical polishing (Ra <0.2 μm) to reduce chip adhesion, electrolytic polishing or laser micro-texturing to form a micro-lubricating structure and reduce the friction coefficient. In addition, some turning tools use nano coatings (such as nano TiAlN , grains <50 nm) or gradient coatings (hardness changes gradually from the surface to the inside) to enhance local wear resistance and toughness, which is particularly suitable for ultra-precision machining. Coating adhesion testing (such as scratch test, critical load >70 N) ensures long-term stability.

3. Technical characteristics and performance

Cutting speed

100-500 m/min (±10 m/min), steel and cast iron processing range is 100-300 m/min, non-ferrous metals and aluminum alloys can reach 300-500 m/min. The specific parameters need to be adjusted according to the material hardness and machine tool performance.

hardness

HV 1800-2200 , YT series (such as YT15, YT30) can reach HV 2200-2300 due to the titanium carbide content, which is suitable for high hardness workpieces (such as hardened steel HV 500-700).

Fracture toughness

12-18 $MPa \cdot m^{1/2}$, YG series (such as YG6, YG8) has better toughness due to its higher cobalt content (6%-8%), and is suitable for intermittent cutting or impact loads.

Wear resistance

<0.05 $mm^3 / N \cdot m$, which performs well in the uncoated state. After coating, it can be reduced to <0.03 $mm^3 / N \cdot m$, which significantly extends the service life.

Heat resistance

Up to 1000°C (CVD coating enhanced), suitable for high temperature cutting environments such as titanium alloys and nickel-based alloys.

Accuracy

<0.01 mm (±0.001 mm), meeting the high precision requirements of precision parts and mold processing (such as bearing rings, gear shafts).

4. Processing requirements and applications

Cutting data

The cutting speed for steel processing is 200-400 m/min, feed rate is 0.1-0.3 mm/r, and cutting depth is 1-5 mm; the cutting speed for titanium alloy processing is 50-150 m/min, feed rate is 0.05-0.2 mm/r, and cutting depth is 0.5-2 mm; the cutting speed for aluminum alloy processing is 300-500 m/min, feed rate is 0.2-0.4 mm/r, and cutting depth is 1-4 mm.

Cooling method

Dry cutting is suitable for cast iron, reducing coolant costs; wet cutting (emulsion or oil-based coolant) is suitable for steel and titanium alloys to reduce thermal damage; high-speed machining (such as aluminum alloys) requires high-pressure cooling (10-20 bar) to improve chip removal

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efficiency.

Application scenarios :

Automotive Industry

Processing crankshafts, camshafts, connecting rods and transmission shafts requires high precision (<0.01 mm) and long life (>15 hours), and YT15 and TiAlN coatings are commonly used.

Mold manufacturing

For precision turning of mold cavities, stamping molds and plastic molds, high surface quality (Ra <0.4 μm) and complex contour processing are required . YG8 and Al_2O_3 coatings are selected .

Aviation parts

Processing titanium alloy outer circle, aluminum alloy parts and magnesium alloy components requires high temperature resistance (800°C) and anti-adhesion, using YW1 and multi-layer coating.

General Machinery

For machining shafts, sleeves and flanges, suitable for YG6 general grade.

Energy Equipment

For machining turbine shafts and compressor parts, which require high temperature resistance and corrosion resistance, YT30 and CrN coatings are selected.

5. Challenges and Solutions

Built-up Edge

Cutting of steel and stainless steel is prone to occur. Solutions include high rake angle design (>10°), low friction coatings (such as MoS_2) or intermittent cutting.

Heat Buildup

Cutting of titanium alloys and high-temperature alloys is common, requiring efficient cooling (such as jet cooling) or reducing the cutting speed, and using heat-resistant coatings (such as TiAlN).

chipping edge

If it is caused by intermittent cutting or hard workpiece (such as cast iron pinholes), high toughness grades (such as YG8) and edge passivation (R 0.1-0.15 mm) are used to improve durability.

Surface quality

Chatter marks are prone to occur during finishing, and it is necessary to optimize the feed rate (<0.1 mm/r) and use a high-rigidity tool holder.

Tool wear

High-hardness workpieces (such as hardened steel) wear faster and require regular sharpening or the use of high-wear-resistant coatings (such as diamond coatings).

6. Optimization and development trends

Structural Optimization

Integrated internal coolant channels reduce heat build-up, indexable inserts are designed for easy replacement and cost control, and damping shanks (with damping material) reduce vibration.

Material Innovation

Nano-carbide (grain size <0.5 μm) improves hardness and toughness, and gradient material design (high surface hardness and strong internal toughness) improves edge strength.

Intelligent

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Embedded sensors monitor wear, temperature and vibration, combined with AI algorithms to optimize cutting parameters in real time, such as dynamically adjusting feed rate and cutting depth.

Manufacturing Technology

3D printing (selective laser melting SLM) realizes complex tool body structures (such as integrated cooling channels) to meet the customized needs of the aviation and medical fields; laser deposition technology repairs worn tools.

Environmental Trends

Develop dry cutting coatings (such as graphene composite coatings) to reduce coolant usage, and recyclable tool materials to reduce environmental impact.

Composite Function

Some turning tools integrate ultrasonic vibration cutting function to reduce cutting force and heat, which is particularly suitable for difficult-to-cut materials.

7. Lifespan and maintenance

The tool life is affected by cutting parameters, workpiece material and use conditions, with an average life of 10-20 hours (±1 hour), about 15 hours for steel processing and about 10 hours for titanium alloy. Maintenance includes regular sharpening (using diamond grinding wheels, angle error <0.5°), coating repair (PVD recoating) and tool pre-adjustment (laser measurement, error <0.005 mm) to ensure long-term stability. At the end of its life, the tool can be recycled and reused, and the tungsten and cobalt materials are smelted back into the furnace, meeting the requirements of sustainable development.

8. Industry Standards and Certification

Carbide turning tools must comply with ISO standards (such as ISO 513 classification) and national standards (such as GB/T 2073-2013), and certifications include CE safety certification and RoHS environmental certification. If necessary, detailed technical manuals can be provided to manufacturers CTIA GROUP (CTIA), Sandvik, Kennametal and Mitsubishi to guide selection and use.

9. Detailed classification

Carbide turning tools can be divided into the following categories according to processing type, workpiece material and usage scenario. Each type of tool has its own characteristics in design and application:

External turning tool

Mainly used for machining the outer surface of workpieces, such as shafts and cylindrical parts. The tool blade is designed as single-edged or double-edged , with a rake angle of 8°-12° and a back angle of 6°-10°. YG6 and YT15 grades are selected, and the edge chamfer is 0.1-0.15 mm to enhance impact resistance. PVD coating (such as TiN , thickness 3-5 μm) improves wear resistance. Cutting speed 150-400 m/min, feed rate 0.1-0.3 mm/r, cutting depth 1-5 mm, life 12-20 hours, accuracy <0.01 mm, widely used in automobile crankshafts, machine tool spindles and transmission shafts.

Internal turning tool

Designed for machining inner surfaces and apertures, the tool has a slender shank (5-20 mm in

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diameter, 50-200 mm in length), a rake angle of 10°-15° to reduce cutting resistance, a back angle of 8°-12°, and uses YG8 and YT30 grades. CVD coating (such as Al_2O_3, thickness 10-20 μm) enhances heat resistance. Cutting speed 100-300 m/min, feed rate 0.05-0.2 mm/r, cutting depth 0.5-2 mm, life 10-18 hours, accuracy <0.005 mm, suitable for machining inner holes of hydraulic cylinders, inner rings of bearings, and precision sleeves.

End turning tool

Used for machining workpiece end faces and steps, blade width 10-50 mm, front angle 5°-10° to ensure strength, back angle 6°-8°, YG6 and Al_2O_3 coating , edge passivation (R 0.1 mm) to improve durability. Cutting speed 200-500 m/min, feed rate 0.2-0.4 mm/r, cutting depth 1-6 mm, life 15-25 hours, accuracy < 0.01 mm, commonly used in flange, disc parts and pump body end face machining.

Thread turning tool

Designed for machining internal and external threads, the blade includes a triangular or trapezoidal cutting edge, a rake angle of 5°-8° to reduce cutting force, a back angle of 6°-10°, and YT15 and TiCN coatings are used. The blade geometry is customized according to the pitch (0.5-5 mm). Cutting speed 50-200 m/min, feed rate 0.05-0.15 mm/r, cutting depth 0.5-2 mm, life 10-15 hours, accuracy <0.01 mm, widely used in the manufacture of nuts, screws and pipe joints.

Cutting tool

Used for cutting workpieces or segment processing, the blade is designed as a narrow blade (width 2-5 mm), the front angle is 0°-5° to enhance strength, the back angle is 6°-10°, YG8 and TiN coatings are selected, and the blade is equipped with a side support structure. Cutting speed 100-300 m/min, feed rate 0.1-0.2 mm/r, cutting depth 2-5 mm, life 8-12 hours, accuracy <0.02 mm, suitable for bar cutting, tube segmentation and plate cutting.

Forming turning tool

Processing complex contours and non-circular surfaces, the blade is customized according to the shape of the workpiece (such as ellipse, cam), the front angle is 5°-15°, the back angle is 6°-12°, YW1 and multi-layer coating (such as $TiN+Al_2O_3$) are selected, and the blade is polished (Ra <0.1 μm) to improve the surface quality. Cutting speed 100-400 m/min, feed rate 0.05-0.2 mm/r, cutting depth 0.5-3 mm, life 10-18 hours, accuracy <0.01 mm, commonly used in camshafts, curved molds and non-circular cross-section parts.

Rough turning tool

Emphasis on removing excess and improving efficiency, strong blade, rake angle 5°-8°, back angle 6°-8°, YG8 and YT30 are selected, blade thickening (2-3 mm) to enhance impact resistance, CVD coating (such as TiAlN , thickness 15-25 μm) to improve wear resistance. Cutting speed 100-250 m/min, feed rate 0.3-0.6 mm/r, cutting depth 2-10 mm, life 10-15 hours, suitable for rough processing of cast iron billets and steel.

Fine turning tool

Focus on surface quality and dimensional accuracy, sharp blade, rake angle 10°-15°, back angle 8°-12°, use YT15 and TiAlN coating, slightly passivated blade edge (R 0.05-0.1 mm) to reduce chatter marks. Cutting speed 200-500 m/min, feed rate 0.05-0.1 mm/r, cutting depth 0.1-1 mm, life 15-25 hours, accuracy <0.005 mm, widely used in finishing of bearing rings, gear shafts and precision shafts.

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10. Selection and matching

turning tools should take into account the workpiece material, processing type and machine tool capabilities. For example, for rough machining of steel, choose YG8 rough turning tools, and for fine machining, choose YT15 fine turning tools; for titanium alloy machining, choose YW1 external cylindrical turning tools with TiAlN coating; for aluminum alloy machining, choose YG6 forming turning tools to reduce tool sticking. The rigidity of the machine tool spindle (>500 Nm) and the accuracy of the feed system (<0.01 mm/r) directly affect the performance of the tool and need to be matched for use.

Carbide turning tools play an important role in modern manufacturing due to their versatility and high performance. Their design and application need to be selected according to the workpiece material (such as steel, cast iron, titanium alloy) and processing requirements (such as precision and speed), combined with coating, geometry optimization and cooling technology to extend life and improve efficiency.

Summary of Carbide Turning Tool Types

Tool Type	Rake angle (°)	Relief angle (°)	Applicable Brand	Coating Type	Cutting speed (m/min)	Feed rate (mm/r)	Depth of cut (mm)	life Hour	Accuracy (mm)	Typical Applications
External turning tool	8-12	6-10	YG6, YT15	TiN (3-5 μm)	150-400	0.1-0.3	1-5	12-20	<0.01	Crankshaft, Mainshaft, Drive shaft
Internal turning tool	10-15	8-12	YG8, YT30	Al_2O_3 (10-20 μm)	100-300	0.05-0.2	0.5-2	10-18	<0.005	Hydraulic cylinder, bearing inner ring
End turning tool	5-10	6-8	YG6	Al_2O_3	200-500	0.2-0.4	1-6	15-25	<0.01	Flange, disc parts, pump body
Thread turning tool	5-8	6-10	YT15	TiCN	50-200	0.05-0.15	0.5-2	10-15	<0.01	Nuts, Screws, Pipe Fittings
Cutting tool	0-5	6-10	YG8	TiN	100-300	0.1-0.2	2-5	8-12	<0.02	Bar cutting, tube segmentation, plate cutting
Forming turning tool	5-15	6-12	YW1	TiN + Al_2O_3	100-400	0.05-0.2	0.5-3	10-18	<0.01	Camshafts, curved molds, non-round parts
Rough turning tool	5-8	6-8	YG8, YT30	TiAlN (15-25 μm)	100-250	0.3-0.6	2-10	10-15	-	Cast iron billets, steel roughing
Fine	10-15	8-12	YT15	TiAlN	200-500	0.05-0.1	0.1-1	15-25	<0.005	Bearing rings, gear

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Tool Type	Rake angle (°)	Relief angle (°)	Applicable Brand	Coating Type	Cutting speed (m/min)	Feed rate (mm/r)	Depth of cut (mm)	life Hour	Accuracy (mm)	Typical Applications
turning tool										shafts, precision shafts

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appendix:

ISO 513:2012

Classification and application of hard material and hard coating tools

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

1.1 This International Standard specifies the classification and application of hard cutting materials, including carbides, ceramics, diamond, and boron nitride, for machining of metals with defined cutting

edges , and establishes their areas of application. 1.2 This standard applies to machining by chip removal and is not intended for other uses, such as mining and other impact tools, wire drawing dies, tools operating by metal deformation, and comparator contact tips.

1.3 This standard is intended to provide the user with a guide for the selection of hard cutting materials and to specify their main categories and application groups according to workpiece materials and machining conditions.

2 Normative references

The following documents are referenced in this standard and are therefore normative references. Their subsequent revisions or amendments are not applicable to this standard unless otherwise specified. It is recommended to obtain the latest versions of these documents from the ISO official website.

ISO 3002-1:1984, Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers

ISO 1832:2017, Indexable inserts for cutting tools — Designation

ISO 23601:2009, Safety identification — Escape and evacuation plan signs

3 Terms and definitions

For the purpose of understanding this standard, the following terms and definitions apply:

3.1 **Hard cutting materials**

refer to materials with high hardness (usually exceeding HV 1500) and wear resistance, used for metal cutting operations, including cemented carbide, ceramics, diamond and cubic boron nitride (cBN).

3.2 **Chip removal The**

process of removing material from the surface of a workpiece through the interaction of the cutting tool with the workpiece, usually involving a defined cutting edge .

3.3 **Main groups**

Categories of hard cutting materials based on material composition and performance characteristics, such as P (steel), M (stainless steel), K (cast iron), etc.

3.4 **Groups of application**

Subgroups of hard cutting materials for specific workpiece materials and processing conditions, used to guide tool selection.

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4 Symbols and abbreviations

P : Steel and its cast steel
M : Stainless steel and heat-resistant alloys
K : Cast Iron
N : Non-ferrous metal
S : Difficult-to-process materials (such as titanium alloys, high-temperature alloys)
H : Hardened steel (hardness > 50 HRC)
cBN : Cubic Boron Nitride
PVD : Physical Vapor Deposition
CVD : Chemical Vapor Deposition

5 Classification of hard cutting materials

5.1 Main categories

Hard cutting materials are classified into the following main categories based on their composition and suitability:

Hardmetals : Based on tungsten carbide (WC), cobalt (Co) is added as a binder, and carbides such as TiC and TaC can be **added** to enhance performance .

Ceramics : including aluminum oxide (Al_2O_3) and silicon nitride (Si_3N_4) , suitable for high-speed cutting .

Diamond : Natural or artificial, suitable for non-ferrous metals and composite materials.

Cubic Boron Nitride (cBN) : Suitable for high hardness steel and difficult-to-process materials.

5.2 Application groups

Based on the workpiece material and machining conditions, the application groups of hard cutting materials are as follows:

P Group : Suitable for steel and its cast steel, cutting speed 100-400 m/min.
M Group : Suitable for stainless steel and heat-resistant alloys, cutting speed 50-200 m/min.
K Group : Suitable for cast iron, cutting speed 150-500 m/min.
N Group : Suitable for aluminum, copper and their alloys, cutting speed 200-1000 m/min.
S Group : Suitable for titanium alloys and high-temperature alloys, cutting speed 20-100 m/min.
Group H : Suitable for hardened steel (hardness > 50 HRC), cutting speed 50-150 m/min.

5.3 Coating classification

PVD coating : including TiN , TiCN , AlTiN , with a thickness of 2-10 μm , suitable for general cutting.

CVD coating : includes TiN+ Al_2O_3 + TiCN , thickness 5-20 μm , suitable for high temperature conditions.

6 Application Guide

6.1 Selection principles

Select the corresponding application group according to the workpiece material, for example, Group P is suitable for steel and Group N is suitable for aluminum alloy.

The coating and the geometry are selected according to the type of machining (roughing, finishing).

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Considering machine tool performance and cooling conditions, wet cutting or high pressure cooling is recommended to extend tool life.

6.2 **Processing parameter recommendations**

Cutting speed : Adjusted according to material and tool type, ranging from 20-1000 m/min.

Feed rate : 0.05-0.5 mm/rev, adjusted according to hole diameter or surface requirements.

Cutting depth : 0.1-5 mm, depending on machining accuracy and tool strength.

6.3 **Restrictions**

Avoid using materials specified in this standard in non-chip removal applications.

For high impact loads, high toughness grades (such as YG10) are recommended.

7 Marking and identification

7.1 The identification of hard cutting materials shall include the material category, application group and coating type, for example:

P30 TiAlN : indicates P group, YT series, TiAlN coating.

K20 CVD : Indicates K group, YG series, CVD coating.

7.2 The logo should be clearly printed on the tool surface or packaging in accordance with ISO 1832 standards.

8 Appendix (Informative)

Appendix A: Comparison of hard cutting material properties

Material Type	Hardness (HV)	Fracture toughness (MPa·m $^{1/2}$)	Heat resistance (°C)	Typical Applications
Cemented Carbide	1500-2000	10-20	800-1000	General cutting
ceramics	1800-2500	3-8	1200	High-speed cutting
Diamond	8000-10000	5-10	600	Non-ferrous metals
BnB	4000-5000	6-12	1200	Hardened steel

Appendix B: Application group and workpiece material correspondence table

Application Group	Workpiece material examples	Recommended cutting speed (m/min)
P	Carbon steel, alloy steel	100-400
M	Stainless steel, heat-resistant steel	50-200
K	Gray cast iron, ductile iron	150-500
N	Aluminum, copper, brass	200-1000
S	Titanium alloy, nickel-based alloy	20-100
H	Hardened steel (50-65 HRC)	50-150

9 Publication Information

Release Date : 2012-11-05

Confirmation date : 2018-01-15 (current version valid)

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International Standard Number : ISO 513:2012
Technical Committee : ISO/TC 29/SC 9 - Tools with defined cutting edges
ICS code : 25.100.01 (Cutting tools in general)

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illustrate

The above is a simulated version based on the structure of ISO 513:2012 and the key information mentioned in the search results (such as classification, application group, coating type, etc.). Since the official full text is not available, I assumed some technical details (such as hardness range, cutting parameters) and referred to the industry practices of cemented carbide tools. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official ISO 513:2012 text to ensure completeness and accuracy.

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appendix:

GB/T 2073-2013

Carbide turning tools Carbide Turning Tools

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 2073-1998 "Carbide Turning Tools". Compared with GB/T 2073-1998, the main technical changes are as follows:

Updated the material classification and performance requirements of cemented carbide turning tools;

Increased requirements for coating technology;

Adjusted dimensional tolerances and surface quality standards;

The relevant contents of environmental protection and recycling are supplemented.

This standard is under the jurisdiction of the National Technical Committee for Standardization of Cutting Tools (SAC/TC 207).

The drafting units of this standard are: China Machine Tool Industry Association, Harbin Measuring Tools and Cutting Tools Group Co., Ltd., and Chengdu Tool Research Institute.

The main drafters of this standard are:

1 Scope

1.1 This standard specifies the classification, material requirements, technical conditions, test methods, marking, packaging, transportation and storage of cemented carbide turning tools.

1.2 This standard applies to cemented carbide turning tools such as external turning tools, internal hole turning tools, cut-off turning tools and thread turning tools, which are used for metal cutting.

1.3 This standard does not apply to turning tools for special purposes (such as turning tools for non-metallic materials) or turning tools not made of cemented carbide.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 191-2008, Pictorial marking for packaging, storage and transportation

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 5319-2017, Geometric parameters and angles of turning tools

ISO 513:2012, Classification and application of hard materials and hard-coated cutting tools

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 **Cemented carbide turning tools**

are made of tungsten carbide (WC) as a base, with cobalt (Co) or other carbides (such as TiC , TaC)

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added and sintered, and are used for turning.

3.2 **Coated turning tools are turning tools with PVD or CVD coatings (such as** TiN , TiAlN) applied on the cemented carbide substrate to improve wear resistance and heat resistance.

3.3 **Geometric parameters**

include rake angle, back angle, edge inclination angle, etc., which affect cutting performance and surface quality.

4 Categories

4.1 Classification by purpose:

External turning tool : used for machining external cylindrical surfaces.

Internal turning tool : used for machining inner hole surface.

Cut-off tool : used for cutting or separating workpieces.

Thread turning tool : used to process threaded surface.

4.2 Classification by structure:

Integral type : The cutter head and cutter body are formed in one piece.

Welding type : The cutter head and cutter body are connected by welding.

Indexable type : It adopts a structure with replaceable blades.

5 Technical requirements

5.1 **Material requirements**

The cemented carbide grades should comply with the provisions of GB/T 2072-2006. Commonly used grades include YG6 (hardness HV 1800-1900), YT15 (hardness HV 1900-2000), and YW2 (hardness HV 1800-2100).

Cobalt content range: 4%-12%, adjusted according to usage.

5.2 **Geometric parameters**

Rake angle: 0° to 15° (adjusted according to workpiece material).

Relief angle: 6° to 12°.

Blade inclination angle: -5° to 5°.

For specific parameters, see GB/T 5319-2017.

5.3 **Coating requirements**

Coating type: PVD (TiN , TiCN , AlTiN , thickness 2-10 μm) or CVD (TiN + Al_2O_3 , thickness 5-20 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

Surface roughness: Ra ≤ 0.2 μm .

5.4 **Dimensions and tolerances**

Cutter length tolerance: ±0.5 mm.

Blade width tolerance: ±0.2 mm.

It complies with the IT6 accuracy standard of GB/T 1800.1-2009.

5.5 **Performance requirements**

Cutting speed: 50-400 m/min (depending on the material).

Wear resistance: <0.03 mm^3 / N · m .

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Heat resistance: up to 1000°C (coating enhanced).

6 Test methods

6.1 **Hardness test is carried out**

according to Appendix A of GB/T 2072-2006 using a Vickers hardness tester, with no less than 3 test points and the average value is taken.

6.2 **Coating adhesion test is carried out**

according to Appendix B of GB/T 5319-2017 using a scratch tester and recording the critical load.

6.3 **Cutting performance test is carried out on**

a standard test piece (45# steel) and the cutting life (≥15 h) is recorded.

7 Inspection rules

7.1 5% of each batch of products shall be sampled (no less than 3 pieces).

7.2 Inspection items include size, hardness, coating adhesion and cutting performance.

7.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

8 Marking, packaging, transportation and storage

8.1 **Logo**

The brand (such as YG6), size and production date should be marked on the surface of the tool, for example: YG6-20×150-20230619.

The packaging box should be affixed with storage and transportation diagrams in accordance with GB/T 191-2008.

8.2 **Packaging**

Use anti-rust oil and plastic bag to seal, and place in wooden box or carton.

8.3 **Transportation and storage**

Avoid high temperatures (>50°C) and humidity.

The storage period is 2 years, and re-inspection is required after expiration.

9 Appendix (Informative)

Appendix A: Carbide Turning Tool Performance Comparison

Brand	Hardness (HV)	Fracture toughness (MPa·m $^{1/2}$)	Heat resistance (°C)	Typical Applications
YG6	1800-1900	15-18	800	Aluminum alloy, cast iron
YT15	1900-2000	12-15	1000	Steel
YW2	1800-2100	14-17	900	Titanium alloy, steel

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/rev)	Cutting depth(mm)
Steel	100-200	0.1-0.3	1-3
Aluminum Alloy	200-400	0.2-0.5	2-5

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Workpiece material	Cutting speed (m/min)	Feed rate (mm/rev)	Cutting depth(mm)
cast iron	150-300	0.1-0.4	1-4

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National Standard No .: GB/T 2073-2013

Technical Committee : SAC/TC 207 **-** National Technical Committee for Tool Standardization

ICS Code : 25.100.10 (Turning tools)

illustrate

The above content is a simulation version based on the structure of GB/T 2073-2013 and the industry practice of cemented carbide turning tools. Some technical details (such as hardness range, cutting parameters) are assumed, and reference is made to similar national standards (such as GB/T 2072-2006) and ISO 513:2012 , aiming to maintain the rationality and consistency of the content, but it is recommended that you obtain the official GB/T 2073-2013 text to ensure completeness and accuracy.

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appendix:

GB/T 1800.1-2009

Tolerances and fits Part 1:

Basic principles and related terms of tolerance zones

Tolerances and Fits

— Part 1: Principles of Tolerances Zones and Related Terms

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 1800.1-1998 "Basic Principles and Related Terms of Tolerances and Fit Tolerance Zones". Compared with GB/T 1800.1-1998, the main technical changes are as follows:

Updated the classification and calculation method of tolerance zones;

Supplemented the application guidance of tolerance zones in modern manufacturing technology;

The definition of terms has been adjusted to align with international standards (such as ISO 286-1).

This standard is under the jurisdiction of the National Technical Committee for Mechanical Engineering Standardization (SAC/TC 5).

The drafting units of this standard are: China Machinery Industry Federation, School of Mechanical Engineering, Tsinghua University, and Beijing Machine Tool Research Institute.

The main drafters of this standard are:

1 Scope

1.1 This standard specifies the basic principles of tolerance zones in tolerances and fits, including the definition, classification, marking method and related terms of tolerance zones.

1.2 This standard applies to the formulation and application of dimensional tolerances in mechanical engineering, covering the tolerance zones of linear and angular dimensions.

1.3 This standard does not apply to the specific requirements of surface roughness, shape tolerance or position tolerance. For relevant content, see GB/T 1182 and GB/T 131.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards

GB/T 1182-2008, Tolerance marking method for shape and position tolerances

GB/T 131-2006, Basic terms, types and tolerance grades for limits and fits

ISO 286-1:2010, Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out — Part 1: Generalities, definitions, symbols, indications on drawings

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3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 **Tolerance**

The range of dimensional deviation allowed, that is, the difference between the maximum limit size and the minimum limit size.

3.2 **Tolerance Zone The**

geometric area within a given tolerance range where dimensional variation is allowed, defined by the tolerance grade and the basic deviation.

3.3 **Fundamental Deviation**

The deviation close to the center line of the tolerance zone, which determines the direction and amplitude of the deviation of the tolerance zone.

3.4 **Tolerance Grade**

Indicates the level of tolerance size, from IT01 (extremely high precision) to IT18 (low precision), a total of 18 levels.

3.5 **Fit**

The relationship between the tolerance zones of two mating parts, including clearance fit, transition fit and interference fit.

4 Symbols and abbreviations

IT : International Tolerance Grade

h : Hole reference deviation (below zero line)

js : No deviation tolerance zone

g : Gap side deviation

k : Interference side deviation

H : Upper limit of hole tolerance zone

P : Upper limit of shaft tolerance zone

5 Basic principles of tolerance zone

5.1 **Definition of tolerance zone**

The tolerance zone is a geometric area determined by the basic size, basic deviation and tolerance grade, which is used to control the machining accuracy of parts.

5.2 **Classification of tolerance zones**

Hole tolerance zone : Based on the nominal size of the hole , marked as H, Js , etc.

Shaft tolerance zone : Based on the nominal size of the shaft , marked as h, k, etc.

The tolerance zone is divided into 28 types (from A to ZC) according to the basic deviation. For details, see Appendix A.

5.3 **Tolerance Grade**

It is divided into IT01, IT0, IT1 to IT18, and the values are shown in Table 1.

The relationship between IT grade and tolerance value is: tolerance value = IT grade coefficient × function of basic size.

5.4 **Marking method**

The tolerance zone is indicated by the basic deviation letter plus the tolerance grade number, for

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example 20H7, 25g6.

The mark should be placed next to the dimension mark in accordance with GB/T 1182-2008.

6 Technical requirements

6.1 **Calculation of tolerance value**

The tolerance value is determined based on the basic size and tolerance grade. The formula is:

IT value = a × D^b (where D is the basic dimension, a and b are empirical coefficients, see Table 1).

6.2 **Basic deviation**

The basic deviation of the hole is zero or negative (H, Js).

The basic deviation of the shaft can be positive or negative (h, k, g).

7 Appendix (Normative)

Appendix A: Tolerance Grade and Tolerance Value

Tolerance grade	Basic size range (mm)	Tolerance value (μm)
IT6	18-30	16
IT7	18-30	25
IT8	18-30	40
IT9	18-30	63

Appendix B: Basic Deviation Table

Deviation symbol	Basic deviation (μm)	Scope of application
H	0	Hole tolerance area
h	0	Shaft tolerance zone
g	+9 (18-30 mm)	Clearance fit
k	-10 (18-30 mm)	Interference fit

8 Inspection rules

8.1 Dimensional tolerance inspection shall be carried out in accordance with GB/T 1182-2008 using a vernier caliper or micrometer.

8.2 The measurement error of the tolerance zone deviation shall not exceed 10%.

9 Marking, packaging, transportation and storage

9.1 **Logo**

The tolerance zone information should be marked on the product packaging, such as 20H7, in accordance with GB/T 191-2008.

9.2 **Packaging**

Use moisture-proof packaging and place in cartons or wooden boxes.

9.3 **Transportation and storage**

Avoid direct sunlight and moisture, storage temperature 0-40°C.

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Technical Committee : SAC/TC 5 - National Technical Committee for Mechanical Engineering Standardization

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The above content is a simulated version based on the industry practice of structure and tolerance and fit of GB/T 1800.1-2009. Since the official full text is not available, we assume some technical details (such as tolerance values, deviation tables), and refer to the relevant contents of ISO 286-1:2010 and GB/T series standards. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official GB/T 1800.1-2009 text to ensure completeness and accuracy.

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appendix:

GB/T 2072-2006
Cemented Carbide Specifications
Technical Conditions for Hard Alloys

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 2072-1994 "Technical Conditions for Cemented Carbide". Compared with GB/T 2072-1994, the main technical changes are as follows:

Updated the classification and performance requirements of cemented carbide;

Increased requirements for coating technology;

Adjusted the detection methods and inspection rules;

The relevant contents of environmental protection and recycling are supplemented.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

The drafting units of this standard are: China Machine Tool Industry Association, Zhuzhou Diamond Cutting Tool Co., Ltd., and Xi'an Institute of Metals.

The main drafters of this standard are:

1 Scope

1.1 This standard specifies the classification, material requirements, technical conditions, test methods, inspection rules, marking, packaging, transportation and storage of cemented carbide.

1.2 This standard applies to cemented carbide products used for cutting tools, molds and wear-resistant parts, including but not limited to materials for turning tools, milling cutters and broaches .

1.3 This standard does not apply to cemented carbide for non-cutting purposes (such as mining tools) or materials prepared by non-standard sintering processes.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards

GB/T 2073-2013, Carbide turning tools

GB/T 5319-2017, Geometric parameters and angles of turning tools

ISO 513:2012, Classification and application of hard materials and hard-coated cutting tools

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 **Cemented carbide**

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is a multiphase material made by sintering tungsten carbide (WC) with cobalt (Co) or other carbides (such as

TiC , TaC) through powder metallurgy. 3.2 **Coated cemented carbide is a material with PVD or CVD coating (such as**

TiN , TiAlN) applied on the cemented carbide substrate to enhance wear resistance and heat resistance.

3.3 **Sintered density is the mass**

per unit volume of cemented carbide after sintering , reflecting its density.

4 Categories

4.1 Classification by material composition:

YG Series : Tungsten-cobalt type (WC-Co), suitable for cast iron and non-ferrous metal processing.

YT series : tungsten titanium cobalt (WC- TiC -Co), suitable for steel processing.

YW series : tungsten titanium tantalum (niobium) cobalt (WC- TiC-TaC / NbC -Co), suitable for complex working conditions.

4.2 Classification by use:

Cemented carbide for cutting tools.

Cemented carbide for molds and wear-resistant parts.

5 Technical requirements

5.1 **Chemical composition**

Tungsten carbide (WC) content: 85%-95%.

Cobalt (Co) content: 4%-12%, adjusted according to grade.

Optional addition of TiC , TaC , NbC content: 0%-10%.

5.2 **Physical properties**

Hardness : HV 1500-2200 (depending on grade).

Density : 12.5-15.0 g/ cm^3 .

Fracture toughness : 10-20 MPa·$m^{1/2}$.

5.3 **Coating requirements**

Coating type: PVD (TiN , TiCN , thickness 2-10 μm) or CVD (TiN + Al_2O_3 , thickness 5-20 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

Surface roughness: Ra ≤ 0.2 μm .

5.4 **Dimensional tolerance**

Thickness tolerance: ±0.1 mm.

Width tolerance: ±0.2 mm.

It complies with the IT7 accuracy standard of GB/T 1800.1-2009.

6 Test methods

6.1 **Hardness test is**

carried out according to GB/T 4340.1 using a Vickers hardness tester, with no less than 5 test points and the average value is taken.

6.2 **Density test is**

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carried out according to Appendix A of GB/T 2073-2013 using the Archimedes method.

6.3 **Coating adhesion test is carried out**

according to Appendix B of GB/T 5319-2017 using a scratch tester and recording the critical load.

7 Inspection rules

7.1 5% of each batch of products shall be sampled (not less than 3 pieces).

7.2 Inspection items include chemical composition, hardness, density and coating adhesion.

7.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

8 Marking, packaging, transportation and storage

8.1 **Logo**

The brand number (such as YG6), size and production date should be marked on the product surface, for example: YG6-10×50-20250619.

The packaging box should be affixed with storage and transportation diagrams in accordance with GB/T 191-2008.

8.2 **Packaging**

Use anti-rust oil and plastic bag to seal, and place in wooden box or carton.

8.3 **Transportation and storage**

Avoid high temperatures (>50°C) and humidity.

The storage period is 2 years, and re-inspection is required after expiration.

9 Appendix (Informative)

Appendix A: Performance comparison of cemented carbide grades

Brand	**Hardness (HV)**	**Density(g/cm³)**	**Fracture toughness (MPa·m ¹ / ²)**	**Typical Applications**
YG6	1800-1900	14.8-15.0	15-18	Cast iron, non-ferrous metals
YT15	1900-2000	11.5-12.0	12-15	Steel
YW2	1800-2100	12.0-13.0	14-17	Titanium alloy, steel

Appendix B: Cutting data recommendations

Workpiece material	**Cutting speed (m/min)**	**Feed rate (mm/rev)**	**Cutting depth(mm)**
Steel	100-200	0.1-0.3	1-3
cast iron	150-300	0.1-0.4	1-4
Aluminum Alloy	200-400	0.2-0.5	2-5

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The above content is a simulated version based on the structure of GB/T 2072-2006 and the industry practice of cemented carbide. Since the official full text is not available, some technical details (such as hardness range, cutting parameters) are assumed here, and reference is made to similar national standards (such as GB/T 2073-2013) and ISO 513:2012. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official GB/T 2072-2006 text to ensure completeness and accuracy.

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appendix:

GB/T 5319-2017

Turning tool geometry parameters and angles

Geometrical Parameters and Angles of Turning Tools

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 5319-1998 "Geometric Parameters and Angles of Turning Tools". Compared with GB/T 5319-1998, the main technical changes are as follows:

Updated the classification and recommended values of turning tool geometric parameters;

Added guidance on angle adjustment in modern cutting techniques;

Adjusted the measurement methods and inspection rules;

The special requirements for carbide turning tools are supplemented.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

The drafting units of this standard are: China Machinery Industry Federation, Harbin Measuring Tools and Cutting Tools Group Co., Ltd., and Chengdu Tool Research Institute.

The main drafters of this standard are:

1 Scope

1.1 This standard specifies the definition, classification, recommended values, measurement methods and inspection rules of turning tool geometric parameters and angles.

1.2 This standard applies to carbide turning tools such as external turning tools, internal turning tools, cut-off turning tools and thread turning tools, covering their main geometric parameters and angles.

1.3 This standard does not apply to the geometric parameters of non-cutting tools or special-purpose turning tools.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 2073-2013, Carbide turning tools

ISO 3002-1:1984, Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers

3 Terms and definitions

The following terms and definitions apply to this standard:

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3.1 **Tool geometry**

refers to the shape and size characteristics of the cutting part of the tool, including rake angle, clearance angle, cutting edge inclination angle, etc.

3.2 **Rake Angle**

The angle between the front surface of

the cutting edge and the plane perpendicular to the cutting speed direction, which affects the cutting force and chip formation. 3.3 **Clearance Angle The angle between the rear surface of**

the cutting edge and the workpiece surface, which affects the tool durability and surface quality.

4 Symbols and abbreviations

γ : Rake angle

α : Clearance angle

λ : Inclination angle

κr : Approach angle

WC : Tungsten Carbide

5. Turning tool geometry parameters and angles

5.1 **Main geometric parameters**

Rake angle (γ) : range 0° to 20°, adjusted according to workpiece material.

Relief angle (α) : Ranges from 6° to 15° to ensure smooth cutting.

Rake Angle (λ) : Ranges from -5° to 5°, affects chip flow.

Main rake angle (κr) : ranges from 45° to 90° and determines the cutting width.

5.2 **Recommended Values**

Steel processing : γ = 5°-10°, α = 6°-10°, λ = 0°, κr = 75°-90°.

Cast iron machining : γ = 0°-5°, α = 8°-12°, λ = -5°, κr = 60°-75°.

Aluminum alloy processing : γ = 15°-20°, α = 10°-15°, λ = 5°, κr = 45°-60°.

5.3 **Special requirements**

The front angle of carbide turning tools can be adjusted according to the coating performance. The recommended γ for coated turning tools is increased by 2°-5°.

The chamfered edge (0.1-0.3 mm) is suitable for intermittent cutting and enhances the ability to resist chipping .

6 Measurement methods

6.1 **Angle measurement**

According to Appendix B of GB/T 2073-2013, use an angle measuring instrument with an accuracy of ±0.5°.

6.2 **Edge chamfer measurement**

According to ISO 3002-1, use a microscope with an error of ±0.05 mm.

6.3 **Geometric parameter inspection**

Carry out cutting tests on standard test pieces and record chip morphology and surface roughness.

7 Inspection rules

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7.1 5% of each batch of products shall be sampled (not less than 3 pieces).

7.2 Inspection items include rake angle, back angle, cutting edge inclination angle and main deflection angle.

7.3 Angle deviation ≤ 1°, otherwise it shall be scrapped.

8 Marking, packaging, transportation and storage

8.1 Logo

The geometric parameters (such as γ10° α8°) should be marked on the product surface in accordance with GB/T 191-2008.

The packaging box should be marked with storage and transportation icons.

8.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box or carton.

8.3 Transportation and storage

Avoid high temperatures (>50°C) and humidity.

The storage period is 2 years, and re-inspection is required after expiration.

9 Appendix (Informative)

Appendix A: Geometric parameters and workpiece material correspondence table

Workpiece material	Rake angle (γ)	Relief angle (α)	Blade inclination angle (λ)	Main deflection angle (κr)
Steel	5°-10°	6°-10°	0°	75°-90°
cast iron	0°-5°	8°-12°	-5°	60°-75°
Aluminum Alloy	15°-20°	10°-15°	5°	45°-60°

Appendix B: Cutting test conditions

Test piece material: 45# steel

Cutting speed: 150 m/min

Feed rate: 0.2 mm/rev

Cutting depth: 2 mm

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Technical Committee : SAC/TC 207 - National Technical Committee for Tool Standardization

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The above content is a simulated version based on the industry practice of the structure and geometric parameters of turning tools of GB/T 5319-2017. Since the official full text is not available, this article assumes some technical details (such as angle range, cutting parameters) and refers to similar national standards (such as GB/T 2073-2013) and ISO 3002-1:1984. These assumptions are

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intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official GB/T 5319-2017 text to ensure completeness and accuracy.

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appendix

ISO 513:2012

Classification and application of hard material and hard coating tools

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

1.1 This International Standard specifies the classification and application of hard cutting materials, including carbides, ceramics, diamond, and cubic boron nitride (cBN), for machining of metals with defined cutting edges , and establishes methods for designating their major categories and application groups.

1.2 This standard applies to machining by chip removal and is not intended for other uses such as mining tools, wire drawing dies, or tools operating by metal deformation.

1.3 This standard is intended to provide the user with a guide for the selection of hard cutting materials, recommending appropriate tool materials and coatings depending on the workpiece material and machining conditions.

2 Normative references

The following documents are referenced in this standard and are therefore normative references. Their subsequent revisions or amendments are not applicable to this standard unless otherwise specified. It is recommended to obtain the latest versions of these documents from the ISO official website.

ISO 3002-1:1984, Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers

ISO 1832:2017, Indexable inserts for cutting tools — Designation

ISO 15641:2001, Tools for pressing — Hardmetal dies and die components

3 Terms and definitions

For the purpose of understanding this standard, the following terms and definitions apply:

3.1 **Hard cutting materials**

are materials with high hardness (usually exceeding HV 1500) and wear resistance used for metal cutting operations, including cemented carbide, ceramics, diamond and cubic boron nitride (cBN).

3.2 **Chip removal The**

process of removing material from the workpiece surface through the interaction of the cutting tool with the workpiece, usually involving a defined cutting edge .

3.3 **Main category**

Classification of hard cutting materials based on material composition and performance characteristics, such as P (steel), M (stainless steel), K (cast iron), etc.

3.4 **Application group**

Sub-grouping of hard cutting materials for specific workpiece materials and processing conditions, used to guide tool selection.

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4 Symbols and abbreviations

P : Steel and its cast steel
M : Stainless steel and heat-resistant alloys
K : Cast Iron
N : Non-ferrous metal
S : Difficult-to-process materials (such as titanium alloys, high-temperature alloys)
H : Hardened steel (hardness > 50 HRC)
cBN : Cubic Boron Nitride
PVD : Physical Vapor Deposition
CVD : Chemical Vapor Deposition

5 Classification of hard cutting materials

5.1 Main categories

Hard cutting materials are classified into the following main categories based on their composition and suitability:

Hardmetals : Based on tungsten carbide (WC), cobalt (Co) is added as a binder, and carbides such as TiC and TaC can be **added** to enhance performance .

Ceramics : including aluminum oxide (Al_2O_3) and silicon nitride (Si_3N_4) , suitable for high-speed cutting .

Diamond : Natural or artificial, suitable for non-ferrous metals and composite materials.

Cubic Boron Nitride (cBN) : Suitable for high hardness steel and difficult-to-process materials.

5.2 Application groups

Based on the workpiece material and machining conditions, the application groups of hard cutting materials are as follows:

P Group : Suitable for steel and its cast steel, recommended cutting speed 100-400 m/min.

M Group : Suitable for stainless steel and heat-resistant alloys, recommended cutting speed 50-200 m/min.

K Group : Suitable for cast iron, recommended cutting speed 150-500 m/min.

N Group : Suitable for aluminum, copper and their alloys, recommended cutting speed 200-1000 m/min.

S Group : Suitable for titanium alloys and high-temperature alloys, recommended cutting speed 20-100 m/min.

Group H : Suitable for hardened steel (hardness > 50 HRC), recommended cutting speed 50-150 m/min.

5.3 Coating classification

PVD coating : including TiN , TiCN , AlTiN , with a thickness of 2-10 μm , suitable for general cutting.

CVD coating : includes TiN+ Al_2O_3 + TiCN , thickness 5-20 μm , suitable for high temperature conditions.

6 Application Guide

6.1 Selection principles

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Select the corresponding application group according to the workpiece material, for example, Group P is suitable for steel and Group N is suitable for aluminum alloy.
The coating and the geometry are selected according to the type of machining (roughing, finishing).
Considering machine tool performance and cooling conditions, wet cutting or high pressure cooling is recommended to extend tool life.

6.2 **Processing parameter recommendations**

Cutting speed : Adjusted according to material and tool type, ranging from 20-1000 m/min.
Feed rate : 0.05-0.5 mm/rev, adjusted according to hole diameter or surface requirements.
Cutting depth : 0.1-5 mm, depending on machining accuracy and tool strength.

6.3 **Restrictions**

Avoid using materials specified in this standard in non-chip removal applications.
For high impact loads, high toughness grades (such as YG10) are recommended.

7 Marking and identification

7.1 The identification of hard cutting materials shall include the material category, application group and coating type, for example:
P30 TiAlN : indicates P group, YT series, TiAlN coating.
K20 CVD : Indicates K group, YG series, CVD coating.
7.2 The logo should be clearly printed on the tool surface or packaging in accordance with ISO 1832:2017.

8 Appendix (Informative)

Appendix A: Comparison of hard cutting material properties

Material Type	Hardness (HV)	Fracture toughness (MPa·m $^{1/2}$)	Heat resistance (°C)	Typical Applications
Cemented Carbide	1500-2000	10-20	800-1000	General cutting
ceramics	1800-2500	3-8	1200	High-speed cutting
Diamond	8000-10000	5-10	600	Non-ferrous metals
BnB	4000-5000	6-12	1200	Hardened steel

Appendix B: Application group and workpiece material correspondence table

Application Group	Workpiece material examples	Recommended cutting speed (m/min)
P	Carbon steel, alloy steel	100-400
M	Stainless steel, heat-resistant steel	50-200
K	Gray cast iron, ductile iron	150-500
N	Aluminum, copper, brass	200-1000
S	Titanium alloy, nickel-based alloy	20-100
H	Hardened steel (50-65 HRC)	50-150

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The above is a simulated version based on the structure of ISO 513:2012 and the key information mentioned in the search results (such as classification, application group, coating type, etc.). Since the official full text is not available, this text assumes some technical details (such as hardness range, cutting parameters) and refers to the industry practice of cemented carbide tools. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official ISO 513:2012 text to ensure completeness and accuracy.

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appendix

Carbide Milling Cutters

Carbide milling cutters play an indispensable role in the field of mechanical processing. With their excellent hardness, wear resistance and impact resistance, they have become irreplaceable tools in milling machine processing. These cutters can flexibly complete the processing tasks of planes, grooves, steps, sides and complex curved surfaces through high-speed rotation, providing strong support for the efficient production of modern manufacturing. Carbide milling cutters use tungsten carbide (WC) as the main component, supplemented by cobalt (Co) as a binder, and sometimes titanium carbide (TiC) or tantalum carbide (TaC) is added to further improve performance. They are sintered using a precision powder metallurgy process. Common material grades such as YG10 are particularly suitable for intermittent cutting due to their excellent toughness; YT30 performs well in high-temperature conditions due to its excellent heat resistance; and YW2 is an ideal choice for a variety of processing scenarios due to its balance of comprehensive performance. The structural design of the cutter is diverse, with both a single cutter body made of integral carbide and a flexible design with replaceable blades. The cutter body is usually made of high-strength steel or carbide to ensure sufficient rigidity and stability during high-speed rotation.

1. Geometry design and optimization

The geometric design of carbide milling cutters is the basis for their efficient operation. Designers carefully adjust various parameters to improve cutting effects and processing quality. The helix angle is usually set between 30° and 45°. This design not only helps to discharge chips smoothly, but also effectively reduces the resistance during cutting. The positive rake angle is generally controlled at 5° to 10°. This angle selection can reduce the friction between the tool and the workpiece, making cutting smoother. In addition, the R angle (0.5-2 mm) design of the blade enhances the edge strength of the tool and extends its service life. End mills are usually equipped with 2 to 4 cutting edges, with a diameter range of 3 to 20 mm, which is particularly suitable for processing small diameter holes or fine processing; while face milling cutters are larger, with a diameter of 50 to 200 mm, and the number of blades ranges from 4 to 12. A multi-blade layout is used to improve the efficiency of large-area milling. The tool handle design focuses on rigidity and vibration resistance, and is mostly cylindrical or conical. Some high-end models even incorporate vibration-damping grooves or dynamic balancing technology to ensure stability at high speeds of up to 20,000 rpm. The depth of the chip groove is adjusted according to processing requirements, usually between 2 and 5 mm. This design effectively prevents chip blockage, which is particularly important in deep processing tasks.

2. Coating and surface treatment

Coating technology has injected new vitality into carbide milling cutters, allowing them to perform well under various harsh conditions. PVD (physical vapor deposition) coatings such as TiN , which are attractive golden yellow and generally 2 to 5 microns thick, provide initial wear protection and are particularly suitable for avoiding adhesion when processing aluminum alloys; CVD (chemical vapor deposition) coatings such as TiAlN , with their purple-black appearance and temperature resistance up to 1100°C, have become the first choice for high-temperature cutting of steel and

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titanium alloys, and their thickness is usually between 10 and 25 microns. Multi-layer coating structures, such as TiN combined with Al_2O_3 and TiCN , combine multiple performance advantages, with a thickness of up to 15 to 30 microns, further improving wear resistance and heat resistance. In terms of surface treatment, the polishing process can control the surface roughness to Ra <0.2 microns, effectively reducing chip adhesion; laser micro-texturing technology carves tiny lubrication grooves on the surface to reduce friction; some advanced milling cutters even use nano-coatings, such as nano- TiAlN (grains less than 50 nanometers), which is particularly suitable for machining tasks that require ultra-high precision. The coating adhesion test is carried out through a scratch test, requiring a critical load of more than 80 Newtons to ensure that the coating will not peel off during high-speed cutting.

3. Technical characteristics and performance

Carbide milling cutters have excellent technical performance and provide reliable guarantee for various processing tasks. Its cutting speed ranges from 200 to 1000 meters per minute, depending on the workpiece material. For example, steel is usually 200 to 400 meters per minute, while aluminum alloy can reach 500 to 1000 meters per minute. The processing parameters need to be flexibly adjusted according to the material properties and machine tool performance. In terms of hardness, the hardness of the milling cutter is generally between HV 1700 and 2100. The YT series products can even reach HV 2100 to 2200 due to titanium carbide, which is enough to cope with high-hardness workpieces. The fracture toughness is 14 to 20 $MPa \cdot m^{1/2}$. The YG series such as YG10 has stronger toughness due to the high cobalt content, which is particularly suitable for scenes that need to withstand intermittent cutting impact. The wear resistance is less than 0.04 cubic millimeters per Newton meter, and can be further reduced to 0.02 cubic millimeters per Newton meter after coating, which greatly extends the service life of the tool. In terms of heat resistance, it can reach up to 1100°C (thanks to the CVD coating enhancement), allowing it to remain stable under high temperature conditions. The processing accuracy is controlled within 0.02 mm, which is enough to meet the requirements of complex surfaces and precision parts.

4. Processing requirements and applications

The processing requirements and application scenarios of carbide milling cutters reflect their multifunctional characteristics. Cutting parameters vary depending on the material. For example, the cutting speed of steel is usually 200 to 400 meters per minute, the feed rate is 0.1 to 0.3 mm per tooth, and the cutting depth is 1 to 5 mm; while aluminum alloys require higher cutting speeds, ranging from 500 to 1000 meters per minute, the feed rate is 0.2 to 0.5 mm per tooth, and the cutting depth can reach 2 to 8 mm. The choice of cooling method is also crucial. Dry cutting is suitable for aluminum alloy processing and can reduce the cost of coolant use; wet cutting using emulsion is more suitable for steel and can effectively reduce thermal damage; and for difficult-to-process materials such as titanium alloys, high-pressure cooling (15-25 bar) can significantly improve chip removal efficiency and tool life. In practical applications, milling cutters are often used in the aerospace field to process aluminum alloy skins and titanium alloy components, which require high precision and heat resistance; the mold industry relies on it to mill complex surfaces and stamping dies, focusing on the fineness of surface quality; and in mechanical processing, it is widely used in

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the processing of grooved parts and gear contours, demonstrating its versatility.

5. Challenges and Solutions

It is inevitable to encounter some challenges when using carbide milling cutters, but these problems can be effectively solved through scientific solutions. Vibration is a prominent problem during high-speed cutting, which can be reduced by using a vibration-damping handle and optimizing the helix angle; heat accumulation in titanium alloy processing is a common problem, which can be effectively alleviated by equipping it with an efficient cooling system and a heat-resistant coating (such as TiAlN); intermittent cutting can easily lead to chipping , and the use of high-toughness grades such as YG10 and edge passivation can significantly improve durability; if the surface roughness is not ideal during finishing, the result can be optimized by reducing the feed rate and using a polishing coating. Together, these solutions ensure the reliable performance of the milling cutter under complex working conditions.

6. Optimization and development trends

The optimization and development direction of cemented carbide milling cutters reflect the industry's pursuit of efficiency and intelligence. In terms of structural optimization, the integrated internal cooling channel can effectively reduce heat accumulation, the replaceable blade design is convenient for replacement and reduces costs, and the dynamic balancing technology improves the stability of high-speed operation. In terms of material innovation, nano-cemented carbide improves hardness and toughness with its fine grains (less than 0.5 microns), and the gradient material design allows the blade to have both high hardness and high toughness. The trend of intelligence allows the milling cutter to be embedded with sensors to monitor wear, temperature and vibration in real time, and dynamically adjust cutting parameters in combination with artificial intelligence algorithms. In terms of manufacturing technology, 3D printing technologies such as selective laser melting (SLM) can create complex tool body structures, such as built-in cooling channels, while laser deposition technology provides the possibility of repairing worn tools. The environmental protection trend has promoted the development of dry cutting coatings (such as graphene composite coatings), reducing dependence on coolants, while the use of recyclable materials also reduces environmental impact.

7. Lifespan and maintenance

The life of carbide milling cutters varies depending on the workpiece material and processing conditions, and is generally between 5 and 15 hours, such as about 10 hours for steel processing and up to 15 hours for aluminum alloy processing. Maintenance work includes regular sharpening , using diamond grinding wheels to ensure that the angle error is less than 0.5°, coating repair through PVD technology to restore performance, and laser pre-adjustment to ensure that the error is less than 0.005 mm. These measures can effectively extend the service life of the tool. After the tool is scrapped, the tungsten and cobalt materials in it can be recycled and reused by smelting and returning to the furnace, reflecting the concept of sustainable development.

8. Industry standards and certification

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The production and use of carbide milling cutters must comply with international and domestic standards, such as ISO 15641 in the ISO standard and the Chinese national standard GB/T series, to ensure quality and safety. In terms of certification, CE safety certification and RoHS environmental certification are essential. Internationally renowned manufacturers such as Sandvik, Kennametal and Mitsubishi provide detailed technical manuals to provide users with professional guidance in selection and operation.

9. Classification of carbide milling cutters

Carbide milling cutters can be divided into several categories according to processing requirements and application scenarios, each type has its own unique design and purpose:

End milling cutter

This milling cutter is made of solid carbide, equipped with 2 to 4 cutting edges, and has a diameter ranging from 3 to 20 mm. The rake angle is set at 5° to 10°, the back angle is between 6° and 12°, the YG10 grade is selected, and a TiN layer (thickness 2-5 microns) is applied to enhance wear resistance. The cutting speed is between 200 and 600 meters per minute, and the processing accuracy is less than 0.02 mm, which is very suitable for small diameter holes and fine processing tasks.

Face milling cutter

The face milling cutter features a replaceable insert design, with a blade number ranging from 4 to 12 and a diameter range of 50 to 200 mm, suitable for large-area milling. The rake angle is 5° to 8°, the back angle is 6° to 10°, and the YT30 grade is selected . The TiAlN coating (thickness 10-25 microns) provides high heat resistance. The cutting speed is 300 to 1000 meters per minute, and the accuracy is less than 0.02 mm. It is widely used in plane milling and mold processing.

Ball end mills

Ball end mills are known for their spherical cutting edges , with diameters ranging from 6 to 30 mm, rake angles of 10° to 15°, back angles of 8° to 12°, and YW2 grades. They are coated with multiple layers for both wear and heat resistance. The cutting speed is 200 to 500 m/min, and the accuracy is less than 0.01 mm, making them particularly suitable for complex curved surface machining of aviation parts.

Forming milling cutter

The cutting edge of this milling cutter is customized according to the specific workpiece shape, with a diameter between 10 and 50 mm, a rake angle of 5° to 15°, a back angle of 6° to 12°, and a YG10 grade . The CrN coating provides additional corrosion resistance. The cutting speed is 100 to 400 meters per minute, and the accuracy is less than 0.02 mm. It is widely used in special contours and mold manufacturing.

Rough milling cutter

Rough milling cutters are known for their sturdy blade design, with 4 to 8 blades, diameters of 20 to 100 mm, rake angles of 5° to 8°, back angles of 6° to 8°, YG8 grade, and TiAlN coating (thickness 15-25 microns) to enhance wear resistance. Cutting speeds range from 200 to 400 m/min, cutting depths of 2 to 10 mm, and they are suitable for roughing tasks of cast iron and steel.

Finishing cutter

The fine milling cutter has sharp edges, 2 to 6 edges , a diameter of 5 to 30 mm, a front angle of 10° to 15°, a back angle of 8° to 12°, and uses the YT15 grade. The TiCN coating provides high-

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precision protection. The cutting speed is 300 to 800 meters per minute, the cutting depth is 0.1 to 2 mm, and the accuracy is less than 0.01 mm. It is widely used in the finishing of gears and precision parts.

10. Selection and matching

Choosing the right carbide milling cutter requires a comprehensive consideration of the workpiece material and the type of processing. For example, when processing steel, the YT30 face milling cutter is an ideal choice; for aluminum alloys, the YG10 end milling cutter can effectively avoid sticking; and titanium alloy processing is more suitable for the YW2 ball end milling cutter with heat-resistant coating. The performance of the machine tool is also critical, the spindle power must exceed 5 kilowatts and the speed must reach more than 10,000 revolutions per minute to give full play to the potential of the milling cutter.

11. Summary of Carbide Milling Cutter Types

Knives type	Number of blades	diameter (mm)	Front Angle (°)	Rear Angle (°)	Applicable Brand	Coating Type	Cutting speed (m/min)	Depth of cut (mm)	Accuracy (mm)	Typical Applications
End milling cutter	2-4	3-20	5-10	6-12	YG10	TiN (2-5 µm)	200-600	1-5	<0.02	Hole and slot machining
Face milling cutter	4-12	50-200	5-8	6-10	YT30	TiAlN (10-25 µm)	300-1000	2-8	<0.02	Surface milling, mold
Ball end mills	-	6-30	10-15	8-12	YW2	Multi-layer coating	200-500	0.5-3	<0.01	Complex surfaces, aviation parts
Forming milling cutter	-	10-50	5-15	6-12	YG10	CrN	100-400	1-4	<0.02	Special profiles, molds
Rough milling cutter	4-8	20-100	5-8	6-8	YG8	TiAlN (15-25 µm)	200-400	2-10	-	Rough machining, Cast iron
Finishing cutter	2-6	5-30	10-15	8-12	YT15	TiCN	300-800	0.1-2	<0.01	Finishing, Gears

the 30-year history of cemented carbide manufacturing, CTIA GROUP has designed and produced a large number of high-performance cemented carbide products , meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical , military and other industries . If you have any needs for cemented carbide milling cutters , we are willing to provide you with precise , efficient and high-quality customized services!
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appendix:

What are Carbide End Mills?

(1) Overview of Carbide End Mills

Carbide end mills are cutting tools with excellent performance, widely used in metal processing, mold manufacturing and other industrial fields that require high precision and efficient production. This tool is known for its excellent wear resistance, high hardness and excellent cutting ability. It is a versatile rotary cutting tool that can achieve complex cutting tasks under various processing conditions. The design of carbide end mills enables it to use the cutting edges of the end and the periphery for axial and radial processing at the same time, which makes it particularly suitable for processing grooves, sides, contours and complex three-dimensional surfaces. Its wide application is due to the special properties of carbide materials, which can withstand high loads and high temperature environments, thus performing well when processing high-strength materials such as stainless steel, titanium alloys and hardened steel . In addition, carbide end mills are often used in conjunction with modern CNC machine tools and machining centers to fully realize their potential for efficient cutting, especially in scenarios that require high precision and complex geometry processing. Whether it is manual processing of small workpieces or mass production of large parts, carbide end mills can provide reliable processing solutions and become an indispensable core tool in modern manufacturing. Its flexibility also lies in the fact that it can be customized according to different workpiece materials and processing requirements, further meeting diverse industrial needs.

(2) Carbide end mill materials and manufacturing

The manufacturing material of cemented carbide end mills is the key basis of their performance. They are usually made of tungsten carbide (WC) as the main component, supplemented by cobalt (Co) as a binder, and sintered through advanced powder metallurgy technology. This composite material achieves a balance between high hardness and a certain toughness through precise formulation and process control, ensuring that the tool can remain sharp during the cutting process while resisting the risk of breakage. The specific cemented carbide grade selection depends on the characteristics of the processing material. Common grades include:

YG6: The cobalt content is about 6%, the hardness range is between HV 1800-1900, the bending strength is about 1800-2000 MPa, it has good wear resistance and impact resistance, and is particularly suitable for processing cast iron, non-ferrous metals (such as aluminum, copper) and some medium hardness materials. It is widely used in general cutting scenarios.
YT15: Contains titanium carbide and tungsten carbide, with a hardness range of HV 1900-2000 and a bending strength of about 1600-1800 MPa. It is suitable for processing steel and alloy steel. Due to its high stability at high temperatures, it is particularly suitable for continuous cutting.
niobium carbide are added , with a hardness range of HV 1800-2100 and a bending strength of about 1700-1900 MPa. It is particularly suitable for processing difficult-to-process materials such as titanium alloys, nickel-based alloys and stainless steel, and is suitable for the aerospace field.

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The manufacturing process begins with the precise mixing of high-purity raw materials to ensure uniform distribution of the ingredients, followed by high-pressure pressing and long-term sintering (usually 6-12 hours) in a high-temperature sintering furnace at 1400°C-1500°C to ensure the density and uniformity of the material. The sintered blank undergoes multiple precision grinding and polishing processes, and the sharpness of the blade is finely polished to micron-level accuracy (surface roughness Ra ≤ 0.1 micron) to ensure cutting quality. In addition, in order to further improve performance, many modern carbide end mills will apply physical vapor deposition (PVD) or chemical vapor deposition (CVD) coatings on the surface. Common coatings include:

TiN (titanium nitride): It is yellow in color, 2-5 microns thick, with a hardness of about 2000-2500 HV. It significantly improves wear resistance and oxidation resistance and is suitable for general steel processing.
TiCN (titanium carbonitride): blue or purple, 3-6 microns thick, hardness about 2500-3000 HV, enhanced anti-adhesion and cutting life, especially suitable for aluminum alloys and stainless steel.
Al_2O_3 (aluminum oxide): It is white, 5-10 microns thick, and has a hardness of about 3000 HV. It is suitable for high-temperature cutting environments, such as machining hardened steel or high-temperature alloys.

These coatings are deposited in a vacuum or inert gas environment and can effectively reduce friction and prevent adhesion between the tool and the workpiece material, thereby extending the service life, especially under high-speed cutting (Vc > 300 m/min) or dry cutting conditions.

(3) Types and structures of carbide end mills

Carbide end mills can be divided into many types according to their use and design structure. Each type is optimized for specific processing needs. The following is a detailed classification and its characteristics:

Straight Shank End Mills

The shank is cylindrical, with a diameter range of 3 mm to 32 mm. It adopts standardized clamping methods (such as spring chucks or hydraulic chucks), suitable for general milling tasks, and widely used in small machine tools and manual operation scenarios. It has a simple structure and is easy to install. It is suitable for processing small and medium-sized workpieces, especially for flexible production lines that require frequent tool changes.

Shank End Milling Cutter

With a 7:24 or Morse taper design, the diameter of the small end of the tapered shank ranges from 16 mm to 50 mm. This design provides higher clamping rigidity (torque transmission capacity can reach more than 500 Nm), suitable for heavy-duty cutting and large machine tools, especially in deep hole processing or rough processing requiring high torque.

Ball nose end mills

The cutting end is spherical, and the ball head radius ranges from 0.5 mm to 10 mm. It is specially

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used for three-dimensional curved surfaces and complex mold processing. Its smooth cutting path can avoid scratches or step effects on the workpiece surface. It is widely used in automotive molds (such as stamping molds) and aviation parts manufacturing (such as blade surfaces).

Flat end mills

The cutting end is flat, with a blade number range of 2-8, suitable for slot milling, side milling and plane processing. Its design focuses on cutting efficiency and stability. It is commonly used in mass production (such as gear groove processing), and the cutting width can reach more than 80% of the tool diameter.

Wave edge end mill

The back side of the blade adopts a wavy design with a waveform amplitude of 0.1-0.3 mm and a wavelength of 2-5 mm. This structure reduces vibration by dispersing the cutting force (the vibration amplitude can be reduced by 30%-50%) and is suitable for high-speed cutting and difficult-to-process materials (such as hardened steel HRC 50-60).

(4) Typical structural parameters of carbide end mills include:

Cutting diameter (D)

1 mm to 40 mm, covering a wide range of needs from micro-machining (microelectronic components) to heavy-duty cutting (large castings).

Total length(L)

50mm to 250mm, ensuring adaptation to different machine tool spindle lengths and workpiece depths, and the extra-long type can reach 300mm.

Effective cutting length (l)

10mm to 100mm, determines the maximum cutting depth of the tool in the workpiece, and deep cavity processing can be customized to 150mm.

Shank diameter (d)

Matching the cutting diameter, the tolerance grade is h6 (0/-0.006 mm), ensuring the clamping accuracy, the maximum diameter can reach 40 mm.

Helix Angle

The range is 15°-45°, the standard value is 30°, which affects the chip discharge efficiency and cutting stability. 35°-40° is usually used for finishing (the chip discharge rate is increased by 15%), and 15°-20° can be used for roughing.

Number of blades

2-10, adjusted according to the diameter and processing material, the more blades there are, the higher the cutting efficiency (the efficiency can be increased by 20%-40%), but the rigidity requirement for the machine tool is also higher (the spindle rigidity needs to be ≥2000 N/ μm).

(5) Technical parameters of carbide end mills

The performance parameters of carbide end mills vary depending on the specific model and application. The following are detailed typical values for user reference and optimized processing:

hardness

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The substrate hardness ranges from HV 1800-2100, and the surface hardness after coating can reach over 3000 HV, far exceeding the hardness of conventional high-speed steel (HSS) (HV 800-900), ensuring wear resistance under high loads (wear rate reduced by over 50%).

Heat resistance

It can maintain cutting performance at high temperatures of 600°C-1000°C, and is particularly suitable for dry cutting or high-temperature alloy processing. Its thermal stability is 2-3 times that of HSS (thermal expansion coefficient is only 5×10^{-6} /°C).

Cutting speed (Vc):

Steel: 100-300 m/min, the recommended value is adjusted according to the hardness of the steel type (e.g. 200 m/min for 45# steel , 120 m/min for HRC 45 hardened steel).

Cast iron: 150-400 m/min, grey cast iron: 250 m/min, ductile iron: 180 m/min, heat-resistant cast iron: 150 m/min.

Aluminum alloy: 200-600 m/min, pure aluminum: 500 m/min, aluminum silicon alloy: 300 m/min, aluminum copper alloy: 400 m/min.

Feed rate (fz)

0.05-0.5 mm/tooth. For soft materials (such as aluminum), 0.3-0.5 mm/tooth is recommended. For hard materials (such as hardened steel), 0.05-0.1 mm/tooth is recommended. The specific value needs to be optimized according to the machine power (≥2 kW) and the workpiece rigidity.

Depth of cut (ap): 0.5-5 mm, 0.5-2 mm for small diameter tools (D<10 mm), 3-5 mm for large diameter tools (D>20 mm), excessive depth of cut (>1.5 times the tool diameter) may cause vibration.

Tolerance: Diameter tolerance ±0.01 mm (IT6 grade), length tolerance ±0.3 mm, taper tolerance ±0.01 mm/100 mm, ensuring processing accuracy (roundness error <0.005 mm).

Surface roughness: Ra of workpiece surface can reach 0.1-0.8 micron under finishing condition and 1.6-3.2 micron under roughing condition, depending on cutting parameters (Vc /fz/ap combination) and tool condition.

(6) Application scenarios of carbide end mills

Carbide end mills excel in many industrial fields due to their versatility and high performance. Specific application scenarios include:

Mold manufacturing

Used for machining precision mold cavities and complex surfaces, such as automotive stamping molds (depth 50-100 mm) and plastic injection molds (curvature radius 5-20 mm). Ball end mills are particularly suitable for fine machining of surface transition areas (error <0.01 mm).

Aerospace

When processing titanium alloy, nickel-based alloy and composite parts, such as aircraft wing ribs (thickness 5-15 mm) and engine blades (surface Ra < 0.4 microns), high heat-resistant coating models (such as Al_2O_3) are required .

Machining

For the production of gears (module 1-5), bearing housings (diameter 50-200 mm) and connectors (hole depth 20-50 mm), flat end mills are extremely efficient in slot milling and side milling (efficiency increase of 30%).

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Woodworking and Composite Materials

Specific coating types (e.g. TiN) are suitable for wood, MDF (medium density fiberboard) and carbon fiber (thickness 2-10 mm) and reduce material tearing (tear rate <5%).

Taking the processing of 45# steel as an example, an end mill with a diameter of 12 mm, 4 edges and a helix angle of 30° is selected. The cutting speed is set to 200 m/min, the feed rate is 0.2 mm/tooth, and the cutting depth is 2 mm. Efficient slot milling (processing efficiency 150 cm³/min) can be achieved , the expected life can reach 20 hours, and the Ra of the workpiece surface after processing is about 0.4 microns.

(7) Precautions for using carbide end mills

In order to give full play to the performance of carbide end mills and extend their service life, the following details should be noted:

Machine selection

It is recommended to use CNC machine tools (such as CNC machining centers) or milling machines with good rigidity, ensure that the spindle runout is less than 0.01 mm, the machine power must match the tool diameter and cutting parameters (for example, a 12 mm diameter tool requires a spindle power ≥ 2.5 kW and a torque ≥ 30 Nm), and check the machine guide accuracy (straightness < 0.02 mm/m).

Cooling and lubrication

It is recommended to use emulsion or cutting oil with a flow rate of 10-20 L/min. When the cutting speed is higher than 300 m/min, high-pressure cooling (pressure ≥5 bar, flow rate ≥15 L/min) is required to reduce the temperature of the cutting zone (<500°C) and reduce thermal deformation.

Cutting parameters optimization

Adjust the cutting speed and feed rate according to the workpiece material to avoid overload that causes premature wear or breakage of the tool. For example, when processing stainless steel, the cutting speed should be controlled at 120-180 m/min, the feed rate at 0.08-0.12 mm/tooth, and the cutting depth at 1-2 mm.

Installation and calibration

The shank and the chuck must fit tightly. After installation, use a tool setting probe to check the coaxiality. The eccentricity should be controlled within 0.005 mm. The clamping force should be uniform (torque 20-30 Nm) to avoid vibration caused by looseness.

Wear monitoring:

Check the blade wear status regularly. When the cutting edge flank wear VB reaches 0.3 mm, or obvious notches (depth > 0.1 mm) appear, the tool needs to be replaced. At the same time, pay attention to the color change of the chips (blue indicates overheating, and Vc needs to be reduced by 10%-20%).

(8) Advantages of carbide end mills

High hardness (3-4 times higher than high-speed steel), can process hardened steel above HRC 60, and its wear resistance is 3-5 times that of HSS.

It has strong wear resistance and its service life is 2-5 times longer than that of HSS, especially in

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continuous cutting (>10 hours).

Suitable for high-speed cutting (Vc up to 600 m/min), significantly improving production efficiency (efficiency increased by 40%-60%).

Customizable design, helix angle, number of edges and coating can be adjusted according to customer needs.

(9) Carbide end mill market and development

The carbide end mill market continues to expand due to the promotion of Industry 4.0 and smart manufacturing . Future development trends include:

Green Manufacturing

Adopting recyclable materials (e.g. cobalt recovery rate > 80%) and coating processes with low environmental impact (carbon emissions reduced by 20%).

Intelligent

Integrated sensors monitor tool wear (real-time detection of VB value) and optimize cutting parameters through AI (efficiency increased by 10%-15%).

Miniaturization

Develop micro end mills with a diameter of less than 1 mm (accuracy < 0.005 mm) to meet the processing needs of microelectronics (chip packaging) and medical devices (orthopedic implants).

(10) Recommended specific product models of carbide end mills

According to different processing requirements, the following are several recommended carbide end mill models for user reference:

Carbide Straight Shank Flat End Mills

Specifications: diameter 12 mm, 4 edges , 30° helix angle, total length 100 mm, effective cutting length 40 mm, shank diameter 12 mm.

Material: YG6, TiN coating .

Applicable scenarios: Processing 45# steel, cast iron, slot milling and side milling .

Recommended parameters: Vc 200 m/min, fz 0.2 mm/tooth, ap 2 mm, life about 20 hours.

Advantages: High cost performance, suitable for small and medium batch production, domestic brands have strong reliability.

Carbide Ball Nose End Mills

Specifications: diameter 16 mm, ball head radius 8 mm, 4 flutes , 35° helix angle, total length 120 mm, effective cutting length 50 mm, taper shank diameter 20 mm.

Material: YW2, coated with TiCN .

Applicable scenarios: Processing titanium alloy and aviation parts surfaces.

Recommended parameters: Vc 150 m/min, fz 0.1 mm/tooth, ap 1.5 mm, life about 25 hours.

Advantages: High heat resistance, suitable for complex surface finishing, international brand quality assurance.

Carbide Wave Edge End Mills

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Specifications: Diameter 10 mm, 3 edges , 40° helix angle, total length 90 mm, effective cutting length 30 mm, shank diameter 10 mm.
: YT15, coated with Al_2O_3 .
Applicable scenarios: Machining hardened steel (HRC 50-60), high-speed cutting.
Recommended parameters: Vc 120 m/min, fz 0.08 mm/tooth, ap 1 mm, life about 15 hours.
Advantages: Good vibration reduction effect, reducing processing vibration by 50%, suitable for high precision requirements.

(11) Optimization of carbide end mill processing solutions

In order to maximize the performance of carbide end mills, the following are optimized processing solutions for different workpiece materials:

Processing 45# steel (medium carbon steel, HRC 20-25) Optimization solution:
Cutting speed: 200 m/min (spindle speed about 5300 RPM, D=12 mm).
Feed rate: 0.2 mm/tooth (feed speed 1200 mm/min).
Cutting depth: 2 mm, cross feed 0.5 mm/time.
Cooling: Use 5% emulsion, flow rate 15 L/min.
Machine tool: CNC machining center, spindle power 3 kW.
Results : Machining efficiency 150 cm³ / min, surface Ra 0.4 microns, tool life 20 hours.
Optimization suggestions: Check the blade wear every 10 hours of processing, and reduce the cutting depth to 1.5 mm if necessary to extend the life (life can be increased by 5 hours). Use the constant height spiral feed strategy to reduce uneven force on the tool.

Optimization solution for machining titanium alloy (Ti-6Al-4V, HRC 30-35):
Cutting speed: 150 m/min (spindle speed about 3000 RPM, D=16 mm).
Feed rate: 0.1 mm/tooth (feed speed 600 mm/min).
Cutting depth: 1.5 mm, cross feed 0.3 mm/time.
Cooling: High pressure cooling (6 bar, 20 L/min) with synthetic cutting fluid.
Machine tool: Five-axis machining center, spindle power 5 kW.
Results: Machining efficiency 80 cm³ / min, surface Ra 0.3 microns, tool life 25 hours.
Optimization suggestion: Use intermittent cutting strategy (lift the tool every 0.5 mm cutting depth), reduce heat accumulation (temperature < 600°C), and replace the coolant every 5 hours to maintain the cooling effect.

Machining hardened steel (HRC 50-60) Optimization solution:
Cutting speed: 120 m/min (spindle speed about 3800 RPM, D=10 mm).
Feed rate: 0.08 mm/tooth (feed speed 300 mm/min).
Cutting depth: 1 mm, cross feed 0.2 mm/time.
Cooling: Dry cutting or minimal quantity lubrication (MQL, flow rate 0.1 mL/min).
Machine tool: High rigidity vertical milling machine, spindle power 2.5 kW.
Results: Machining efficiency 50 cm³ / min, surface Ra 0.6 microns, tool life 15 hours.
Optimization suggestions: Reduce the spindle speed by 10% (Vc 108 m/min) to reduce vibration

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(vibration amplitude <0.01 mm), clean the chips regularly (once every 30 minutes), and preheat the machine tool for 5 minutes before cutting to stabilize the rigidity.

With its excellent cutting performance, versatility and high adaptability, carbide end mills have become the core tools in modern machining. Whether it is the complex surface processing of precision molds or the production of large quantities of metal parts, it can provide efficient and stable solutions. By selecting the right model, optimizing cutting parameters (such as Vc 200 m/min, fz 0.2 mm/tooth), and combining correct operation and maintenance methods, users can maximize its performance and significantly extend its service life.

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appendix:

What is a Carbide Face Mill?

Definition and function of carbide face milling cutter

Carbide face milling cutter is a high-performance rotary cutting tool designed for high-efficiency plane cutting. It is widely used in metal processing, mold manufacturing, mechanical parts production and other industrial fields that require large-area surface processing. As a multi- edge cutting tool, its core function is to achieve fast and uniform material removal through multiple cutting edges acting on the workpiece surface at the same time, so as to efficiently complete tasks such as plane milling, step processing, surface finishing and wide-width contour processing. Compared with traditional single-edge or few -edge tools, carbide face milling cutters can significantly improve cutting efficiency, reduce single-edge load and extend tool life due to their multi-edge design. As its main material, cemented carbide gives face milling cutters ultra-high hardness (usually reaching HV 1600-1900) and wear resistance, enabling them to cope with the cutting needs of high-strength materials such as stainless steel, titanium alloy, hardened steel and cast iron and other difficult-to-process materials. In addition, carbide face milling cutters are usually used in conjunction with modern CNC machine tools (CNC), machining centers or large milling machines, which can give full play to their performance advantages under high speed (up to 8000 RPM) and high feed rate (up to 5000 mm/min). In industrial production, carbide face milling cutters are regarded as key tools to improve processing efficiency, optimize surface quality and reduce production costs, especially in high-demand fields such as automotive parts, aerospace components, energy equipment manufacturing and precision mold processing. It plays an irreplaceable role. Its design flexibility also allows customization according to specific workpiece materials and processing processes, such as adjusting the cutting angle or number of edges to meet diverse processing needs.

Structural features of carbide face milling cutter

The structural design of carbide face milling cutters is the basis of their high performance. They usually adopt disc-shaped or polygonal cutter bodies with cutting edges distributed on their circumference and end faces, focusing on rigidity, balance and chip control. The structural parameters of the cutter are precisely calculated and optimized to ensure stability during high-speed rotation and heavy-load cutting. Its main structural features include:

Diameter(D)

The range is from 50 mm to 400 mm, covering the processing needs of small workpieces (such as automobile cylinder heads, with an area of 0.5 m^2) to large plates (such as wind turbine blade bases, with an area of 2-4 m^2) . The larger the diameter, the higher the cutting width and material removal rate, but the rigidity requirements of the machine tool also increase accordingly.

Cutting width

It can reach 70%-100% of the tool diameter, depending on the number of edges and cutter head design. For example, a 200 mm diameter face milling cutter can achieve an effective cutting width of 150-200 mm, which is suitable for large-area flat surface processing.

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Handle form

These include straight shanks (20-50 mm diameter), tapered shanks (7:24 taper, sizes ranging from 16 mm to 80 mm) or modular toolholders (such as KM or HSK systems). The tapered shank design provides higher clamping torque (up to 1000 Nm) for heavy-duty cutting, while the modular toolholders facilitate quick replacement and maintenance.

Number of blades

4-20 cutting edges , adjusted according to tool diameter and processing requirements. Small diameter (D<100 mm) usually has 4-8 edges , and medium and large diameter (D>150 mm) can reach 10-20 edges. Increasing the number of edges can improve cutting efficiency (efficiency increased by 20%-40%), but it is necessary to ensure that the machine tool spindle power and rigidity match.

Cutting Angle

The rake angle is 5°-15° (positive rake angle optimizes cutting force, and the back angle is 5°-10° (reduces back tool wear). The cutting angle design is adjusted according to the workpiece material. For example, the rake angle can be 12°-15° when processing aluminum alloy and 5°-8° when processing steel.

Body Type

There are two types: integral type (the blade and the cutter body are integrally formed, with a diameter of 50-150 mm) and replaceable blade type (the cutter body is made of steel and loaded with carbide blades, with a diameter of 150-400 mm). The integral type is suitable for small and medium-sized processing, while the replaceable blade type is convenient for blade replacement and reduces long-term use costs.

edge of the tool is precision ground in multiple passes (accuracy of ±0.005 mm) to ensure the sharpness and consistency of the cutting edge (edge roughness Ra ≤ 0.1 micron), and the tool body is dynamically balanced (unbalance <10 g·mm /kg) to reduce vibration at high speeds (vibration amplitude <0.01 mm). In addition, modern face milling cutters may also integrate cooling channels or chip grooves to optimize chip evacuation and thermal management.

Materials and Manufacturing of Carbide Face Milling Cutter

The excellent performance of cemented carbide face milling cutters comes from their high-quality materials and complex manufacturing processes. The matrix material is usually a composite material of tungsten carbide (WC) and cobalt (Co), sintered by powder metallurgy. Tungsten carbide provides high hardness and wear resistance, cobalt as a bonding phase enhances toughness, and the formula and particle size (0.5-2 microns) directly affect the performance of the tool. Common cemented carbide grades include:

YG8: Cobalt content is 8%, hardness is HV 1700-1800, bending strength is 2000-2200 MPa, suitable for machining cast iron (such as HT250, HB 180-220), non-ferrous metals (such as aluminum, copper, HB 50-100) and some medium hardness materials (HB 200-300). It is widely used for rough machining due to its good impact resistance.

YC40: Cobalt content 10%, hardness HV 1600-1700, bending strength 2200-2400 MPa, suitable for processing steel (such as 45# steel, HRC 20-25) and stainless steel (such as 304, HRC 15-20),

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and remains stable at high temperatures (above 600°C).

YW1: Contains tantalum carbide (TaC) and niobium carbide (NbC), hardness HV 1800-1900, bending strength 1900-2100 MPa, specially designed for high temperature alloys (such as Inconel 718, HRC 35-40) and titanium alloys (such as Ti-6Al-4V, HRC 30-35), heat resistance up to 900°C.

The manufacturing process is divided into several precise steps:

Raw material preparation: High purity tungsten carbide powder and cobalt powder are mixed in proportion (accuracy ±0.1%), and a small amount of rare earth elements (such as Ce, Y) are added to optimize the microstructure.

Pressing: Using a hydraulic press to apply 100-200 MPa pressure, the cutter body or blade blank is formed to ensure a density of 14.5-15 g/ cm^3 .

High temperature sintering: In a vacuum or hydrogen protected sintering furnace, the temperature is controlled at 1400°C-1500°C for 8-12 hours to eliminate pores and form a dense structure.

Post-processing: After sintering, the blank undergoes turning (external runout <0.01 mm), grinding (surface Ra ≤ 0.2 microns) and polishing (edge Ra ≤ 0.1 microns). The tool body also needs to be dynamically balanced .

To further improve performance, tool surfaces are often coated, deposited by PVD or CVD processes:

TiAlN (titanium aluminum nitride): thickness 3-8 microns, hardness 2800-3200 HV, heat resistance up to 900°C, excellent oxidation resistance, suitable for dry cutting.

CrN (chromium nitride): thickness 2-5 microns, hardness 2500-2800 HV, friction coefficient <0.3, strong anti-adhesion, especially suitable for aluminum alloy processing.

Multilayer coating: TiN+ Al_2O_3 + TiCN combination, thickness 5-12 microns, comprehensive hardness above 3000 HV , both wear resistance and heat resistance, suitable for multi -material processing.

These coatings significantly reduce friction (20%-30% reduction), improve tool life (50%-100% longer than uncoated), and perform well in high-speed cutting (Vc > 300 m/min) or intermittent cutting.

Carbide Face Milling Cutter Types

Based on their structure and purpose, carbide face milling cutters can be subdivided into the following types, each optimized for specific machining needs:

Solid Carbide Face Milling Cutter

The blade and the cutter body are integrally formed, with a diameter of 50-150 mm, suitable for small and medium-sized flat surface processing (such as automobile cylinder heads, area 0.5 m^2) . Its advantages are compact structure, easy installation, and suitable for small and medium-sized batch production, but the tool needs to be replaced as a whole after wear.

Replaceable blade face milling cutter

The cutter body is made of high-strength steel (such as 40CrMo, HB 250-300), loaded with carbide blades, with a diameter of 150-400 mm, suitable for large-area cutting (such as wind turbine blade base, area 2-4 m^2) . The blades can be replaced individually, reducing long-term use costs, and the cutter head design supports a variety of blade angles (0°-15°).

Roughing face milling cutter

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of edges is 4-8, the cutting depth can reach 5-10 mm, the focus is on removing large amounts of material (such as cast iron blanks, cutting volume 500 cm^3 / min), and the blade back angle is large (10°-15°) to reduce cutting forces.

Finishing face milling cutter

of edges is 10-20, the cutting depth is 1-3 mm, and the surface finish is emphasized (Ra 0.4-0.8 microns). The blade rake angle is small (5°-8°) to improve accuracy. It is widely used in mold bottom surface processing.

Corrugated edge milling cutter

The blade is wavy with a waveform amplitude of 0.2-0.4 mm and a wavelength of 3-6 mm. It reduces vibration by dispersing the cutting force (the amplitude is reduced by 40%-60%) and is suitable for thin-walled parts (such as aluminum alloy skins with a thickness of 5-10 mm) or high-precision processing.

Technical parameters of carbide face milling cutter

The performance parameters of carbide face milling cutters vary depending on the model and application scenario. The following are detailed typical values for user reference and optimization:

Hardness: The substrate hardness ranges from HV 1600-1900, and the surface hardness after coating can reach more than 3000 HV, which is much higher than high-speed steel (HV 800-900), ensuring wear resistance under high loads (wear rate reduced by 60%).

Heat resistance: It can maintain cutting performance at high temperatures of 600°C-1000°C. Its thermal stability is 2-3 times that of HSS (thermal expansion coefficient 5×10^{-6} /°C), making it suitable for dry cutting or high-temperature alloy processing.

Cutting speed (Vc):

Steel: 150-300 m/min, 45# steel: 200 m/min, HRC 40 hardened steel: 120 m/min.

Cast iron: 200-400 m/min, grey cast iron: 250 m/min, ductile iron: 180 m/min.

Aluminum alloy: 300-800 m/min, pure aluminum: 600 m/min, aluminum silicon alloy: 350 m/min.

Feed rate (fz): 0.1-0.5 mm/tooth, 0.3-0.5 mm/tooth for roughing (feed speed 3000-5000 mm/min), 0.1-0.2 mm/tooth for finishing (feed speed 1000-2000 mm/min).

Depth of cut (ap): 1-10 mm, roughing 5-10 mm (material removal rate 500-1000 cm^3 / min), finishing 1-3 mm (accuracy ±0.01 mm).

Tolerance: Diameter tolerance ±0.02 mm (IT6 grade), flatness <0.01 mm, verticality <0.015 mm.

Surface roughness: Finishing Ra 0.4-0.8 microns, roughing Ra 1.6-3.2 microns, depending on cutting parameters and tool condition (new edge Ra can reach 0.2 microns).

Application scenarios of carbide face milling cutters

Carbide face milling cutters have performed well in many industrial fields due to their high efficiency and large-area processing capabilities. Specific application scenarios include:

Automobile industry : Processing cylinder blocks and cylinder head surfaces (area 0.5-2 m^2) , cutting speed 200-300 m/min, efficiency 200-500 cm^3 / min, surface Ra<1.6 microns, ensuring airtightness.

Aerospace: Milling aluminum alloy skin (thickness 5-20 mm), cutting speed 400-600 m/min, surface Ra < 0.6 microns, meeting aviation-grade flatness requirements (flatness < 0.02 mm).

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Energy equipment: Processing of wind turbine blade bases (2-4 m in diameter), cutting depth 8-10 mm, cutting speed 150-250 m/min, material removal rate 800-1200 cm³ / min.
Mould manufacturing: Finishing of mould bottom surface (area 0.2-1 m²) , cutting depth 1-2 mm, cutting speed 150-200 m/min, flatness <0.005 mm, Ra <0.4 micron.
Actual case: An automobile factory uses a 250 mm diameter, 12- edge replaceable blade face milling cutter to process the cylinder head plane, Vc 250 m/min, fz 0.4 mm/tooth, ap 6 mm, processing efficiency of 400 cm³ / min, surface Ra 1.2 microns, and tool life of 50 hours.

Precautions for using carbide face milling cutters

In order to give full play to the performance of carbide face milling cutters and extend their service life, the following details should be noted:
Machine tool rigidity: High-rigidity machine tools are required (spindle rigidity >3000 N/ μm , bed rigidity >5000 N/ μm), spindle runout <0.01 mm, and machine tool guide rail accuracy (straightness <0.02 mm/m) directly affect the processing quality.
Cooling and lubrication: It is recommended to use cutting fluid (such as 5%-10% emulsion) or synthetic oil with a flow rate of 20-50 L/min. When the cutting speed is higher than 300 m/min, high-pressure cooling (pressure 5-10 bar, flow rate ≥20 L/min) is required to reduce the temperature of the cutting zone (<500°C).
Cutting parameter adjustment: Roughing Vc 200-300 m/min, ap 5-10 mm, fz 0.3-0.5 mm/tooth; Finishing Vc 150-200 m/min, ap 1-3 mm, fz 0.1-0.2 mm/tooth. Parameters need to be optimized according to workpiece material and machine power (e.g. spindle power ≥10 kW).
Installation and calibration: Ensure that the tool is coaxial with the spindle, use a tool setting probe to calibrate , eccentricity <0.005 mm, clamping torque 30-50 Nm (adjusted according to the weight of the tool) to avoid vibration caused by looseness.
Wear inspection: Check the blade wear status regularly. Replace the insert/tool when the cutting edge wear VB reaches 0.4 mm or chipping occurs (depth > 0.1 mm). Pay attention to the chip color (blue indicates overheating, and Vc needs to be reduced by 10%-15%) and chip shape (long curled chips indicate appropriate parameters).

Advantages of Carbide Face Milling Cutter

High efficiency (2-3 times higher than end mills), strong large area processing capability, 500-1000 cm³ of material can be removed in a single cut .
Long service life (50-100 hours, depending on coating and working conditions), 3-5 times longer than HSS face milling cutters.
The surface quality is excellent, and the finishing Ra can reach 0.4 microns, meeting high precision requirements.
The replaceable blade design reduces maintenance costs, and the blade replacement time is less than 5 minutes.
Carbide face milling cutters also have limitations . They are costly and require a large initial investment, making them suitable for mass production . They have high requirements for machine tools (power ≥ 10 kW, rigidity > 3000 N/ μm), and are difficult to support with ordinary machine tools . They are not suitable for complex curved surfaces or deep cavity processing, and their scope

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of application is limited (cutting depth < 10 mm).

Carbide Face Milling Cutter Market and Development

Smart tools

Integrated sensors monitor cutting force (range 0-5000 N) and temperature (<1000°C), and AI optimizes parameters to increase efficiency by 10%-15%.

Environmental Technology

By adopting a low-cobalt formula (Co content <6%) and a recyclable coating process, carbon emissions are reduced by 20%-30%.

Large diameter development

Launched 400-600 mm extra-large face milling cutters suitable for wind power and shipbuilding industries, with a cutting width of up to 500 mm.

Difference between carbide face milling cutter and carbide end milling cutter

There are significant differences between carbide face milling cutters and end mills in design and application:

Cutting method: Face milling cutters focus on large-area flat machining (cutting width up to 70%-100% of the diameter), end milling cutters are mostly used for slots, sides and complex curved surfaces (cutting depth up to 150 mm).

blades : Face milling cutters have more blades (4-20) and disperse the cutting load; end milling cutters have fewer blades (2-10) and are suitable for fine processing.

Application scenarios: Face milling cutters are used for planes and steps (such as cylinder planes), and end milling cutters are used for deep holes and 3D surfaces (such as mold cavities).

Structure: Face milling cutters are mostly disc-shaped or have replaceable inserts, while end mills are straight shank or ball-end type.

Efficiency and precision: Face milling cutters have high efficiency (500-1000 cm^3 / min) and medium precision (Ra 0.4-1.6 microns); end milling cutters have low efficiency (50-200 cm^3 / min) and high precision (Ra 0.1-0.8 microns).

Carbide face milling cutters are ideal for efficient plane machining. Their high performance, versatility and large area cutting capacity meet the dual needs of modern industry for efficiency and quality. Production efficiency can be significantly improved by optimizing cutting parameters (such as Vc 250 m/min, ap 6 mm) and correct maintenance (such as regular replacement of inserts).

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appendix:

What is a Carbide Ball End Mill?

Definition and function of carbide ball end mill

Carbide ball end mills are high-precision, versatile rotary cutting tools that are widely used in metalworking, mold making, aerospace, and other industrial fields that require complex surface processing. Its unique feature is the spherical design of the cutting end (i.e., the ball end), which enables the tool to achieve smooth transition cutting, especially suitable for processing three-dimensional surfaces, bevels, and complex geometries. Carbide ball end mills use carbide as the base material, combined with its high hardness (HV 1800-2100) and wear resistance, can efficiently cut high-strength materials such as stainless steel, titanium alloy, hardened steel, and composite materials. Its functions are not limited to surface processing, but can also perform side milling , slot milling, and contour milling, especially in scenarios that require high surface quality and fine geometric accuracy. Carbide ball end mills are usually used in conjunction with CNC machine tools (CNC), five-axis machining centers, or engraving machines to give full play to their processing capabilities under high speed (up to 12,000 RPM) and low cutting depth (0.1-2 mm). In modern manufacturing, especially in the manufacture of automotive molds, aerospace parts and medical devices, carbide ball end mills have become indispensable tools due to their flexibility and precision. Their design can also be customized according to specific workpiece materials and processing requirements to meet diverse industrial needs.

Structural features of carbide ball end mills

The structural design of carbide ball end mills is the basis for efficient processing of complex curved surfaces. They usually adopt straight shank or tapered shank structure, with hemispherical cutting end and blades distributed on the spherical surface and periphery. The following are its main structural features:

Diameter(D)

Ranging from 1 mm to 32 mm, micro ball end mills (D < 6 mm) are used for fine engraving, and large ball end mills (D > 12 mm) are suitable for rough machining of molds.

Ball head radius (R)

From 0.5 mm to 16 mm, the radius size directly affects the smoothness and cutting depth of surface machining, and the R value is usually D/2.

Total length(L)

50mm to 200mm, suitable for different machine tool spindle lengths and workpiece depths, and the extra-long type can reach 250mm.

Effective cutting length (l)

5mm to 100mm, determines the maximum cutting depth of the tool in the workpiece, and deep cavity processing can be customized to 150mm.

Shank diameter (d)

Matching the cutting diameter, ranging from 3 mm to 32 mm, with tolerance grade h6 (0/-0.006

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mm), ensures clamping accuracy.
Helix Angle
15°-45°, the standard value is 30°, which affects chip discharge and cutting stability, and 35°-40° is commonly used for finishing (chip discharge rate increases by 15%).
Number of blades
2-6 cutting edges , small diameter (D<10 mm) usually has 2-3 edges, medium and large diameter (D>10 mm) has 4-6 edges. Increasing the number of edges can improve cutting efficiency but requires higher rigidity of the machine tool.

edge of the ball end mill is precision ground in multiple passes (accuracy ±0.005 mm) to ensure the sharpness and consistency of the cutting edge (cutting edge roughness Ra ≤ 0.1 micron), and the spherical part is polished with high precision to avoid scratches during processing. The cutter body is also dynamically balanced (unbalance <5 g·mm /kg) to reduce vibration during high-speed rotation (amplitude <0.01 mm). In addition , some models integrate internal cooling channels to optimize thermal management and chip removal in the cutting zone .

Carbide ball end mill material

The performance of cemented carbide ball end mills depends on their high-quality materials and precision manufacturing processes. The base material is a composite material of tungsten carbide (WC) and cobalt (Co), sintered by powder metallurgy. Tungsten carbide provides high hardness and wear resistance, cobalt enhances toughness, and the formula and particle size (0.5-2 microns) are adjusted according to processing requirements. Common cemented carbide grades include:
YG6: Cobalt content is 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for processing cast iron, non-ferrous metals (such as aluminum, copper) and medium hardness materials (such as 45# steel, HRC 20-25).
YT15: Contains titanium carbide and tungsten carbide, hardness HV 1900-2000, bending strength 1600-1800 MPa, suitable for steel and alloy steel, and is stable at high temperatures (above 700°C).
YW2: Contains tantalum carbide (TaC) and niobium carbide (NbC), hardness HV 1800-2100, bending strength 1700-1900 MPa, specially designed for difficult-to-machine materials such as titanium alloys (Ti-6Al-4V, HRC 30-35) and nickel-based alloys (Inconel 718, HRC 40-45).

Manufacturing process of carbide ball end mills

Raw material preparation
High-purity tungsten carbide powder and cobalt powder are mixed in proportion (accuracy ±0.1%), and trace rare earth elements (such as Ce, Y) are added to optimize the microstructure.
Pressing
The tool body blank is formed using a hydraulic press with a pressure of 100-200 MPa and a density of 14.5-15 g/ cm³ .
High temperature sintering
In a vacuum or hydrogen-protected sintering furnace, the temperature is 1400°C-1500°C for 8-12

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hours to eliminate pores and form a dense structure.
Post-processing
After sintering, the blank is turned (external runout <0.01 mm), ground (surface Ra ≤ 0.2 microns) and polished (edge Ra ≤ 0.1 microns). The ball head part needs to be processed by a special spherical grinder. To improve performance, the tool surface is coated:
TiN (Titanium Nitride)
Thickness 2-5 microns, hardness 2000-2500 HV, strong wear resistance and oxidation resistance, suitable for general steel.
TiCN (Titanium Carbonitride)
Thickness 3-6 microns, hardness 2500-3000 HV, excellent anti-adhesion, suitable for aluminum alloy and stainless steel.
Al_2O_3 (aluminum oxide)
Thickness 5-10 microns, hardness 3000 HV, heat resistance up to 1000°C, specially designed for high temperature alloys.
The coating is deposited by PVD or CVD process, reducing friction (coefficient < 0.3) and extending life (50%-100% higher than uncoated), especially in high-speed cutting (Vc > 300 m/min).

Carbide ball end mill types

Based on design and use, carbide ball end mills can be divided into the following types:
Standard ball end mills
of blades is 2-4, the helix angle is 30°, and the diameter is 6-20 mm. It is suitable for general surface processing (such as mold cavities).
Roughing ball end mills
of edges is 2-3, the cutting depth is 2-5 mm, and the focus is on removing material, which is suitable for the initial processing stage.
Finishing ball end mill
edges : 4-6, cutting depth: 0.1-2 mm, focus on surface quality (Ra 0.1-0.4 μm), used for finishing.
Long neck ball end milling cutter
The effective cutting length is 50-150 mm, the shank is slender, and it is suitable for deep cavity processing (such as engine cylinder block).
Micro ball end mills
Diameter 1-6 mm, number of edges 2, accuracy ±0.005 mm, specially designed for microelectronics and medical devices.

Technical parameters of carbide ball end mills

Performance parameters vary by model, typical values are as follows:
Hardness: substrate HV 1800-2100, coating reaches 3000 HV, wear resistance is better than HSS (HV 800-900).
Heat resistance: 600°C-1000°C, thermal stability is 2-3 times that of HSS.

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Cutting speed (Vc):
Steel: 100-250 m/min (200 m/min for 45# steel).
Titanium alloy: 50-150 m/min (Ti-6Al-4V takes 100 m/min).
Aluminum alloy: 200-500 m/min (pure aluminum: 400 m/min).
Feed rate (fz): 0.05-0.3 mm/tooth, finishing 0.05-0.1 mm/tooth.
Depth of cut (ap): 0.1-5 mm, finishing 0.1-2 mm.
Tolerance: diameter ±0.01 mm (IT6 grade), ball roundness <0.005 mm.
Surface roughness: Ra 0.1-0.8 microns, fine finishing can reach 0.1 microns.

Application scenarios of carbide ball end mills

Mould manufacturing: Processing of automotive mould surfaces (curvature 5-20 mm), Ra<0.4 microns.
Aerospace: Milling of titanium alloy blades (5-15 mm thick), flatness < 0.01 mm.
Medical devices: Engraving of orthopedic implants (10-50 mm diameter) with an accuracy of ±0.01 mm.
Electronics industry: Processing circuit board cavity (depth 5-20 mm), Ra<0.2 micron.

Precautions for using carbide ball end mills

Machine tool: five-axis CNC, runout <0.01 mm, spindle power ≥3 kW.
Cooling: High-pressure cutting fluid (pressure 5 bar, flow rate 15 L/min).
Parameters: Vc 150 m/min, fz 0.1 mm/tooth, ap 1 mm.
Installation: Coaxiality <0.005 mm, clamping force 20-30 Nm.
Wear: Replace when VB reaches 0.3 mm or when the blade is chipped.

Differences between carbide ball end mills and end mills/face mills

Cutting methods: ball end mill for curved surfaces, end mill for slots/sides, face mill for flat surfaces.
cutting edges : Ball nose 2-6, end mill 2-10, face mill 4-20.
Application : Ball nose fine, end mill universal, face mill large area.

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appendix:

What is a Carbide Profile Milling Cutter?

Definition and function of cemented carbide forming milling cutter

Carbide profile milling cutters are high-precision, highly specialized rotary cutting tools that are widely used in metal processing, mold manufacturing, and mechanical parts production. Their core feature is that the shape of the blade matches the specific contour or profile surface required by the workpiece. Unlike general-purpose milling cutters, carbide profile milling cutters are designed to directly replicate predefined complex geometries such as tooth shapes, grooves, splines, or special curves, thereby completing the profile process in one cut without the need for subsequent finishing. Carbide as its base material gives profile milling cutters high hardness (HV 1800-2100), excellent wear resistance and thermal stability, enabling them to efficiently cut high-strength materials such as steel (HRC 20-50), titanium alloys, nickel-based alloys, and hard cast iron. Profile milling cutters are usually used in conjunction with CNC machine tools (CNC), gear processing machines, or special profile machines, and can achieve accurate replication of complex contours at high speeds (up to 10,000 RPM) and precise feeds (0.01-0.2 mm/tooth). Its application scenarios are mainly concentrated in industrial fields that require high precision and specific shapes, such as automotive transmission systems, aircraft engine components, gear manufacturing, and precision mold processing. The design flexibility of cemented carbide forming milling cutters is extremely high, and the blade shape and size can be customized according to the workpiece requirements to further meet diverse processing requirements.

Structural features of cemented carbide forming milling cutters

The structural design of cemented carbide forming milling cutters is centered on its special purpose. The shape of the blade directly reflects the target contour of the workpiece. It usually adopts a straight shank, a tapered shank or a modular shank structure. The following are its main structural features:

Diameter (D): Ranging from 4 mm to 50 mm, micro profile milling cutters (D < 10 mm) are used for fine processing, and large profile milling cutters (D > 20 mm) are suitable for heavy-duty profile tasks.

Blade profile: Customized according to workpiece requirements, such as tooth profiles with a module of 1-8, grooves with a radius of 2-20 mm or complex curves, with a profile accuracy of up to ±0.005 mm.

Total length (L): 60 mm to 250 mm, suitable for different machine tool spindles and workpiece depths, and the extra-long type can reach 300 mm.

Effective cutting length (l): 10 mm to 120 mm, determines the maximum cutting depth of the tool in the workpiece, deep groove forming can be customized up to 150 mm.

Shank diameter (d): Matches the cutting diameter, ranging from 6 mm to 50 mm, with tolerance class h6 (0/-0.006 mm) to ensure clamping accuracy.

Helix angle: 10°-40°, adjusted according to the molding shape, the standard value is 25°-30°, which

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affects chip discharge and cutting stability. 35°-40° can be selected for complex curved surfaces.
cutting edges : 2-10 cutting edges , depending on diameter and forming complexity, usually 2-4 for small diameter (D<15 mm) and 6-10 for large diameter (D>15 mm).
The cutting edge of the forming milling cutter is processed by a high-precision CNC grinder (accuracy ±0.002 mm) to ensure that the profile is consistent with the design (profile roughness Ra ≤ 0.05 microns). The cutter body is dynamically balanced (unbalance <5 g·mm /kg) to reduce vibration during high-speed rotation (amplitude <0.01 mm). Some models have built-in cooling channels to optimize thermal management and chip removal in the cutting area, especially for deep grooves or closed forming.

Carbide Forming Milling Cutter Materials

The performance of cemented carbide forming milling cutters depends on their high-quality materials and complex manufacturing processes. The base material is a composite material of tungsten carbide (WC) and cobalt (Co), sintered by powder metallurgy. Tungsten carbide provides high hardness and wear resistance, cobalt enhances toughness, and the formula and particle size (0.5-2 microns) are optimized according to processing requirements. Common cemented carbide grades include:
YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for processing cast iron, non-ferrous metals and medium hardness steel (HRC 20-30).
YT14: Contains titanium carbide and tungsten carbide, hardness HV 1900-2000, bending strength 1600-1800 MPa, suitable for steel and alloy steel (HRC 30-40), good high temperature stability.
YW3: Contains tantalum carbide (TaC) and niobium carbide (NbC), hardness HV 1800-2100, bending strength 1700-1900 MPa, specially designed for difficult-to-machine materials such as titanium alloys (HRC 30-35) and nickel-based alloys (HRC 40-45).

Manufacturing process of cemented carbide forming milling cutter

Raw material preparation: High-purity tungsten carbide powder and cobalt powder are mixed in proportion (accuracy ±0.1%), and a trace amount of carbide stabilizer (such as VC, Cr_3C_2) is added to improve the microstructure.
Pressing: Using a hydraulic press to apply 150-250 MPa pressure, the tool body blank is formed to a density of 14.5-15.2 g/ cm^3 .
High temperature sintering: In a vacuum or hydrogen protected sintering furnace, the temperature is 1400°C-1600°C for 10-14 hours to eliminate pores and form a high-density structure.
Post-processing: After sintering, the blank is turned (external runout <0.01 mm), CNC ground (profile accuracy ±0.002 mm) and polished (cutting edge Ra ≤ 0.05 microns). The cutting edge needs to be processed by a special profile grinder.
To improve performance, coatings are applied to the tool surface:
TiAlN (titanium aluminum nitride): thickness 3-8 microns, hardness 2800-3200 HV, heat resistance up to 900°C, suitable for dry cutting.
TiCN (titanium carbonitride): thickness 3-6 microns, hardness 2500-3000 HV, strong anti-adhesion,

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suitable for aluminum alloys and stainless steel.
DLC (Diamond-Like Coating): Thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1, designed for high-precision molding.
The coating is deposited by a PVD process, which reduces friction (coefficient < 0.3) and extends life (60%-120% higher than uncoated), especially in high-speed cutting (Vc > 200 m/min).

Carbide Profile Milling Cutter Types

According to the design and use, carbide profile milling cutters can be divided into the following types:
Tooth profile milling cutter: The cutting edge has a tooth profile of module 1-8, a diameter of 10-30 mm, and is specifically used for gear processing (such as automobile transmission gears).
Groove forming milling cutter: The cutting edge is a groove with a radius of 2-20 mm, suitable for machining keyways or bearing seats.
Curve forming milling cutter: The cutting edge is a complex curve, suitable for mold cavities or decorative parts.
Long- edge forming milling cutter: effective cutting length 50-120 mm, suitable for deep grooves or multi-level forming.
Micro Profile Milling Cutter: 4-10mm diameter, accuracy ±0.005mm, specially designed for microelectronics and precision parts.

Technical parameters of cemented carbide forming milling cutter

Performance parameters vary by model, typical values are as follows:
Hardness: Base material HV 1800-2100, after coating, it reaches 3000-3500 HV, and the wear resistance is better than HSS.
Heat resistance : 600°C-1000°C, high thermal stability.
Cutting speed (Vc):
Steel: 100-250 m/min (45# steel takes 180 m/min).
Titanium alloy: 50-120 m/min (Ti-6Al-4V takes 80 m/min).
Aluminum alloy: 150-400 m/min (pure aluminum: 300 m/min).
Feed rate (fz): 0.01-0.2 mm/tooth, finishing 0.01-0.05 mm/tooth.
Depth of cut (ap): 0.1-5 mm, finishing 0.1-2 mm.
Tolerance: diameter ±0.01 mm (IT6 grade), contour accuracy <0.005 mm.
Surface roughness: Ra 0.1-0.6 microns, finishing can reach 0.1 microns.

Application scenarios of cemented carbide forming milling cutters
Gear Manufacturing: Processing automotive gears (module 3-5), precision grade 6-8, Ra<0.4 micron.
Mold industry: Forming mold cavity (depth 20-50 mm), flatness <0.01 mm.
Aerospace parts: Milling of turbine blade roots (thickness 10-20 mm), Ra<0.3 microns.
Decorative parts: Processing of complex curved surfaces (area 0.1-0.5 m²) , accuracy ±0.01 mm.

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Precautions for using carbide forming milling cutters

Machine tool: CNC or gear machine, runout <0.01 mm, spindle power ≥2.5 kW.
Cooling: Cutting fluid (flow rate 10-20 L/min), high pressure cooling (5 bar).
Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 1 mm.
Installation: Coaxiality <0.005 mm, clamping force 20-30 Nm.
Wear: Replace when VB reaches 0.3 mm or profile is deformed.

Differences between carbide forming milling cutter and end mill/ball end mill/face mill

Cutting methods: Profile milling cutter specific contours, end milling cutter slot/side, ball end milling cutter curved surface, face milling cutter flat surface.
blades : Forming 2-10, end mill 2-10, ball nose 2-6, face mill 4-20.
Application: Special for forming, general for end milling, fine for ball head, large area for face milling.
Structure: Customized profiled blade, end mill straight blade , ball head spherical surface, face milling disc.

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appendix:

What is a carbide rough milling cutter?

Definition and function of carbide rough milling cutter

Carbide rough milling cutter is a high-efficiency, heavy-duty rotary cutting tool widely used in metal processing, casting finishing and initial machining of mechanical parts. Its main function is to quickly remove a large amount of material to complete the initial shaping of the workpiece surface, laying the foundation for subsequent finishing (such as using carbide finishing milling cutter or forming milling cutter). Carbide rough milling cutter uses carbide as the base material. With its high hardness (HV 1600-1900), excellent wear resistance and impact resistance, it can cope with the rough cutting of high-strength materials (such as cast iron, steel, stainless steel). Its design features a strong blade structure and optimized cutting angle to withstand large cutting depths and large feeds. It is usually used in conjunction with CNC machine tools (CNC), vertical milling machines or heavy machining centers. It is suitable for processing conditions with high speeds (up to 6000 RPM) and high material removal rates (500-2000 cm^3 / min). Carbide rough milling cutters are particularly important in industrial production, especially in the automotive, energy equipment and heavy machinery industries, for quickly removing blanks, trimming casting burrs or machining large workpiece surfaces. Its design flexibility allows the number of edges and geometry to be adjusted according to the workpiece material and processing requirements, further improving roughing efficiency.

Structural features of carbide rough milling cutter

The structural design of carbide rough milling cutters is aimed at withstanding high cutting forces and large material removal rates. They usually adopt straight shanks, tapered shanks or large-diameter cutter disc structures, with thick and evenly distributed cutting edges. The following are its main structural features:
Diameter (D): ranging from 10 mm to 100 mm, micro roughing cutters ($D < 20$ mm) are used for small workpieces, and large roughing cutters ($D > 50$ mm) are suitable for heavy cutting tasks.
Cutting width: can reach 50%-80% of the tool diameter, for example, a 50 mm diameter roughing cutter can achieve an effective cutting width of 25-40 mm.
Total length (L): 80 mm to 300 mm, suitable for different machine tool spindles and workpiece depths, and the extra-long type can reach 350 mm.
Effective cutting length (l): 20 mm to 150 mm, determines the maximum cutting depth of the tool in the workpiece, suitable for deep grooves or large-area roughing.
Shank diameter (d): Matches the cutting diameter, ranging from 12 mm to 80 mm, with tolerance class h6 (0/-0.006 mm) to ensure clamping stability.
Helix angle: 10°-30°, standard value is 15°-20°, optimize cutting force and chip discharge, lower helix angle is often used for rough machining to enhance strength.
cutting edges : 2-12 cutting edges , depending on the diameter and cutting load, 2-4 for small diameter ($D<30$ mm), 6-12 for large diameter ($D>30$ mm), increasing the number of cutting edges

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can disperse the cutting force.
The cutting edge of the roughing cutter is made of coarse-grained carbide (grain size 2-5 microns) to enhance impact resistance (bending strength 2000-2400 MPa), and the cutting edge is intensively ground (accuracy ±0.01 mm) to ensure durability (cutting edge roughness Ra ≤ 0.2 microns). The cutter body is dynamically balanced (unbalance <10 g·mm /kg) to reduce vibration during high-speed cutting (amplitude <0.02 mm). Some models are designed with widened chip grooves or strengthening ribs to optimize chip removal and structural rigidity.

Carbide rough milling cutter materials

The performance of cemented carbide rough milling cutters depends on their high toughness and impact resistance. The base material is a composite material of tungsten carbide (WC) and a high cobalt content, sintered by a powder metallurgy process. The high cobalt content enhances toughness and resists intermittent cutting and impact loads during roughing. Common cemented carbide grades include:
YG10: Cobalt content 10%, hardness HV 1600-1700, bending strength 2200-2400 MPa, suitable for processing cast iron (such as HT300, HB 200-250) and steel rough billet (HRC 20-30).
YC45: Cobalt content 12%, hardness HV 1500-1600, bending strength 2400-2600 MPa, suitable for stainless steel (such as 304, HRC 15-20) and high toughness materials.
YW4: Contains tantalum carbide (TaC) and niobium carbide (NbC), hardness HV 1700-1800, bending strength 2000-2200 MPa, specially designed for rough machining of titanium alloys (HRC 30-35) and nickel-based alloys.

Manufacturing process of carbide rough milling cutter
Raw material preparation: High purity tungsten carbide powder and cobalt powder are mixed in proportion (accuracy ±0.1%), and titanium carbide (TiC) or niobium carbide (NbC) is added to improve high temperature performance.
Pressing: Using a hydraulic press to apply 200-300 MPa pressure, the tool body blank is formed to a density of 14.2-14.8 g/ cm^3 .
High temperature sintering: In a vacuum or hydrogen protected sintering furnace, the temperature is 1400°C-1550°C for 10-15 hours to form a high toughness structure.
Post-treatment: After sintering, the blank is turned (external runout <0.01 mm), ground (surface Ra ≤ 0.3 microns) and strengthened (surface hardening layer 0.1-0.2 mm).
To improve durability, the tool surface is coated:
TiAlN (titanium aluminum nitride): thickness 4-10 microns, hardness 2800-3200 HV, heat resistance up to 1000°C, strong impact and oxidation resistance.
AlCrN (aluminum chromium nitride): thickness 3-7 microns, hardness 3000-3400 HV, excellent wear resistance and corrosion resistance, suitable for dry cutting.
Multilayer coating: TiN+AlCrN+TiCN , thickness 6-12 microns, with outstanding comprehensive performance.
The coating is deposited by a PVD process, which reduces friction (coefficient < 0.3) and extends life (50%-100% longer than uncoated), especially in intermittent cutting and heavy load conditions.

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Carbide Rough Milling Cutter Types

Based on design and use, carbide rough milling cutters can be divided into the following types:
Straight edge rough milling cutter: number of edges 2-4, helix angle 15°, diameter 10-30 mm, suitable for initial processing of castings.
Corrugated edge roughing milling cutter: The wave amplitude of the blade is 0.2-0.5 mm, which reduces vibration and is suitable for rough processing of thin-walled parts.
Large diameter roughing cutter: diameter 50-100 mm, number of edges 6-12, designed for roughing large areas.
Side roughing milling cutter : The side edge is widened, the cutting width is 30-80 mm, suitable for rough machining of sides and steps.
Deep slot roughing milling cutter: effective cutting length 50-150 mm, suitable for deep cavity roughing.

Technical parameters of carbide rough milling cutter

Performance parameters vary by model, typical values are as follows:
Hardness: Base material HV 1500-1800, after coating, it reaches 3000-3400 HV, with strong impact resistance.
Heat resistance: 600°C-900°C, suitable for heavy-duty cutting.
Cutting speed (Vc):
Steel: 80-200 m/min (150 m/min for 45# steel).
Cast iron: 120-300 m/min (HT300 takes 200 m/min).
Titanium alloy : 40-100 m/min (Ti-6Al-4V takes 70 m/min).
Feed rate (fz): 0.2-0.8 mm/tooth, roughing 0.5-0.8 mm/tooth.
Depth of cut (ap): 2-15 mm, roughing 5-15 mm.
Tolerance: diameter ±0.02 mm (IT6 grade), flatness <0.02 mm.
Surface roughness: Ra 3.2-12.5 microns, typical value for roughing is 6.3 microns.

Application scenarios of carbide rough milling cutters

Casting finishing: Removal of excess from cast iron blanks (thickness 5-20 mm), efficiency 1000 cm^3 / min.
Automobile industry: Rough machining of cylinder surface (area 1-3 m^2) , Ra<6.3 microns.
Energy equipment: Milling of wind turbine towers (depth 50-100 mm), cutting depth 10-15 mm.
Heavy machinery: Machining of large steel plates (thickness 20-50 mm) with a material removal rate of 1500 cm^3 / min.

Precautions for using carbide rough milling cutters

Machine tool: heavy-duty CNC, runout < 0.02 mm, spindle power ≥ 10 kW.
Cooling: High flow cutting fluid (30-60 L/min), high pressure cooling (7 bar).
Parameters: Vc 150 m/min, fz 0.6 mm/tooth, ap 10 mm.

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Installation: Coaxiality <0.01 mm, clamping force 50-80 Nm.
Wear: Replace when VB reaches 0.5 mm or when the blade is chipped.

Differences between carbide rough milling cutter and end mill/ball end mill/face mill/forming mill

Cutting methods: Roughing cutter for large stock removal, end mill for slot/side, ball end mill for curved surface, face mill for flat surface, profile mill for specific contour.
cutting edges : Roughing cutter 2-12, end milling cutter 2-10, ball nose cutter 2-6, face milling cutter 4-20, forming cutter 2-10.
Application: Rough milling cutter for initial processing, end milling cutter for general purpose, ball head milling cutter for fine processing, face milling cutter for large area, special for forming.
Structure: Rough milling cutter with thick blade, end milling cutter with straight blade , ball head and spherical surface, face milling cutter with disc, customized molding.

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appendix:

What is a carbide finishing cutter ?

Definition and function of cemented carbide finishing cutter

Carbide finishing milling cutters are high-precision, high-surface quality rotary cutting tools that are widely used in metalworking, mold manufacturing, aerospace, and precision machinery parts production. Its core function is to achieve high flatness, high finish, and precise geometry on the workpiece surface through fine cutting, usually as a follow-up process after roughing (such as carbide roughing milling cutters). Carbide finishing milling cutters use carbide as the substrate. With its high hardness (HV 1800-2100), excellent wear resistance and stability, it can efficiently cut high-strength materials such as steel (HRC 20-50), titanium alloys, stainless steel, and aluminum alloys. Its design features a fine blade and optimized cutting angles to reduce vibration and surface defects. It is usually used in conjunction with CNC machine tools (CNC), high-precision machining centers , or five-axis machine tools . It is suitable for finishing conditions with medium speeds (3000-8000 RPM) and low cutting depths (0.05-2 mm). Carbide milling cutters are essential in industrial production, especially in the manufacture of automotive engine parts, aerospace turbine blades, precision molds and electronic components, to improve surface quality and dimensional accuracy. Its design flexibility allows the number of edges , helix angles and coatings to be customized according to workpiece requirements, further meeting high-precision machining requirements.

Structural features of cemented carbide finishing milling cutter

The structural design of carbide milling cutters is aimed at high precision and surface quality. They usually adopt straight shank or tapered shank structure, and the cutting edge is finely ground to reduce cutting marks. The following are its main structural features:

Diameter (D): ranging from 2 mm to 40 mm, micro fine milling cutters (D<10 mm) are used for fine engraving, and large fine milling cutters (D>20 mm) are suitable for large area finishing.

Cutting width: can reach 50%-70% of the tool diameter, for example, a 20 mm diameter milling cutter can achieve an effective cutting width of 10-14 mm.

Total length (L): 50 mm to 200 mm, suitable for different machine tool spindles and workpiece depths, and the extra-long type can reach 250 mm.

Effective cutting length (l): 5 mm to 80 mm, determines the maximum cutting depth of the tool in the workpiece and is suitable for shallow finishing.

Shank diameter (d): Matches the cutting diameter, ranging from 3 mm to 40 mm, with tolerance class h6 (0/-0.006 mm) to ensure clamping accuracy.

Helix angle: 25°-45°, standard value is 30°-35°, which optimizes chip evacuation and surface finish. Higher helix angles are often used in finishing to reduce vibration.

cutting edges : 2-10 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<15 mm) has 2-4 edges, and large diameter (D>15 mm) has 6-10 edges. Increasing the number of edges can improve the surface quality but requires high-rigidity machine tool support.

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The cutting edge of the milling cutter is made of fine-grain carbide (grain size 0.5-2 microns) for enhanced wear resistance (bending strength 1800-2000 MPa), and the cutting edge is ultra-precision ground (accuracy ±0.002 mm) to ensure sharpness and consistency (edge roughness Ra ≤ 0.05 microns). The cutter body is dynamically balanced (unbalance <5 g·mm /kg) to reduce vibration during high-speed cutting (amplitude <0.005 mm). Some models have integrated micro cooling holes to optimize thermal management and chip control in the cutting zone.

Carbide milling cutter materials

The performance of cemented carbide finishing milling cutters relies on their high hardness and wear-resistant material properties. The base material is a composite material of tungsten carbide (WC) with a moderate cobalt content, sintered by a powder metallurgy process. The fine particle structure and optimized coating ensure that it maintains stability and surface quality during finishing.
Common cemented carbide grades include:
YG6N: Cobalt content 6%, hardness HV 1800-1900, flexural strength 1800-2000 MPa, suitable for processing steel and cast iron, with excellent surface finish.
YT10: Contains titanium carbide and tungsten carbide, hardness HV 1900-2000, bending strength 1600-1800 MPa, suitable for alloy steel and stainless steel.
YW1T: Contains tantalum carbide (TaC) and niobium carbide (NbC), hardness HV 1800-2100, bending strength 1700-1900 MPa, specially designed for finishing of titanium alloys and nickel-based alloys.

Manufacturing process of cemented carbide finishing milling cutter

Raw material preparation: High-purity tungsten carbide powder and cobalt powder are mixed in proportion (accuracy ±0.1%), and titanium carbide (TiC) is added to improve wear resistance.
Pressing: Use a hydraulic press to apply 150-200 MPa pressure to form the tool body blank with a density of 14.5-15 g/ cm^3 .
High temperature sintering: In a vacuum or hydrogen protected sintering furnace, the temperature is 1400°C-1500°C for 8-12 hours to form a high-density structure.
Post-processing: After sintering, the blanks are turned (external runout <0.01 mm), ultra-precision ground (profile accuracy ±0.002 mm) and polished (edge Ra ≤ 0.05 microns).
To improve performance, coatings are applied to the tool surface:
TiAlN (titanium aluminum nitride): thickness 3-8 microns, hardness 2800-3200 HV, heat resistance up to 900°C, reduces surface scratches.
DLC (Diamond-Like Carbon Coating): Thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1, designed for high finish processing.
Multilayer coating: TiN+TiCN+Al_2O_3 , thickness 5-12 microns, comprehensive wear resistance and heat resistance.
The coating is deposited by a PVD process, which reduces friction (coefficient < 0.2) and extends life (60%-120% higher than uncoated), especially in low-cut finishing.

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Carbide finishing cutter types

According to the design and application, carbide finishing cutters can be divided into the following types:

Standard finishing cutter: 2-4 blades , 30° helix angle, 6-20 mm diameter, suitable for general finishing.

Ball nose milling cutter : The cutting end is spherical, with a radius of 1-10 mm, specially designed for finishing curved surfaces.

Flat finishing milling cutter: number of blades 6-10, cutting depth 0.1-2 mm, suitable for plane finishing.

Long neck finishing milling cutter: effective cutting length 50-80 mm, suitable for deep cavity finishing.

Micro milling cutter: diameter 2-10 mm, accuracy ±0.005 mm, specially designed for microelectronics and medical parts.

Technical parameters of carbide finishing cutter

Performance parameters vary by model, typical values are as follows:

Hardness: Base material HV 1800-2100, after coating, it reaches 3000-3500 HV, with strong wear resistance.

Heat resistance: 600°C-900°C, suitable for precision cutting.

Cutting speed (Vc):

Steel: 120-250 m/min (180 m/min for 45# steel).

Titanium alloy: 60-150 m/min (Ti-6Al-4V takes 100 m/min).

Aluminum alloy: 200-500 m/min (pure aluminum: 350 m/min).

Feed rate (fz): 0.01-0.2 mm/tooth, finishing 0.01-0.05 mm/tooth.

Depth of cut (ap): 0.05-2 mm, finishing 0.05-1 mm.

Tolerance: diameter ±0.01 mm (IT6 grade), flatness <0.005 mm.

Surface roughness: Ra 0.05-0.4 microns, finishing can reach 0.05 microns.

Application scenarios of carbide finishing cutters

Mould manufacturing: Finishing of mould surface (area 0.2-1 m²) , Ra<0.2 micron.

Aerospace: Milling of aluminum alloy skins (5-15 mm thick), flatness < 0.01 mm.

Automotive industry: Finishing of cylinder head surfaces (area 0.5-2 m²) , Ra<0.1 micron.

Electronics industry: Processing circuit board edges (depth 5-10 mm), accuracy ±0.005 mm.

Precautions for using carbide finishing cutters

Machine tool: high-precision CNC, runout <0.005 mm, spindle power ≥2 kW.

Cooling: Cutting fluid (flow rate 10-20 L/min), minimum quantity lubrication (MQL) optional.

Parameters: Vc 180 m/min, fz 0.03 mm/tooth, ap 0.5 mm.

Installation: Coaxiality <0.002 mm, clamping force 15-25 Nm.

Wear: Replace when VB reaches 0.2 mm or surface scratches occur.

Differences between carbide finishing milling cutter and end milling cutter/ball end milling

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cutter/face milling cutter/forming milling cutter/rough milling cutter

Cutting method: fine milling cutter for fine surfaces, end milling cutter for slots/sides, ball end milling cutter for curved surfaces, face milling cutter for flat surfaces, profile milling cutter for specific contours, rough milling cutter for large stock removal.

cutting edges : finishing cutter 2-10, end mill 2-10, ball nose 2-6, face mill 4-20, forming 2-10, rough mill 2-12.

Application: Fine milling cutter for finishing, end milling cutter for general purpose, ball head for precision, face milling cutter for large area, special for forming, rough milling cutter for preliminary processing.

Structure: The finishing milling cutter has a fine edge, the end milling cutter has a straight edge and a ball head, the face milling cutter has a disc and is custom-made, and the roughing cutter is thick and strong.

Comparison of Carbide Milling Cutter Types

category	Finishing cutter	End milling cutter	Ball end mills	Face milling cutter	Forming milling cutter	Rough milling cutter
Cutting method	Fine surface	Slot/Side	Surface	flat	Specific outline	Large material removal
Number of blades	2-10	2-10	2-6	4-20	2-10	2-12
application	finishing	General	fine	Large area	dedicated	Primary processing
structure	Fine blade	Straight Edge	Spherical	disc	custom made	

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appendix:

What are the Chinese standards for carbide milling cutters?

China has formulated a number of national and industry standards for cemented carbide milling cutters, covering their classification, type and size, technical conditions, etc. These standards are managed by the National Technical Committee for Standardization of Cutting Tools (SAC/TC 207) and are intended to regulate the design, manufacture and application of cemented carbide milling cutters to ensure product quality and processing performance. The following is an overview of the main standards and related contents:

1. National Standards

GB/T 16456.2-2008 Carbide helical tooth end mills Part 2: 7:24 Taper shank end mills Types and dimensions

taper shank end mills among carbide spiral tooth end mills are specified , which are suitable for slot milling and side milling in metal cutting .

Implementation date: 2009-01-01, replacing GB/T 16456.2-1996.

GB/T 16456.3-2008 Carbide helical tooth end mills Part 3: Morse taper shank end mills types and dimensions

spiral tooth end mills with Morse taper shank are specified , which are suitable for high-precision machining.

Implementation date: 2009-01-01.

GB/T 16770.1-2008 Solid carbide straight shank end mills Part 1: Types and dimensions

Specifies the types and sizes of solid carbide straight shank end mills, covering a wide range of specifications and suitable for general milling.

GB/T 25992-2010 Dimensions of solid carbide and ceramic straight shank ball nose end mills

Specifies the dimensions of straight shank ball nose end mills made of solid carbide and ceramic materials, suitable for complex surface machining.

GB/T 10948-2006 Carbide T-slot milling cutter

The types and sizes of carbide T-slot milling cutters are specified, which are suitable for machining T-slots.

GB/T 14301-2008 Solid carbide saw blade milling cutter

Specifies the types and sizes of solid carbide saw blade milling cutters suitable for cutting and dividing operations.

GB/T 6120-2012 Saw blade milling cutter

Specifies the types and sizes of saw blade milling cutters, including the use of carbide materials.

2. Industry Standards

JB/T 7971-1999 Carbide helical gear straight shank end mill

Specifies the types and sizes of carbide helical tooth straight shank end mills suitable for inclined cutting.

Replaces JB/T 7971-1995.

JB/T 7972-1999 Carbide helical tooth taper shank end mill

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Specifies the types and sizes of carbide helical tooth taper shank end mills , suitable for tapered machining.
Replaces JB/T 7972-1995.
JB/T 11744-2013 Solid carbide rear wave edge end mills
Specifies the types and sizes of solid carbide rear wave -edge end mills, suitable for high-efficiency cutting.
JB/T 13685-2020 Solid carbide thread milling cutter
Specifies the types and sizes of solid carbide thread milling cutters suitable for thread machining.
JB/T 7966 Series (Mold Milling Cutter)
Including JB/T 7966.2-1999 (flattened straight shank cylindrical ball nose end mill), JB/T 7966.3-1995 (Morse taper shank cylindrical ball nose end mill), JB/T 7966.8-1999 (Morse taper shank conical end mill), JB/T 7966.9-1995 (Morse taper shank conical ball nose end mill), which are specifications for carbide milling cutters used in mold processing.
JB/T 8776-2018 Carbide Circular Milling Cutter for Woodworking
Specifies the types and sizes of carbide circular milling cutters for woodworking, suitable for wood processing.

3. Technical requirements and applications
Carbide milling cutters usually use YG (tungsten-cobalt), YT (tungsten-titanium-cobalt) or YW (tungsten-titanium-tantalum-cobalt) grades, which meet the technical requirements of GB/T 2072-2006.
Coatings (such as PVD TiN or CVD TiAlN) can increase wear resistance and heat resistance according to GB/T 2073-2013 requirements.
Cutting parameter recommendations: 100-400 m/min for steel, 200-1000 m/min for aluminum alloy, 150-500 m/min for cast iron. For details, see GB/T 5319-2017 Geometric Parameter Guide.
4. Characteristics and development
These standards reflect the diversified development of China's cemented carbide milling cutters from general-purpose to special-purpose (such as thread milling cutters and ball end mills).
Some standards are equivalent to ISO standards (such as GB/T 16456 series refers to ISO 6108:1978), reflecting international standards.
In recent years, the application of solid carbide milling cutters (such as JB/T 13685-2020) in CNC machining has increased, and export tax rebate policies (such as the 13% tax rebate rate under item 82077000) have also promoted the development of the industry.

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appendix:

JB/T 8776-2018
Carbide Circular Milling Cutter for Woodworking
Carbide Circular Arc Milling Cutters for Woodworking

Preface

This standard was drafted in accordance with the provisions of JB/T 1-1996 "Rules for Drafting Machinery Industry Standards". This standard replaces JB/T 8776-2010 "Carbide Circular Milling Cutters for Woodworking". Compared with JB/T 8776-2010, the main technical changes include: updating the size range and tolerance requirements of circular milling cutters, adding coating applicability instructions, adjusting the blade design specifications, and partially aligning with international woodworking tool standards.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., Nanjing Forestry University.

Main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of carbide circular milling cutters for woodworking.

1.2 This standard applies to circular forming, slot milling and edge trimming in woodworking . The tool material is carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to non-circular milling cutters or cutting tools for non-woodworking applications.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

JB/T 1-1996, Rules for drafting machinery industry standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

ISO 1565:1975, Woodworking tools — Vocabulary

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 **Carbide Arc Milling Cutter for Woodworking**

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Arc cutting tool made of carbide, specially used for arc forming and edge trimming in wood material processing.

3.2 **Arc Radius**

The radius of the arc part of the blade, which affects the processing curvature and surface quality.

3.3 **Number of**

cutting edges The number of cutting edges of the tool, which determines the cutting efficiency and surface finish.

4 Symbols and abbreviations

D : Tool diameter (mm)

L : Total length (mm)

R : Arc radius (mm)

d : Shank diameter (mm)

WC : Tungsten Carbide

5 Type and size

5.1 **Type**

Standard type: single-end arc blade , 2-4 blades, suitable for general arc forming.

Rough machining type: 2-3 cutting edges, larger arc radius, and deeper chip groove.

Finishing type: 4-6 cutting edges, precise arc radius and high surface finish.

5.2 **Size range**

Diameter (D) : 6 mm to 25 mm.

Total length (L) : 50 mm to 120 mm.

Arc radius (R) : 2 mm to 12 mm.

Shank diameter (d) : 6 mm to 25 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).

5.3 **Tolerance**

Diameter tolerance: ±0.02 mm (grade IT6).

Length tolerance: ±0.3 mm.

Shank diameter tolerance: h6 (0/-0.006 mm).

Arc radius tolerance: ±0.05 mm.

5.4 **Number of blades**

D ≤ 12 mm: 2-3 blades .

D > 12 mm: 3-6 blades .

6 Technical requirements

6.1 **Materials**

It complies with GB/T 2072-2006, recommended grades are YG6 (HV 1800-1900) and YW2 (HV 1800-2100), suitable for wood processing.

6.2 **Coating**

Optional PVD coating (TiN , TiCN , thickness 2-4 μm) can improve wear resistance and anti-adhesion properties.

Coating adhesion: Scratch test critical load ≥ 60 N.

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6.3 **Surface quality**

Surface roughness Ra ≤ 0.2 μm .

6.4 **Blade Design**

The arc blade has a smooth transition and the cutting edge is chamfered by 0.1 mm to reduce wood tearing.

7 Test methods

7.1 **Dimension measurement shall be carried out**

in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 **Arc radius measurement shall**

be carried out using a roundness meter with an error of ±0.05 mm.

7.3 **Cutting performance test A 10 mm deep arc groove**

shall be machined on an oak specimen with a cutting speed of 200 m/min and a surface finish of Ra ≤ 6.3 μm .

8 Inspection rules

8.1 5% of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length, arc radius and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 **Logo**

The tool surface marking specifications (such as YG6-10×80-R5) comply with GB/T 191-2008.

9.2 **Packaging**

Use moisture-proof packaging and plastic bags to seal, and place in wooden boxes.

9.3 **Transportation and storage**

Avoid high temperature (>40°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Arc radius (R, mm)	Shank diameter (d, mm)	Number of blades
6	50	2	6	2
10	80	5	10	3
16	100	8	16	4
25	120	12	25	6

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
hardwood	150-300	0.1-0.3	1-3

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Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
cork	200-400	0.2-0.4	2-5
MDF	180-350	0.15-0.35	1-4

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Industry Standard No .: JB/T 8776-2018

Technical Committee : SAC/TC 207 **-** National Technical Committee for Tool Standardization

ICS Code : 25.100.70 (Tools for woodworking)

illustrate

The above content is a simulated version based on the structure of JB/T 8776-2018 and the industry practice of woodworking carbide arc milling cutters. Since the official full text is not available, this article assumes some technical details (such as size range, cutting parameters) and refers to the general characteristics of arc milling cutters in woodworking processing (such as arc radius, blade design). These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official JB/T 8776-2018 text to ensure completeness and accuracy.

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appendix:

What is a woodworking carbide arc milling cutter?

1. Definition and function of carbide circular milling cutter for woodworking

The carbide circular milling cutter for woodworking is a high-performance precision cutting tool designed for woodworking processing. It is widely used in furniture manufacturing, wooden decoration processing, wooden structure building component production, wood product molding, and wood craft carving. Its blade adopts a unique arc design, which is specially optimized for the processing of various wood materials such as wood, plywood, medium-density fiberboard (MDF), particleboard, laminate, bamboo, cork, and artificial board. Its core function is to achieve smooth curve processing, slot milling, edge chamfering, complex contour molding, and decorative carving through the arc-shaped cutting edge . It can achieve high-precision and high-quality surface treatment in a single cut. It is particularly suitable for woodworking projects that require smooth transitions or beautiful curves, such as streamlined design of furniture edges, decorative chamfers of door panels or window frames, fine carvings of wooden crafts, and curve trimming of musical instrument parts. Cemented carbide as its substrate provides high hardness (HV 1500-1800), excellent wear resistance and anti-adhesion properties, enabling it to withstand the high speed (up to 18,000 RPM), high-frequency cutting and impact loads caused by impurities in wood (such as knots, resins or foreign matter) in wood processing.

Carbide circular milling cutters for woodworking are usually used in conjunction with woodworking engraving machines, CNC machines (CNC), multi-axis machining centers, professional handheld milling machines or even manual engraving equipment, and are particularly good in custom furniture production, interior decoration production, traditional wood carving art and musical instrument manufacturing. Its design flexibility is extremely high, and the arc radius (from a small arc such as 2 mm to a wide curve such as 25 mm), blade angle, cutting depth and number of blades can be customized according to processing requirements, further meeting the diverse requirements from hand engraving to industrial mass production. In the woodworking industry, this tool is highly favored for its high efficiency, protection of wood fibers, reduced need for secondary processing, and high adaptability to complex curves, especially in the high-end furniture market, artistic wood carving field and environmentally friendly wood products processing. It has gradually become a standard. In addition, with the popularization of intelligent woodworking equipment (such as CNC with AI optimization parameters), circular milling cutters also support integration with intelligent control systems to dynamically adjust cutting parameters to adapt to changes in density and humidity of different woods.

2. Structural features of carbide circular milling cutters for woodworking

The structural design of woodworking carbide arc milling cutters aims to achieve precise curve processing, reduce wood tearing, optimize chip discharge and improve processing stability. They usually adopt a straight shank structure (occasionally seen in tapered shank designs for large industrial equipment), with an arc-shaped blade and cutting edges distributed on the circumference and end face, taking into account both axial and radial cutting capabilities. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter(D)

Ranging from 6 mm to 50 mm, small arc milling cutters (D<15 mm) are suitable for fine carving (such as small wooden ornaments, models or miniature furniture parts), medium-sized (D=15-30 mm) are suitable for furniture edge processing, door panel trimming or medium-sized decorative panel curve forming, large arc milling cutters (D>30 mm) are used for large-area curve forming, building component trimming or thick plate processing (such as solid wood beams and columns).

Arc radius (R)

From 2 mm to 25 mm, the radius size is customized according to the processing curvature and aesthetic requirements. For example, R=2-5 mm is suitable for micro chamfers or delicate carvings (such as wooden jewelry boxes), R=10-15 mm is suitable for wide arc transitions on the edges of door frames, window frames or cabinets, and R=20-25 mm is used for streamlined curves of large decorative panels or curved ceiling panels. The radius accuracy is controlled within ±0.01 mm through CNC grinding.

Total length(L)

50 mm to 150 mm, suitable for spindle lengths from handheld tools (50-80 mm) to industrial CNC machine tools (100-150 mm). The extra-long type (200 mm) is often used for deep curve processing, multi-layer wood stacking cutting or complex workpieces requiring long overhangs . The length tolerance is controlled at ±0.1 mm.

Effective cutting length (l)

10 mm to 60 mm, which determines the maximum cutting depth of the tool in the workpiece. Shallow processing (10-20 mm) is suitable for surface decoration or thin plate edge trimming, medium-deep processing (30-60 mm) is suitable for slot milling , thick plate forming or deep engraving. The ratio of cutting length to tool diameter is usually not more than 3:1 to avoid vibration.

Shank diameter (d)

Matching the cutting diameter, common specifications are 6 mm, 8 mm, 10 mm and 12 mm, with tolerance grade h6 (0/-0.006 mm), ensuring a tight fit with the chuck or spindle. The maximum diameter can reach 12 mm to support high torque transmission (torque range 5-20 Nm), and the surface hardening treatment is used to improve wear resistance.

Helix Angle

15°-30°, standard value is 20°-25°, the helix angle design reduces wood fiber tearing by optimizing the chip flow path, 25° is commonly used for fine processing to improve surface smoothness (reduce Ra value by 10%-15%), and 15°-20° can be selected for rough processing to enhance cutting

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strength and impact resistance. Some customized models support adjustable helix angles to adapt to different wood textures.

Number of blades

2-4 cutting edges , small diameter (D<15 mm) is usually 2-edge to reduce cutting resistance and reduce heat accumulation, medium and large diameter (D>15 mm) is 3-4 edges to improve cutting efficiency and load distribution, the blade spacing is precisely calculated (error <0.02 mm) to ensure uniform cutting load and reduce local wear.

The cutting edge of the arc milling cutter is processed by a high-precision CNC grinder (accuracy ±0.01 mm) to ensure that the arc profile is smooth and without serrations (profile roughness Ra ≤ 0.1 micron). The cutting edge is designed with a negative rake angle (0° to -5°) or a slightly positive rake angle (0°-5°) to protect the wood texture and prevent edge collapse, burrs or fiber tearing, especially in cross-grain cutting. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 12000 RPM) to ensure minimum vibration (amplitude <0.01 mm) at high-speed rotation, extending the life of the tool and machine tools. Some high-end models are equipped with widened chip grooves (width 1-2 mm), lateral chip removal channels or special chamfer designs (angle 5°-10°), which significantly improve chip removal efficiency (increase 20%-30%) and reduce the temperature of the cutting zone (<150°C), especially suitable for continuous long-term processing or high-humidity wood (such as fresh pine). In addition, some new arc milling cutters also integrate anti-vibration designs, such as vibration-damping grooves or multi-stage helix angles, to reduce noise (to below 70 dB) and workpiece deformation during cutting.

3. Materials and manufacturing of carbide circular milling cutters for woodworking

The performance of woodworking carbide circular milling cutters depends on their high hardness, wear resistance and adaptability to wood processing. The base material is a composite material of tungsten carbide (WC) and cobalt (Co), sintered by powder metallurgy. The lower cobalt content (5%-8%) and fine particle structure (0.5-2 microns) ensure that it maintains sharpness during wood cutting while avoiding brittle fracture caused by excessive hardness. It is particularly suitable for the soft and hard alternating areas in wood. Common carbide grades include:

YG6: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for softwood (such as pine, fir, walnut, density 0.4-0.6 g/cm³) and medium density fiberboard (MDF, density 0.6-0.8 g/cm³) , widely used in general woodworking due to its good wear resistance and moderate toughness, cutting life can reach 20-30 hours.

YG8: Cobalt content 8%, hardness HV 1700-1800, bending strength 2000-2200 MPa, suitable for hardwood (such as oak, maple, cherry, hardness Brinell 40-60 HB) and plywood (3-13 layers, thickness 3-25 mm), performs well in high-load cutting (such as thick plate processing), and the service life can reach 25-35 hours.

K10: Cobalt content 5%-6%, hardness HV 1850-1950, flexural strength 1700-1900 MPa, designed for high-precision woodworking processing, especially suitable for particleboard (density 0.6-0.9 g/cm³) , laminate and bamboo, surface finish can reach Ra 0.1 micron, suitable for fine carving and

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decorative parts processing.

Manufacturing process of carbide circular milling cutter for woodworking

Raw material preparation

High-purity tungsten carbide powder is mixed with cobalt powder in proportion (accuracy ±0.1%), and a small amount of titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC) is added to improve wear resistance and anti-adhesion. At the same time, the powder particle size (0.5-2 microns) is controlled to optimize cutting performance. The mixing process uses a ball mill (speed 50-100 RPM, time 24-48 hours) to ensure uniformity.

Pressing

The tool body blank is formed using a hydraulic press with a pressure of 100-150 MPa to ensure a density of 14.5-15 g/cm^3 . Cold isostatic pressing (CIP, pressure 150-200 MPa) is used during the pressing process to improve the internal uniformity and crack resistance of the material. The molding die accuracy is controlled within ±0.02 mm.

High temperature sintering

In a vacuum (pressure 10^{-2} Pa) or hydrogen -protected sintering furnace, the temperature is 1350°C-1450°C for 8-10 hours. The pores are eliminated by step-by-step heating (50°C per hour) to form a highly dense and tough microstructure. The grain size after sintering is controlled at 1-2 microns.

Post-processing

After sintering, the blanks are turned (external runout <0.01 mm), precision CNC ground (arc accuracy ±0.01 mm, surface Ra ≤ 0.2 microns) and mirror polished (edge Ra ≤ 0.1 microns). Some models are electropolished (current density 0.1-0.2 A/cm^2) or diamond abrasive finished to further improve the sharpness and durability of the blade, and the edge chamfer (0.1-0.2 mm) enhances the ability to resist edge collapse.

Tool surface coating

TiN (Titanium Nitride)

The thickness is 2-4 microns, the hardness is 2000-2500 HV, it is golden yellow, reduces the adhesion of wood resin and dust, is suitable for general cork and MDF processing, and the cutting life can be extended by 20%-30%. It is especially stable in environments with high humidity.

ZrN (Zirconium Nitride)

The thickness is 1-3 microns, the hardness is 2200-2600 HV, it is light gray, has strong oxidation resistance, is suitable for high speed (>12000 RPM) or hardwood processing, has heat resistance of 600°C, and has a service life increased by 30%-40%. It is often used in industrial mass production.

Uncoated : Some models keep the original carbide surface to avoid chemical reactions on the wood surface (such as resin discoloration) that may be caused by coating, which is especially suitable for handmade woodworking projects or natural wood processing with high environmental requirements.

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The coating is deposited by physical vapor deposition (PVD) in a vacuum environment (pressure 10^{-3} Pa , temperature 400-500°C), which reduces the friction coefficient (<0.3) and significantly extends tool life (30%-50% higher than uncoated), especially in continuous cutting, high-humidity wood (such as fresh pine, with a moisture content of 20%-40%) or resinous wood (such as rosin wood).

4. Technical parameters of woodworking carbide arc milling cutter

Performance parameters vary by model, application and wood species, typical values are as follows, covering a wide range of processing conditions and material properties:

hardness
The substrate hardness ranges from HV 1700-1900, and the surface hardness after coating can reach 2500 HV, which is far higher than traditional high-speed steel (HSS, HV 800-900), ensuring wear resistance in high-frequency cutting (wear rate is reduced by more than 50%), and impact resistance of 2000-2200 MPa, which is suitable for hard knots in wood.

Heat resistance
400°C-600°C, suitable for dry or wet cutting of woodworking, with better thermal stability than HSS (thermal expansion coefficient 5×10^{-6} /°C), avoiding wood burning (charring temperature is about 250°C) or tool annealing due to overheating, and thermal deformation <0.01 mm under long-term use.

Cutting speed (Vc)
Softwood (such as pine, spruce, density 0.4-0.5 g/ cm^3)
200-400 m/min, recommended value 300 m/min, suitable for fast edge trimming or thin plate processing. Too high speed (>400 m/min) may cause fiber tearing.
Hardwood (such as oak, teak, density 0.6-0.9 g/ cm^3)
150-300 m/min, recommended value 200 m/min, needs to be adjusted according to the hardness of the wood (Brinell 40-60 HB) and moisture content (10%-15%). Too low speed may cause resin accumulation.
MDF and particleboard (density 0.6-0.9 g/ cm^3)
300-500 m/min, recommended value 400 m/min, suitable for high-efficiency flat plate processing, attention should be paid to the adhesion of the adhesive to the tool.

Feed rate (fz)
0.05-0.3 mm/tooth, 0.2-0.3 mm/tooth for roughing (feed speed 1200-1800 mm/min), suitable for rapid prototyping or initial processing of thick plates, 0.05-0.1 mm/tooth for fine processing (feed speed 300-600 mm/min), to ensure surface finish, the specific value needs to be optimized according to wood density (0.4-0.9 g/cm^3) , grain direction and machine rigidity.

Depth of cut (ap)

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0.1-5 mm, rough machining 1-5 mm (suitable for rapid prototyping or blank trimming), finishing 0.1-2 mm (to ensure a smooth surface), excessive cutting depth (> 1.5 times the tool diameter) may cause vibration, tearing or tool overload, and layered cutting (0.5-1 mm per layer) is recommended.

tolerance

Diameter tolerance is ±0.01 mm (IT6 grade), arc profile tolerance is <0.01 mm, ensuring processing accuracy (roundness error <0.005 mm), suitable for high-precision furniture parts or decorative parts.

Surface roughness

The Ra of the workpiece surface under finishing conditions can reach 0.1-0.4 microns, and Ra 0.8-1.6 microns under roughing conditions, depending on the cutting parameters (Vc /fz/ap combination), wood texture (along the grain or across the grain), moisture content (10%-20%) and tool condition (new edge Ra can reach 0.05 microns).

5. Application scenarios of carbide arc milling cutters for woodworking

Woodworking carbide arc milling cutters have excellent performance in a variety of woodworking processing scenarios due to their arc design and excellent performance. Specific applications include the following diverse fields, and their effects are explained in combination with actual cases:

Furniture Manufacturing

Processing door panel or cabinet edge chamfer (arc radius R = 10 mm), cutting speed 300 m/min, feed rate 0.1 mm/tooth, cutting depth 1 mm, surface Ra <0.4 microns after processing, ensuring smooth and beautiful touch. It is widely used in modern minimalist style furniture (such as Nordic style cabinets) or classical carved furniture. In the case, a factory produces 100,000 door panels annually, the tool life is 30 hours, and the efficiency is improved by 15%.

Decoration Craft

Carved wooden vases or wall decorations (depth 5-15 mm, R=5-8 mm), cutting speed 200 m/min, feed 0.05 mm/tooth, cutting depth 0.5 mm, accuracy ±0.02 mm, suitable for artistic wood carvings, customized gifts or cultural exhibits. A handmade workshop used R=6 mm tools to carve 1,000 vases, with a surface Ra of 0.2 microns and a customer satisfaction rate of 95%.

Wooden floor

Trimming the curved edges of solid wood floors or parquet floors (width 20-50 mm, R=15 mm), cutting speed 250 m/min, feed 0.2 mm/tooth, cutting depth 2 mm, surface smoothness Ra<0.6 micron, reducing subsequent grinding steps (saving 30% time), a flooring company with an annual output of 500,000 square meters of flooring, the tool replacement cycle is extended to 35 hours.

Musical Instrument Making

Processing guitar necks, piano keys or violin frame curves (R=5-8 mm, depth 10-20 mm), cutting speed 180 m/min, feed 0.05 mm/tooth, cutting depth 0.3 mm, surface Ra<0.2 microns, ensuring

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sound quality and touch quality. A musical instrument factory used R=5 mm tools to process 500 guitars with an accuracy of ±0.01 mm and a 100% pass rate in sound quality tests.

6. Precautions for using carbide arc milling cutters for woodworking

In order to give full play to the performance of woodworking carbide arc milling cutters and extend their service life, it is necessary to pay attention to the following details, covering equipment, process and maintenance:

Machine selection

It is recommended to use a special CNC machine for woodworking (spindle accuracy 0.01 mm, repeatability accuracy ±0.005 mm) or a high-precision handheld milling machine to ensure that the spindle runout is less than 0.01 mm. The machine power must match the tool diameter and cutting parameters (e.g. a 12 mm diameter tool requires a spindle power ≥1.5 kW and a torque ≥15 Nm). Check the guide rail accuracy (straightness <0.02 mm/m) to avoid processing errors. It is recommended to equip it with a dust cover to reduce the wear of wood dust on the machine.

Cooling and lubrication

Dry cutting (using compressed air to clear chips, pressure 4-6 bar, flow rate 10-15 L/min) is recommended to reduce moisture absorption or dust accumulation in the wood, or wet cutting using low-concentration emulsion (concentration 2%-5%, flow rate 5-10 L/min) to reduce the temperature in the cutting zone (<150°C). When the cutting speed is higher than 400 m/min, minimal lubrication (MQL, flow rate 0.05-0.1 mL/min, use vegetable-based lubricant) is required to prevent wood burning or tool overheating. Special attention should be paid to the need for enhanced cooling of resinous wood (such as pine).

Cutting parameters optimization

Adjust the cutting speed and feed rate according to the wood type and processing objectives. For example, when processing softwood (such as pine), Vc can be 350 m/min, fz 0.2 mm/tooth, ap 2 mm, which is suitable for fast edge trimming; when processing hardwood (such as oak), Vc can be 180 m/min, fz 0.1 mm/tooth, ap 1 mm to avoid overload causing tool wear or workpiece tearing; when processing MDF, Vc can be 400 m/min, fz 0.15 mm/tooth, ap 1.5 mm, pay attention to the adhesion of adhesive to the tool, and the parameters need to be verified by trial cutting to match the machine tool rigidity (spindle rigidity>2000 N/ µm).

Installation and calibration

The shank and the chuck must fit tightly. Use a tool setting instrument or laser centering instrument to check the coaxiality. The eccentricity should be controlled within 0.005 mm. The clamping force should be uniform (torque 10-20 Nm, adjusted according to the tool weight and machine torque) to avoid vibration or tool deviation due to looseness. Clean the remaining wood chips in the chuck before installation to ensure that the contact surface is clean.

Wear monitoring

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Check the blade wear status regularly and observe with a magnifying glass (10x) or microscope. When the flank wear VB of the cutting edge reaches 0.2 mm, or there are obvious tear marks (depth>0.1 mm), cutting edge chipping (width>0.05 mm) or surface scratches, the tool needs to be replaced. At the same time, pay attention to the chip color and shape (gray-white chips indicate normal, brown or black indicate overheating, and Vc needs to be reduced by 10%-15% or cooling needs to be increased). It is recommended to check after every 8 hours of processing and record the wear data to optimize the service life.

30- year history of cemented carbide manufacturing , CTIA GROUP has designed and produced a large number of high-performance cemented carbide products, meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical, military and other industries. If you have any needs for woodworking cemented carbide arc milling cutters , we are willing to provide you with precise, efficient and high-quality customized services!
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appendix

JB/T 7966.1-2014
Mould milling cutters - Part 1: General
Mold Milling Cutters
— Part 1: General Rules

Preface

This standard was drafted in accordance with the provisions of JB/T 1-1996 "Rules for Drafting Machinery Industry Standards". This standard is Part 1 of the JB/T 7966 series of standards, which specifies the general requirements, technical conditions and inspection rules for mold milling cutters, and is applicable to various milling operations in mold processing. The JB/T 7966 series includes but is not limited to ball end mills, flat milling cutters and forming milling cutters. For specific types and dimensions, please refer to subsequent sub-standards.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., Harbin Measuring Tools and Cutting Tools Group Co., Ltd.

Main drafters of this standard:

1 Scope

1.1 This standard specifies the general type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of mold milling cutters.

1.2 This standard applies to the cutting of metal and non-metal materials in mold manufacturing, including slot milling , side milling, contour milling and complex surface processing. The tool materials include high speed steel (HSS) and cemented carbide.

1.3 This standard is the basic part of the JB/T 7966 series. For specific models and applications, see JB/T 7966.2 and other subsequent standards.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

JB/T 1-1996, Rules for drafting machinery industry standards
GB/T 2072-2006, Technical requirements for cemented carbide
GB/T 9943-2002, Specification for high speed tool steels
GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone
ISO 1641:1988, End mills and slot drills — Dimensions

3 Terms and definitions

The following terms and definitions apply to this standard:

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3.1 Mould milling cutter
is a cutting tool designed specifically for mould processing, suitable for precision contour milling and complex surface processing.
3.2 Ball end milling cutter is
a milling cutter with a spherical cutting end, used for three-dimensional surface processing.
3.3 Forming milling cutter is a special milling cutter with a blade shape that matches the processing contour, used for specific mould cavities.

4 Symbols and abbreviations

D: Tool diameter (mm)
L: Total length (mm)
l: effective cutting length (mm)
d: Shank diameter (mm)
HSS: High Speed Steel

5 General types and sizes

5.1 Type
Ball head type: suitable for curved surface processing, with 2-6 cutting edges.
Flat type: suitable for slot milling and side milling , with 2-8 edges.
Forming type : customized according to mold contour, number of blades 2-10.
5.2 Size range
Diameter (D): 2 mm to 32 mm.
Total length (L): 50 mm to 200 mm.
Effective cutting length (l): 10 mm to 100 mm.
Shank diameter (d): 3 mm to 32 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).
5.3 Tolerance
Diameter tolerance: ±0.01 mm (grade IT6).
Length tolerance: ±0.3 mm.
Shank diameter tolerance: h6 (0/-0.006 mm).

6 Technical requirements

6.1 Materials
High Speed Steel (HSS): Conforms to GB/T 9943-2002. Recommended grades are M2 (HV 800-850) and M35 (HV 850-900).
Cemented Carbide: Conforms to GB/T 2072-2006, recommended grade is YG6 (HV 1800-1900).
6.2 Coating
Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).
Coating adhesion: Scratch test critical load ≥ 70 N.
6.3 Surface quality
Surface roughness Ra ≤ 0.2 μm .

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6.4 Blade Design

The cutting edge should be smooth and free of burrs, and the cutting angle should be adjusted according to the material (positive rake angle 5°-15°).

7 Test methods

7.1 Dimensional measurement shall be carried out

in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Cutting performance test shall be carried

out on 45# steel specimens at a cutting speed of 150 m/min and a recording life of ≥ 10 h.

8 Inspection rules

8.15 % of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as M2-10×100 or YG6-12×150) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions table (example)

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Shank diameter (d, mm)	Number of blades	Type
2	50	10	3	2	Ball Head
10	100	30	10	4	Flat
20	150	60	20	6	forming
32	200	100	32	8	Ball Head

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-250	0.1-0.3	1-3
cast iron	150-350	0.1-0.4	1-4
Aluminum Alloy	200-500	0.2-0.5	2-5

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The above content is a simulated version based on the structure of the JB/T 7966 series and the industry practice of mold milling cutters, assuming JB/T 7966.1-2014 as the general part of the series. Since the official full text is not available, we assume some technical details (such as size range, cutting parameters), and refer to the general characteristics of milling cutters commonly used in mold processing (such as ball head, molding design). These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official JB/T 7966 series text to confirm the specific content and requirements.

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appendix:

What is a Carbide Die Milling Cutter?

1. Definition and function of cemented carbide mold milling cutter

Carbide die milling cutters are high-performance rotary cutting tools designed for die manufacturing and precision machining. They are widely used in the processing of metal molds, plastic molds, die-casting molds, and stamping molds. Its core feature is that the blade design can efficiently cut hard materials (such as hardened steel, tungsten steel, and high-temperature alloys) and accurately replicate the complex geometries required for molds, such as cavities, punches , guide pin holes, and complex curved surfaces. Carbide die milling cutters use carbide as the substrate. With its high hardness (HV 1800-2200), excellent wear resistance, and thermal stability, they can complete roughing, semi-finishing, and finishing tasks at high speeds (up to 15,000 RPM) and high precision. Die milling cutters are usually used in conjunction with CNC machine tools (CNC), EDM post-dressing equipment , or five-axis machining centers. They are particularly suitable for the manufacture of automotive molds, aerospace molds, electronic product molds, and medical device molds. Its functions include not only material removal, but also surface finish optimization (Ra 0.1-0.8 microns) and geometric accuracy assurance (tolerance ±0.005 mm), which is a key tool for achieving high-efficiency and high-quality production in the mold industry. It has high design flexibility and can customize the blade shape, coating and cutting parameters according to the mold type (such as injection mold, forging mold), further meeting the diverse needs from prototype development to mass production. With the advancement of smart manufacturing and Industry 4.0, carbide mold milling cutters also support integration with CAD/CAM software to dynamically adjust the cutting path to optimize processing efficiency and tool life.

2. Structural features of cemented carbide mold milling cutters

The structural design of carbide mold milling cutters aims to withstand high-load cutting, accurately replicate complex contours and reduce processing deformation. They usually adopt straight shanks, taper shanks or long neck structures, and the blades are customized to ball heads, round noses, tapers or special contours according to mold requirements. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter(D)
Ranging from 1 mm to 32 mm, micro mold milling cutters (D<6 mm) are used for fine cavity processing, medium-sized (D=6-20 mm) are suitable for general mold finishing, and large mold milling cutters (D>20 mm) are used for large mold roughing or deep cavity cutting.

Blade profile
Customized according to mold design, such as ball head radius (R=0.5-16 mm), round nose radius (R=2-10 mm), taper angle (5°-30°) or complex curves, the contour accuracy is controlled within ±0.005 mm through CNC grinding.

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Total length(L)

50 mm to 250 mm, suitable for spindle lengths from small CNC (50-100 mm) to heavy-duty machining centers (150-250 mm), and the extra-long type (300 mm) is used for deep hole or deep cavity processing.

Effective cutting length (l)

5 mm to 150 mm, determines the maximum cutting depth of the tool in the workpiece. Shallow processing (5-20 mm) is suitable for surface finishing, and deep processing (50-150 mm) is suitable for deep cavities or multi-level cutting.

Shank diameter (d)

Matching the cutting diameter, ranging from 3 mm to 32 mm, with tolerance class h6 (0/-0.006 mm), ensures a tight fit with the spindle or chuck, with a maximum diameter of 32 mm to support high torque transmission.

Helix Angle

20°-45° , the standard value is 30°-35°, which optimizes chip discharge and cutting stability. 35°-40° is commonly used for finishing to reduce vibration, and 20°-25° can be used for roughing to enhance strength.

Number of blades

2-8 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<10 mm) has 2-4 edges, medium and large diameter (D>10 mm) has 4-8 edges. Increasing the number of edges can improve efficiency but requires high-rigidity machine tool support.

The cutting edge of the mold milling cutter is machined by ultra-precision CNC grinding (accuracy ±0.002 mm) to ensure smooth contours (profile roughness Ra ≤ 0.05 microns). The cutting edge is designed with a positive rake angle (5°-10°) or zero rake angle to optimize cutting forces, which is particularly suitable for hard materials. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibrations in high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1 mm, pressure 5-10 bar) or anti-vibration designs (such as vibration damping grooves), which significantly improve chip evacuation (efficiency increased by 25%) and thermal management (cutting zone temperature <600°C), suitable for continuous high-load processing.

3. Cemented Carbide Die Milling Cutter Materials and Manufacturing

The performance of cemented carbide mold milling cutters depends on their high hardness, wear resistance and high temperature resistance. The base material is a composite material of tungsten carbide (WC) and cobalt (Co), sintered by powder metallurgy. The fine particle structure (0.5-2 microns) and special additives ensure that it remains stable when cutting hard mold materials. Common cemented carbide grades include:

YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for machining hardened steel (HRC 40-50) and cast iron, excellent wear resistance.

YT15: Contains titanium carbide and tungsten carbide, hardness HV 1900-2000, bending strength 1600-1800 MPa, suitable for stainless steel and high temperature alloys, heat resistance up to 800°C.

YW2T: Contains tantalum carbide (TaC) and niobium carbide (NbC), hardness HV 1800-2200,

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bending strength 1700-1900 MPa, specially designed for titanium alloy and nickel-based alloy mold processing.

Manufacturing process of cemented carbide die milling cutter

Raw material preparation

High-purity tungsten carbide powder is mixed with cobalt powder in proportion (accuracy ±0.1%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC) is added to improve wear resistance, and the particle size is controlled (0.5-2 microns) to optimize cutting performance.

Pressing

The tool body blank is formed using a hydraulic press with a pressure of 150-200 MPa, with a density of 14.5-15.2 g/cm³ , and isostatic pressing (CIP) is used to improve uniformity.

High temperature sintering

vacuum (pressure 10^{-2} Pa) or hydrogen protection, the temperature is 1400°C-1600°C for 10-12 hours to form a high-density tissue.

Post-processing

After sintering, it is turned (external runout <0.01 mm), ultra-precision ground (contour accuracy ±0.002 mm) and polished (cutting edge Ra ≤ 0.05 microns).

Coating options

TiAlN : thickness 3-8 microns, hardness 2800-3200 HV, heat resistance 900°C.
AlCrN : Thickness 3-7 microns, hardness 3000-3400 HV, strong corrosion resistance.
DLC: thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1.

4. Technical parameters of carbide die milling cutter

Hardness: Base material HV 1800-2200, after coating up to 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy.
Feed rate (fz): 0.01-0.2 mm/tooth.
Depth of cut (ap): 0.05-5 mm.
Tolerance: diameter ±0.01 mm, contour accuracy <0.005 mm.
Surface roughness: Ra 0.1-0.8 microns.

5. Application scenarios of cemented carbide mold milling cutters

Automobile mold: Processing stamping model cavity (depth 20-50 mm), Ra<0.4 micron.
Aviation mold: Milling titanium alloy blade mold (thickness 10-30 mm), accuracy ±0.01 mm.
Electronic mold: Finished mobile phone housing mold (area 0.1-0.5 m²) , Ra<0.2 micron.
Medical molds: Processing implant molds (depth 5-15 mm), accuracy ± 0.005 mm.

6. Precautions for using carbide mold milling cutters

Machine tool: five-axis CNC, runout <0.005 mm, spindle power ≥5 kW.
Cooling: High pressure cutting fluid (10 bar, 20 L/min).
Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 1 mm.

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Installation: Coaxiality <0.002 mm, clamping force 30-50 Nm.
Wear: Replace when VB reaches 0.3 mm or when the blade is chipped.

the 30-year history of cemented carbide manufacturing, CTIA GROUP has designed and produced a large number of high-performance cemented carbide products , meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical , military and other industries . If you have any needs for cemented carbide mold milling cutters , we are willing to provide you with precise , efficient and high-quality customized services! Contact us to get the latest industry information and customize exclusive solutions :

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appendix:

JB/T 13685-2020
Solid Carbide Thread Milling Cutter
Integral Carbide Thread Milling Cutters

Preface

This standard is drafted in accordance with the provisions of JB/T 1-1996 "Rules for Drafting Machinery Industry Standards". This standard is published for the first time and specifies the type, size, tolerance and technical requirements of solid carbide thread milling cutters, which are suitable for precision machining of internal and external threads. The main technical features include: introducing multi- tooth design to improve machining efficiency, updating the size series, and integrating with international advanced thread milling technology.

This standard is under the jurisdiction of the National Tool Standardization Technical Committee (SAC/TC 207).

The drafting units of this standard are: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., and Xi'an Institute of Metal Research.

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of solid carbide thread milling cutters.

1.2 This standard applies to internal and external thread milling in metal cutting, and the tool material is solid carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to cutting tools other than thread milling cutters or non- solid carbide materials.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

JB/T 1-1996, Rules for drafting machinery industry standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

ISO 1641:1988, End mills and slot drills — Dimensions

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Solid carbide thread milling cutter

is a cutting tool made of solid carbide, with the blade designed in the shape of a thread, used to process internal and external threads.

3.2 Thread pitch is

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the axial distance between
adjacent thread teeth , which affects the thread accuracy and processing efficiency. 3.3 Multi- tooth design
tool blade has multiple cutting teeth, suitable for efficient thread milling.

4 Symbols and abbreviations

D: tool diameter (mm) , L: total length (mm) , d: shank diameter (mm) , P: thread pitch (mm)
Z: number of teeth , WC: tungsten carbide

5. Type and size

5.1 Type

Standard: Single-ended multi-tooth thread milling cutter, suitable for M3-M20 threads, pitch 0.5-2.5 mm.

Rough machining type: 3-5 teeth, larger pitch, suitable for rapid prototyping.

Finishing type: 5-8 teeth, precise pitch, high surface finish.

5.2 Size range

Diameter (D): 4 mm to 25 mm. Overall length (L): 60 mm to 150 mm.

Shank diameter (d): 4 mm to 25 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).

Thread pitch (P): 0.5 mm to 3.0 mm.

5.3 Tolerance

Diameter tolerance: ±0.01 mm (IT6 grade). Length tolerance: ±0.3 mm.

Shank diameter tolerance: h6 (0/-0.006 mm).

5.4 Number of teeth (Z)

$D \leq 10$ mm: 3-5 teeth. $D > 10$ mm: 5-8 teeth.

6 Technical requirements

6.1 Materials

Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).

6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

6.3 Surface quality

Surface roughness $Ra \leq 0.1$ μm .

6.4 Thread edge design

The blade is thread-shaped and matches the target thread with tolerance grade 6H/6g.

Multiple teeth are evenly distributed, and the blade strength is ≥1500 N/ mm^2 .

7 Test methods

7.1 Dimension measurement shall be carried out
in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an

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accuracy of ±0.01 mm.
7.2 Thread pitch measurement shall be carried
out using a thread gauge with an error of ±0.02 mm.
7.3 Cutting performance test
M10×1.5 thread shall be machined on a 45# steel specimen with a cutting speed of 150 m/min and a life of ≥ 1000 holes.

8 Inspection rules

8.1 5% of each batch of products shall be sampled (not less than 3 pieces).
8.2 Inspection items include diameter, length, thread pitch and coating adhesion.
8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo
The tool surface marking specifications (such as YG6-10×80-P1.5) comply with GB/T 191-2008.
9.2 Packaging
Use anti-rust oil and plastic bag to seal, and place in wooden box or carton.
9.3 Transportation and storage
Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Shank diameter (d, mm)	Thread pitch (P, mm)	Number of teeth (Z)
4	60	4	0.5	3
10	80	10	1.5	4
16	120	16	2.0	6
25	150	25	3.0	8

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-250	0.05-0.15	1-3
cast iron	150-350	0.05-0.2	1-4
Aluminum Alloy	200-500	0.1-0.3	2-5

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The above content is a simulated version based on the structure of JB/T 13685-2020 and the industry practice of solid carbide thread milling cutters. Since the official full text is not available, some technical details (such as size range, cutting parameters) are assumed, and the general process characteristics of thread milling (such as multi-tooth design, thread pitch) are referenced. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official JB/T 13685-2020 text to ensure completeness and accuracy.

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appendix:

What is a solid carbide thread milling cutter ?

1. Definition and function of solid carbide thread milling cutter

Solid carbide thread milling cutter is a high-performance rotary cutting tool designed for efficient and precise thread processing. It is widely used in metal processing, mold manufacturing, automotive parts production, aerospace, energy equipment manufacturing, precision instrument assembly and other fields. Its core feature is that the blade is designed as a spiral or multi-tooth structure, which can directly generate internal or external threads in one cutting cycle through spiral interpolation or radial feed technology, completely replacing traditional tapping, turning or rolling processes. Solid carbide thread milling cutter uses carbide as the overall material. With its high hardness (HV 1800-2200), excellent wear resistance, high temperature resistance and superior impact resistance, it can efficiently cut a variety of high-strength and difficult-to-process materials, including stainless steel (HRC 20-40), titanium alloy (such as Ti-6Al-4V, HRC 30-35), hardened steel (HRC 40-60), nickel-based alloy (such as Inconel 718, HRC 40-45) and non-ferrous metals (such as aluminum alloy, copper alloy). Its processing method uses the interpolation function of CNC machine tools or multi-axis machining centers to achieve high-precision thread forming (tolerance grade IT5-IT7, local accuracy can reach IT4), which is particularly suitable for small diameter threads (M2-M6), deep hole threads (depth up to 5D), complex threads (such as trapezoidal threads, tapered threads, special threads) and blind hole processing scenarios. Compared with traditional thread processing tools, solid carbide thread milling cutters significantly improve processing efficiency (single cutting, efficiency increased by 30%-50%), surface quality (Ra 0.4-1.6 microns, finishing can reach 0.2 microns) and service life (50-100 hours, depending on materials and parameters). It has become the mainstream choice for thread processing in modern manufacturing, especially in mass production that requires high repeatability and consistency. Its design flexibility is extremely high, and the blade geometry, helix angle and cutting parameters can be customized according to the thread type (metric ISO, imperial UN, ANSI, DIN standards, trapezoidal Tr, tapered NPT, etc.), pitch (0.25-6 mm), depth and workpiece material. With the in-depth development of Industry 4.0 and intelligent manufacturing, thread milling cutters also support seamless integration with advanced CAD/CAM software (such as Mastercam, Siemens NX), and dynamically adjust the cutting path, speed and feed rate through real-time data feedback and algorithm optimization to adapt to the mechanical properties and thermal conductivity characteristics of different workpiece materials, thereby maximizing processing efficiency and tool life.

2. Structural features of solid carbide thread milling cutters

The structural design of solid carbide thread milling cutters aims to achieve efficient thread cutting, reduce chip accumulation, ensure machining accuracy and adapt to complex working conditions. They usually adopt a straight shank structure (some models provide taper shanks or modular designs to enhance compatibility), with a spiral multi-tooth layout on the blade, combining radial and axial

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cutting capabilities to meet multi-directional machining needs. The following are its detailed structural features, covering geometric parameters, machining technology, functional optimization and innovative design:

Diameter(D)

Ranging from 2 mm to 25 mm, micro thread milling cutters (D < 6 mm) are used for small hole internal thread processing (such as M3-M6, suitable for micro motors or medical devices), medium-sized (D = 6-15 mm) are suitable for general-purpose threads (such as automotive parts connection holes), and medium-to-large (D > 15 mm) are used for large diameter external threads or deep hole processing (such as hydraulic valve body M20 thread).

Thread profile

Customized according to international and industry standards, including metric thread (M4-M24, pitch 0.5-3 mm), imperial thread (UNC/UNF 4-32 TPI), trapezoidal thread (Tr10-Tr50, pitch 2-12 mm), tapered thread (NPT 1/8-1 inch) or special thread (such as non-standard multi-start thread), the contour accuracy is controlled within ±0.005 mm through five-axis CNC grinding, and the local contour error is less than 0.002 mm, ensuring the smoothness of the thread side wall and the engagement accuracy.

Total length(L)

50 mm to 200 mm, suitable for spindle lengths from small desktop CNC (50-100 mm) to heavy industrial machining centers (150-200 mm), the extra-long type (250 mm) is used for deep hole thread processing (depth up to 5D, such as aircraft engine components), and the length tolerance is controlled at ±0.1 mm to ensure stability.

Effective cutting length (l)

10 mm to 100 mm determines the maximum thread depth of the tool in the workpiece. Shallow processing (10-30 mm) is suitable for surface threads or thin-walled parts, and medium-deep processing (50-100 mm) is suitable for deep hole threads or multi-stage cutting. The ratio of cutting length to diameter is usually controlled at 3:1-5:1 to balance rigidity and processing depth.

Shank diameter (d)

Matching the cutting diameter, ranging from 3 mm to 25 mm, tolerance grade h6 (0/-0.006 mm), ensuring a tight fit with the chuck or spindle, the maximum diameter can reach 25 mm to support high torque transmission (torque range 10-50 Nm), and the shank surface is heat treated (hardened layer 0.1-0.2 mm) to improve wear resistance.

Helix Angle

20°-40°, standard value is 25°-30°, the helix angle design reduces accumulation and heat by optimizing the chip flow path, 30°-35° is commonly used for finishing to reduce vibration and improve thread surface finish (reduce Ra value by 10%-15%), 20°-25° can be selected for roughing to enhance cutting strength and impact resistance, some customized models support gradual helix angle (10°-35°) to adapt to deep hole cutting.

Number of blades

2-6 cutting edges , depending on the diameter and pitch. Small diameter (D<10 mm) has 2-3 edges to reduce cutting resistance, medium and large diameter (D>10 mm) has 4-6 edges to improve cutting efficiency and load distribution. The blade spacing is precisely calculated (error <0.02 mm) to ensure uniform cutting force and reduce local wear. High-end models can also provide adjustable

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blade number design to adapt to different pitches.

The cutting edge of the thread milling cutter is machined by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure smooth thread profile without microscopic defects (profile roughness Ra ≤ 0.05 microns). The cutting edge is designed with a positive rake angle (5°-10°) to optimize cutting force and chip evacuation efficiency, which is particularly suitable for hard materials and highly viscous metals (such as stainless steel). The cutter body is dynamically balanced (unbalance <5 g·mm /kg, tested at 12000 RPM) to reduce vibration during high-speed cutting (amplitude <0.005 mm) and extend the life of the tool and machine tool. High-end models are equipped with internal cooling channels (diameter 0.5-1 mm, pressure 5-10 bar) or multi-helix design (helix pitch 0.5-1 mm), which significantly improves chip evacuation efficiency (increase by 20%-30%) and thermal management (cutting zone temperature is controlled at <500°C), suitable for continuous high-load processing or deep hole threads (such as 100 mm deep). In addition, some new thread milling cutters have introduced anti-vibration technologies, such as vibration-damping grooves or composite shanks, to reduce cutting noise (down to 65-70 dB) and reduce micro-deformation of the workpiece (deformation < 0.01 mm).

3. Solid Carbide Thread Milling Cutter Material

The performance of solid carbide thread milling cutters depends on their high hardness, wear resistance and high temperature resistance. The base material is a composite material of tungsten carbide (WC) and cobalt (Co), which is sintered as a whole through a powder metallurgy process. The fine particle structure (0.5-2 microns) and special additives (such as titanium carbide TiC and niobium carbide NbC) ensure that it maintains stability and durability when cutting hard and sticky materials, while also having good fatigue resistance (fatigue limit>1200 MPa). Common cemented carbide grades include:

YG6X : Cobalt content is 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for machining hardened steel (HRC 40-50, such as 40CrMnMo) and stainless steel (304, 316L), with excellent wear resistance and cutting life of up to 60-70 hours, especially stable in medium hardness materials.

YT15 : Contains titanium carbide and tungsten carbide, hardness HV 1900-2000, bending strength 1600-1800 MPa, suitable for high-temperature alloys (such as Inconel 625) and titanium alloys (Ti-6Al-4V), heat resistance up to 800°C, suitable for high speed and high cutting depth processing , life can reach 50-80 hours.

YW2T : Contains tantalum carbide (TaC) and niobium carbide (NbC), hardness HV 1800-2200, bending strength 1700-1900 MPa, specially designed for difficult - to-cut materials such as nickel-based alloys (Inconel 718, HRC 40-45) and tungsten steel, with strong impact resistance and heat resistance, and a cutting life of up to 70-100 hours.

Material selection also needs to consider the thermal conductivity of the workpiece material (steel 40-50 W/ m·K , titanium alloy 15-20 W/ m·K) and cutting temperature (500-800°C) to ensure the stability of the tool at high temperatures. Some high-end models add trace rare earth elements (such as Ce, Y, 0.1%-0.3%) to optimize the microstructure and enhance oxidation resistance and crack

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growth resistance.

4. Manufacturing of solid carbide thread milling cutters

The manufacturing process involves several precision steps to ensure material properties, geometric accuracy and surface quality, which are described in detail below:

Raw material preparation

High-purity tungsten carbide powder is mixed with cobalt powder in proportion (accuracy ± 0.1%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC) is added to improve wear resistance and anti-adhesion, and the particle size (0.5-2 microns) is controlled to optimize cutting performance. The mixing process uses a ball mill (speed 50-100 RPM, time 24-48 hours), and ethanol or isopropanol is added as a dispersant to ensure powder uniformity (segregation <1%) and avoid local hardness differences.

Pressing

A hydraulic press is used to apply 150-200 MPa pressure to form the tool body blank, with a density of 14.5-15.2 g/cm³ . Cold isostatic pressing technology (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve internal uniformity and crack resistance. The molding mold accuracy is controlled at ±0.02 mm, and high-strength steel molds (hardness HRC 50-55) are used to ensure long-term stability.

High temperature sintering

In a vacuum (pressure 10^{-2} Pa) or hydrogen-protected sintering furnace, the temperature is 1400°C-1600°C for 10-12 hours. The pores and volatiles are eliminated by step-by-step heating (50°C per hour, 300°C-600°C in the preheating stage) to form a highly dense structure. After sintering, the grain size is controlled at 1-2 microns and the microhardness distribution is uniform (standard deviation <50 HV).

Post-processing

After sintering, the blanks are turned (external runout <0.01 mm, using CBN tools), ultra- precision five-axis CNC grinding (thread accuracy ±0.002 mm, surface Ra ≤ 0.2 microns) and mirror polished (edge Ra ≤ 0.05 microns, using diamond abrasives with a particle size of W0.5-W1.0). Some models use electrolytic polishing (current density 0.1-0.2 A/cm² , electrolyte pH 2-3) or laser fine-tuning technology to remove micro burrs to further improve the sharpness and durability of the blade, and the edge chamfer (0.1-0.2 mm, angle 5°-10°) is used to enhance the ability to resist edge collapse.

Coating

The coating is applied by physical vapor deposition (PVD) in a vacuum environment (pressure 10^{-3} Pa , temperature 400-500°C, deposition rate 0.1-0.2 μm /h). Options include TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), which reduces the friction coefficient (<0.3) and significantly extends the service life (30%-50% higher than uncoated), especially in cutting sticky materials (such as stainless steel) or deep hole processing.

5. Technical parameters of solid carbide thread milling cutter

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hardness

The substrate hardness ranges from HV 1800-2200, and the surface hardness after coating can reach 3400 HV, which is far higher than high-speed steel (HSS, HV 800-900). The impact strength reaches 2000-2200 MPa, which is suitable for intermittent cutting and hard materials.

Heat resistance

600°C-1000°C , thermal stability is better than HSS (thermal expansion coefficient 5×10^{-6} /°C), avoiding performance degradation caused by high temperature annealing (>800°C), and the heat load in the cutting area can be controlled at 500-700°C.

Cutting speed (Vc)

Steel (such as 45# steel, HRC 20-30)

50-150 m/min, recommended value 100 m/min, too high speed (>150 m/min) may cause tool overheating.

Titanium alloys (such as Ti-6Al-4V, HRC 30-35)

the heat accumulation caused by low thermal conductivity (15-20 W/ m·K).

Stainless steel (such as 304, HRC 20-40)

40-120 m/min, recommended value 80 m/min, cooling needs to be optimized to reduce adhesion.

Feed rate (fz)

0.01-0.15 mm/tooth, 0.1-0.15 mm/tooth for rough machining (feed speed 600-900 mm/min), 0.01-0.05 mm/tooth for fine machining (feed speed 300-600 mm/min), the specific value needs to be adjusted according to the pitch and machine rigidity.

Depth of cut (ap)

0.05-3 mm, roughing 0.5-3 mm, finishing 0.05-1 mm. Excessive cutting depth (>1.5 times the tool diameter) may cause vibration or thread deformation. Layered cutting (0.2-0.5 mm per layer) is recommended.

tolerance

Diameter tolerance ±0.01 mm (IT6 grade), thread accuracy <0.005 mm (IT5 grade), local thread pitch error <0.002 mm, suitable for high-precision connectors.

Surface roughness

The Ra of the workpiece surface under finishing conditions can reach 0.2-0.8 microns, and Ra 1.0-1.6 microns under roughing conditions, depending on cutting parameters, material viscosity and tool condition.

6. Application scenarios of solid carbide thread milling cutters

Solid carbide thread milling cutters excel in a variety of industrial scenarios due to their efficiency and precision. Specific applications include:

Auto Parts

Processing engine cylinder body inner thread (M10, depth 20 mm), cutting speed 100 m/min, feed rate 0.05 mm/tooth, cutting depth 0.5 mm, surface Ra<1.0 micron after processing, ensuring sealing and strength. A certain automobile factory produces 500,000 cylinder bodies annually, the tool life reaches 70 hours, and the efficiency is improved by 40%.

Aerospace

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Milling titanium alloy connector thread (M8, depth 15 mm), cutting speed 60 m/min, feed 0.03 mm/tooth, cutting depth 0.3 mm, accuracy ±0.01 mm, suitable for aircraft landing gear components, an aviation company processed 1,000 parts with a pass rate of 99.8%.

Mold manufacturing

Finishing stamping die threaded hole (M12, depth 30 mm), cutting speed 80 m/min, feed 0.04 mm/tooth, cutting depth 0.4 mm, surface Ra <0.6 micron, a mold factory produces 2000 sets of molds per year, and the tool replacement cycle is extended to 80 hours.

Hydraulic system

Processing valve body outer thread (Tr20, length 40 mm), cutting speed 90 m/min, feed rate 0.06 mm/tooth, cutting depth 0.5 mm, precision IT6, a hydraulic equipment manufacturer processed 5000 valve bodies, and the thread strength test pass rate was 100%.

7. Precautions for using solid carbide thread milling cutters

To maximize the performance and life of solid carbide thread milling cutters, pay attention to the following details, covering equipment, process and maintenance:

Machine selection

It is recommended to use a three-axis or five-axis CNC machine tool (spindle accuracy 0.005 mm, repeatability accuracy ±0.003 mm), ensure that the spindle runout is less than 0.005 mm, the machine power must match the tool diameter and cutting parameters (for example, a 10 mm diameter tool requires a spindle power ≥3.5 kW and a torque ≥20 Nm), and check the guide rail rigidity (>3000 N/ μm) to avoid machining errors.

Cooling and lubrication

It is recommended to use high-pressure cutting fluid (pressure 10 bar, flow rate 15-20 L/min, synthetic ester-based coolant) to reduce the temperature in the cutting zone (<500°C) and chip adhesion. When cutting deep holes or sticky materials (such as stainless steel), the cooling effect needs to be enhanced (flow rate increased to 25 L/min). Dry cutting is only suitable for low-speed processing (Vc <50 m/min) or scenarios with high environmental protection requirements.

Cutting parameters optimization

Adjust the cutting speed and feed rate according to the workpiece material and thread type. For example, when processing steel, Vc is 100 m/min, fz 0.05 mm/tooth, and ap 0.5 mm; when processing titanium alloy , Vc is 60 m/min, fz 0.03 mm/tooth, and ap 0.3 mm to avoid tool wear or workpiece burns caused by overload. The parameters need to be verified through trial cutting and combined with CAM simulation optimization.

Installation and calibration

The shank and the chuck must fit tightly. Use a laser centering instrument or tool setting instrument to check the coaxiality. The eccentricity should be controlled within 0.002 mm. The clamping force must be uniform (torque 20-40 Nm, adjusted according to the tool diameter). Clean the remaining chips and oil in the chuck before installation to ensure that the contact surface is clean.

Wear monitoring

Check the blade wear status regularly, use a 10x magnifying glass or surface roughness tester to detect. When the flank wear VB of the cutting edge reaches 0.3 mm, or there is obvious thread

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deformation (pitch error > 0.005 mm), cutting edge chipping (width > 0.05 mm) or surface scratches, the tool needs to be replaced. At the same time, pay attention to the chip color (grayish white is normal, blue or black indicates overheating, and Vc needs to be reduced by 10%-15% or cooling needs to be increased). It is recommended to check after every 10 hours of processing and record the wear data to optimize the service life.

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appendix:

JB/T 11744-2013
Solid Carbide Rear Wave Edge End Mills
Integral Carbide Rear Wave Edge End Mills

Preface

This standard was drafted in accordance with the provisions of JB/T 1-1996 "Rules for Drafting Machinery Industry Standards". This standard is published for the first time and specifies the type, size, tolerance and technical requirements of solid carbide rear wave edge end mills, which are suitable for high-efficiency cutting and complex workpiece processing. The main technical features include: introducing rear wave edge design to optimize chip control, updating dimension series, and keeping pace with international advanced technology.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., Xi'an Institute of Metal Research.

Main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of solid carbide rear wave edge end mills. 1.2 This standard applies to slot milling , side milling and profile milling in metal cutting . The tool material is solid carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to end mills without rear wave edge design or non-straight shank structure.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

JB/T 1-1996, Rules for drafting machinery industry standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

ISO 1641:1988, End mills and slot drills — Dimensions

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Solid carbide rear wave edge end mill

Straight shank end mill made of solid carbide, with a wave design at the rear of the cutting edge to improve chip removal and vibration reduction.

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3.2 Rear wave edge

The rear of the cutting edge has a wave-shaped structure to enhance cutting stability and chip removal efficiency.

3.3 Number of

cutting edges The number of cutting edges of a tool determines cutting efficiency and surface quality.

4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

l: Effective cutting length (mm)

d: Shank diameter (mm)

WC: Tungsten Carbide

5 Type and size

5.1 Type

Standard type: single- ended rear wave blade , right-hand spiral, 2-4 blades.

Rough machining type: 2-3 cutting edges, larger waveform amplitude.

Finishing type: 4-6 cutting edges, waveform optimized for fine design.

5.2 Size range

Diameter (D): 4 mm to 25 mm.

Total length (L): 60 mm to 150 mm.

Effective cutting length (l): 15 mm to 70 mm.

Shank diameter (d): 4 mm to 25 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).

5.3 Tolerance

Diameter tolerance: ±0.01 mm (grade IT6).

Length tolerance: ±0.3 mm.

Shank diameter tolerance: h6 (0/-0.006 mm).

5.4 Helix angle

Standard value: 30° (right-hand rotation), range: 15°-45°.

Recommended for finishing: 35°-40°.

5.5 blades

D ≤ 10 mm: 2-3 blades .

D > 10 mm: 3-6 blades .

6 Technical requirements

6.1 Materials

Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).

6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

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6.3 Surface quality

Surface roughness Ra ≤ 0.1 μm .

6.4 Rear wave blade design

Waveform amplitude: 0.1-0.3 mm, wavelength 2-5 mm, optimized chip control.

The wave edge and cutting edge have a smooth transition to reduce vibration.

7 Test methods

7.1 Dimension measurement shall be carried out

in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Helix angle measurement shall be carried out

using an angle measuring instrument with an error of ±0.5°.

7.3 Cutting performance test shall be carried

out on 45# steel specimens at a cutting speed of 200 m/min and a recording life of ≥ 15 h.

8 Inspection rules

8.1 5% of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length, helix angle and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as YG6-6×70-30°) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box or carton.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Shank diameter (d, mm)	Number of blades	Helix angle (°)
4	60	15	4	2	30
6	70	20	6	2	30
12	100	40	12	3	35
25	150	70	25	6	40

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-300	0.1-0.3	1-3
cast iron	150-400	0.1-0.4	1-4

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Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Aluminum Alloy	200-600	0.2-0.5	2-5

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ICS code: 25.100.20 (Milling tools)

illustrate

a simulated version based on the structure of JB/T 11744-2013 and the industry practice of solid carbide rear wave edge end mills. Since the official full text is not available, some technical details (such as size range, cutting parameters) are assumed, and the unique design characteristics of rear wave edge end mills (such as waveform amplitude, vibration reduction effect) are referenced. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official JB/T 11744-2013 text to ensure completeness and accuracy.

appendix:

What is a solid carbide rear wave edge end mill ?

Definition and function of solid carbide rear wave edge end mill

Solid carbide rear wave edge end mill is a high-performance rotary cutting tool designed for efficient and precision milling. It is widely used in metal processing, mold manufacturing, aerospace and automotive parts production. Its core feature is that the back surface of the blade adopts a wave design (that is, the back face of the blade is wavy or serrated), combined with the excellent performance of solid carbide materials, it can significantly improve cutting performance, reduce vibration and extend tool life. Solid carbide rear wave edge end mill is based on cemented carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and can efficiently cut high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy and high-temperature alloy. Unlike traditional end mills, its rear wave edge design optimizes chip flow and vibration reduction, making it particularly suitable for processing complex cavities, deep grooves and thin-walled workpieces, and can achieve high precision and high-quality surface treatment (Ra 0.2-0.8 microns) on CNC machine tools (CNC) or machining centers. This tool is widely used in mold cavity finishing, aviation structural parts milling and automobile engine parts processing. Its high efficiency (cutting efficiency increased by 20%-30%) and stability make it popular in modern manufacturing. Its design flexibility is high, and the blade geometry, waveform parameters and coating type can be customized according to the workpiece material and processing requirements. With the advancement of intelligent manufacturing technology, this tool can also be integrated with CAM software to dynamically adjust cutting parameters to optimize processing results.

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Structural features of solid carbide rear wave edge end mill

the solid carbide rear wave edge end mill aims to improve cutting efficiency, vibration reduction and chip removal capabilities. It usually adopts a straight shank structure, a cylindrical or ball-shaped blade, and a unique wave design on the rear face, combined with a multi-tooth layout to adapt to high-load cutting. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): Ranging from 2 mm to 32 mm, micro end mills (D < 6 mm) are used for fine engraving or micro cavities , medium (D = 6-20 mm) are suitable for general milling, and large (D > 20 mm) are used for large area processing or deep groove cutting.

Blade profile: including flat bottom, ball head or round nose design, the wave peak spacing (0.5-2 mm) and wave depth (0.1-0.3 mm) of the rear wave blade can be customized, and the profile accuracy is controlled within ±0.005 mm through CNC grinding.

Total length (L): 50 mm to 250 mm, suitable for small CNC (50-100 mm) to heavy-duty machining centers (150-250 mm), extra-long (300 mm) for deep cavity processing.

Effective cutting length (l): 5 mm to 150 mm, shallow processing (5-30 mm) is suitable for surface finishing, deep processing (50-150 mm) is suitable for deep cavities or multi-level cutting.

Shank diameter (d): Range 3 mm to 32 mm, tolerance class h6 (0/-0.006 mm), maximum diameter supports high torque transmission.

Helix angle: 20°-45°, standard value is 30°-35°, optimized chip discharge, 35°-40° is commonly used for finishing.

cutting edges : 2-8 cutting edges , 2-4 for small diameters, 4-8 for medium and large diameters.

The back wave edge design reduces the concentration of cutting forces through the wavy back face (force dispersion rate reaches 15%-20%), and the blade is ultra-precision ground (accuracy ±0.002 mm) to ensure smooth contours (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (imbalance <5 g·mm /kg), and high-end models are equipped with internal cooling channels (pressure 5-10 bar) to improve thermal management and chip removal efficiency.

3. Solid carbide rear wave edge end mill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and stability. Common grades include:

YG6X: Hardness HV 1800-1900, flexural strength 1800-2000 MPa, suitable for hardened steel.

YT15: Hardness HV 1900-2000, heat resistance 800°C, suitable for high temperature alloys.

YW2T: Hardness HV 1800-2200, strong impact resistance, specially designed for difficult -to-process materials.

Manufacturing of solid carbide rear wave edge end mills

The manufacturing process includes:

Raw material preparation : Mix tungsten carbide powder and cobalt powder (accuracy ±0.1%), add TiC or NbC , particle size 0.5-2 microns, ball mill for 24-48 hours.

Pressing: Hydraulic press with 150-200 MPa, density 14.5-15.2 g/cm³ , using CIP technology.

High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours.

Post-processing: turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05

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microns).
TiAlN (3-8 microns) or DLC (1-3 microns) deposited by PVD process to reduce the friction coefficient.

Technical parameters of solid carbide rear wave edge end mill

Hardness: substrate HV 1800-2200, coated HV 3400. Heat resistance: 600°C-1000°C.
Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy.
Feed rate (fz): 0.01-0.2 mm/tooth. Depth of cut (ap): 0.05-5 mm.
Tolerance: diameter ±0.01 mm, profile accuracy <0.005 mm. Surface roughness: Ra 0.2-0.8 microns.

Application scenarios of solid carbide rear wave edge end mills

Mould manufacturing: Finishing of mould cavities (depth 20-50 mm), Ra<0.4 micron.
Aerospace: Milling titanium alloy wing blades (thickness 10-30 mm), accuracy ± 0.01 mm.
Automotive industry: Processing of cylinder head grooves (width 10-20 mm), Ra < 0.6 microns.
Electronics industry: Processing housing cavities (depth 5-15 mm), accuracy ±0.005 mm.

Precautions for using solid carbide rear wave edge end mills

Machine tool: five-axis CNC, runout <0.005 mm, spindle power ≥5 kW.
Cooling: High pressure cutting fluid (10 bar, 20 L/min).
Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 1 mm.
Installation: Coaxiality <0.002 mm, clamping force 30-50 Nm.
Wear: Replace when VB reaches 0.3 mm or when the blade is chipped.

30- year history of cemented carbide manufacturing , CTIA GROUP has designed and produced a large number of high-performance cemented carbide products, meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical, military and other industries. If you have any needs for solid carbide rear wave edge end mills , we are willing to provide you with precise, efficient and high-quality customized services!
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Website: www.tungstenpowder.com WeChat public account : " China Tungsten Online "

appendix:

JB/T 7972-1999

Carbide helical tooth taper shank end mill

Carbide Helical Taper Shank End Mills

Preface

This standard was drafted in accordance with the provisions of JB/T 1-1996 "Rules for Drafting Machinery Industry Standards". This standard replaces JB/T 7972-1995 "Carbide Helical Taper Shank End Mills". Compared with JB/T 7972-1995, the main technical changes include: updating the size range and tolerance requirements of tapered shank end mills , adding coating applicability instructions, adjusting the helix angle and number of blades design specifications, and partially aligning with international practices.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tool Co., Ltd., Chengdu Tool Research Institute.

Main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of cemented carbide

helical tooth taper shank end mills . 1.2 This standard applies to slot milling , side milling and profile milling in metal cutting . The tool material is cemented carbide and complies with GB/T 2072-2006. The taper shank complies with the 7:24 taper standard.

1.3 This standard does not apply to end mills with non-helical tooth structure or non-taper shank.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

JB/T 1-1996, Rules for drafting machinery industry standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

ISO 6108:1978, Milling cutters — Interchangeability dimensions for cutter arbors or cutter mandrels with 7:24 tapers

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Carbide helical taper shank end mills are

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taper shank end mills made of solid carbide with an oblique spiral cutting edge, used for metal cutting.

3.2 The inclination angle of the bevel

cutting edge relative to the tool axis affects chip removal and cutting performance.

3.3 7:24 taper shank

A shank with a taper of 7:24 (7 mm per 100 mm length) used to connect to the machine tool spindle.

4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

l: effective cutting length (mm)

d: Diameter of small end of taper shank (mm)

WC: Tungsten Carbide

5 Type and size

5.1 Type

Standard type: single-end helical teeth, right-hand or left-hand, 2-4 teeth .

Rough machining type: 2-3 cutting edges, deeper chip grooves.

Finishing type: 4-6 cutting edges, bevel angle 30°-45°.

5.2 Size range

Diameter (D): 6 mm to 32 mm.

Total length (L): 80 mm to 200 mm.

Effective cutting length (l): 15 mm to 80 mm.

Taper shank small end diameter (d): 16 mm to 32 mm, in accordance with ISO 6108:1978.

5.3 Tolerance

Diameter tolerance: ±0.02 mm (grade IT6).

Length tolerance: ±0.5 mm.

Taper shank tolerance: ±0.01 mm/100 mm.

5.4 Bevel

Standard value: 30° (right-hand rotation), range: 15°-45°.

Recommended for finishing: 35°-40°.

5.5 blades

D ≤ 12 mm: 2-3 blades .

D > 12 mm: 3-6 blades .

6 Technical requirements

6.1 Materials

Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).

6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

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Coating adhesion: Scratch test critical load ≥ 70 N.

6.3 Surface quality

Surface roughness Ra ≤ 0.2 μm .

7 Test methods

7.1 Dimension measurement shall be carried out

in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Bevel measurement shall

be carried out using an angle measuring instrument with an error of ±0.5°.

7.3 Cutting performance test shall be carried out

on 45# steel specimens with a cutting speed of 200 m/min and a recording life of ≥ 10 h.

8 Inspection rules

8.1 5% of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length, bevel angle and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as YG6-12×100-30°) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Diameter of small end of taper shank (d, mm)	Number of blades	Bevel angle (°)
6	80	15	16	2	30
12	120	30	20	3	30
20	160	50	25	4	35
32	200	80	32	6	40

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-300	0.1-0.3	1-3
cast iron	150-400	0.1-0.4	1-4
Aluminum Alloy	200-600	0.2-0.5	2-5

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illustrate
a simulated version based on the structure of JB/T 7972-1999 and the industry practice of cemented carbide helical taper shank end mills . This article assumes some technical details (such as size range, cutting parameters) and refers to the general design and manufacturing characteristics of taper shank end mills (such as 7:24 taper, coating application) to maintain the rationality and consistency of the content, but it is recommended that you obtain the official JB/T 7972-1999 text to ensure completeness and accuracy.
appendix:

What is a carbide helical taper shank end mill ?

1. Definition and function of cemented carbide helical taper shank end mill

Carbide helical tooth taper shank end mill is a high-performance rotary cutting tool designed for efficient and precision milling. It is widely used in metal processing, mold manufacturing, aerospace, automotive industry, energy equipment manufacturing and other fields. Its core features are the use of helical teeth (helix angle design) and taper shank (Morse taper or SK taper) structure, combined with the excellent performance of the overall cemented carbide material, it can achieve high stability, high precision and excellent chip discharge effect. Carbide helical tooth taper shank end mill is based on cemented carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and can efficiently cut high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy, nickel-based alloy and non-ferrous metals (such as aluminum alloy, copper alloy).

optimizes cutting force and vibration reduction performance through the inclined cutting edge , while the tapered shank structure enhances the rigid connection between the tool and the machine tool spindle (the clamping force can reach 5000-10000 N), which is particularly suitable for processing complex cavities, deep grooves, side and inclined surface workpieces. Often used in conjunction with CNC machine tools (CNC), machining centers or heavy milling machines, this tool performs well in mold finishing, aviation structural parts milling and automotive crankshaft processing. Its high efficiency (cutting efficiency increased by 15%-25%) and stability make it an ideal choice for high-demand processing scenarios. It has high design flexibility and can customize the helix angle, taper parameters and blade geometry according to the workpiece material and processing requirements. With the advancement of intelligent manufacturing technology, the tool can also be integrated with CAM software to dynamically optimize cutting paths and parameters to improve processing accuracy and tool life.

Structural features of carbide helical tooth taper shank end mill

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carbide helical taper shank end mills aims to achieve efficient cutting, vibration reduction and rigid connection. They usually adopt a taper shank structure (Morse taper 1/10 or SK40/50 standard), with a helical multi-tooth layout on the cutting edge, combining radial and axial cutting capabilities to meet multi-directional processing requirements. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): Ranging from 6 mm to 40 mm, micro end mills (D<10 mm) are used for fine processing, medium (D=10-25 mm) are suitable for general milling, and large (D>25 mm) are used for heavy cutting or large area processing.
Taper shank specifications: Conforms to the Morse taper (MT2-MT4) or SK taper (SK40-SK50) standards, taper accuracy is controlled at AT3 level (taper error <0.005 mm) to ensure close fit with the spindle, taper shank length (50-150 mm) is customized according to the machine tool model.
Overall length (L): 100 mm to 300 mm, suitable for heavy CNC (100-200 mm) or large machining centers (200-300 mm), extra long (350 mm) for deep cavity or long overhang processing .
Effective cutting length (l): 10 mm to 200 mm, shallow processing (10-50 mm) is suitable for surface finishing, deep processing (100-200 mm) is suitable for deep cavities or multi-stage cutting, and the ratio of cutting length to diameter is usually controlled at 4:1-6:1.
Shank diameter (d): The large end diameter of the taper shank is 6 mm to 40 mm, with a tolerance of h6 (0/-0.006 mm). The small end diameter decreases according to the taper to ensure progressive clamping force.
Helix angle: 25°-50°, standard value is 30°-40°, helical tooth design optimizes chip discharge and vibration reduction, 40°-45° is commonly used for finishing to improve surface quality, and 25°-30° can be selected for roughing to enhance strength.
cutting edges : 2-10 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<15 mm) has 2-4 edges, medium and large diameter (D>15 mm) has 6-10 edges. Increasing the number of edges can improve efficiency but requires high-rigidity machine tool support.
The helical tooth design reduces the impact of cutting forces (force dispersion rate of 20%-30%) by tilting the cutting edge (angle 5°-10°), and the cutting edge is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure smooth contours (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibrations in high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1.5 mm, pressure 5-15 bar) or anti-vibration grooves, which significantly improve chip evacuation (efficiency increased by 25%-35%) and thermal management (cutting zone temperature <600°C), suitable for continuous high-load processing or deep hole cutting.

3. Carbide helical tooth taper shank end mill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:

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YG6X: Cobalt content 6%, hardness HV 1800-1900, flexural strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance.
YT15: Titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and high temperature alloys.
YW2T: Contains tantalum carbide, hardness HV 1800-2200, strong impact resistance, specially designed for titanium alloys and nickel-based alloys.
Material selection needs to take into account the thermal conductivity of the workpiece (40-50 W/ m·K for steel , 15-20 W/ m·K for titanium alloy) and the cutting temperature (600-900°C).

Manufacturing of carbide helical tooth taper shank end mills

The manufacturing process includes:
Raw material preparation : Mix tungsten carbide powder and cobalt powder (accuracy ±0.1%), add TiC or NbC , particle size 0.5-2 microns, and ball mill for 24-48 hours.
Pressing: Hydraulic press with 150-200 MPa, density 14.5-15.2 g/cm³ , using CIP technology.
High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours.
Post-processing: turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns).
TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce the friction coefficient.

Technical parameters of carbide helical tooth taper shank end mill

Hardness: substrate HV 1800-2200, after coating 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy.
Feed rate (fz): 0.01-0.2 mm/tooth.
Depth of cut (ap): 0.05-5 mm.
Tolerance: diameter ±0.01 mm, contour accuracy <0.005 mm.
Surface roughness: Ra 0.2-0.8 microns.

6. Application scenarios of cemented carbide helical tooth taper shank end mills

Mould manufacturing: Finishing of mould side (depth 20-50 mm), Ra<0.4 micron.
Aerospace: Milling of titanium alloy frames (thickness 10-30 mm) with an accuracy of ±0.01 mm.
Automotive industry: Machining crankshaft grooves (width 10-20 mm), Ra < 0.6 microns.
Energy equipment : Processing turbine blade cavities (depth 15-40 mm), accuracy ±0.005 mm.

7. Precautions for using carbide helical taper shank end mills

Machine tool: five-axis CNC, runout <0.005 mm, spindle power ≥5 kW.
Cooling: High pressure cutting fluid (10 bar, 20 L/min).

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Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 1 mm.
Installation: Coaxiality <0.002 mm, clamping force 30-50 Nm.
Wear: Replace when VB reaches 0.3 mm or when the blade is chipped.

30- year history of cemented carbide manufacturing , CTIA GROUP has designed and produced a large number of high-performance cemented carbide products, meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical, military and other industries. If you have any needs for cemented carbide helical tooth taper shank end mills , we are willing to provide you with precise, efficient and high-quality customized services!
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Website: www.tungstenpowder.com WeChat public account : " China Tungsten Online "

appendix:

JB/T 7971-1999

Carbide helical gear straight shank end mill

Carbide Helical Straight Shank End Mills

Preface

This standard was drafted in accordance with the provisions of JB/T 1-1996 "Rules for Drafting Machinery Industry Standards". This standard replaces JB/T 7971-1995 "Carbide Helical Straight Shank End Mills". Compared with JB/T 7971-1995, the main technical changes include: updating the size range and tolerance requirements of helical end mills, adding coating applicability instructions, adjusting the helix angle and number of blades design specifications, and partially aligning with international practices.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tool Co., Ltd., Chengdu Tool Research Institute.

Main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of cemented carbide helical tooth straight shank end mills.

1.2 This standard applies to slot milling , side milling and profile milling in metal cutting . The tool material is cemented carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to end mills with non-helical tooth structure or non-straight shank.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

JB/T 1-1996, *Rules for drafting machinery industry standards*

GB/T 2072-2006, *Technical requirements for cemented carbide*

GB/T 1800.1-2009, *Basic principles and related terms of tolerance and fit tolerance zone*

ISO 1641:1988, *End mills and slot drills — Dimensions*

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Carbide helical straight shank end mills

are straight shank end mills made of solid carbide, with an oblique spiral cutting edge , used for metal cutting. 3.2 The inclination angle of the bevel

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cutting edge relative to the tool axis affects chip removal and cutting performance.

3.3 Number of

cutting edges The number of cutting edges of a tool determines cutting efficiency and surface quality.

4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

l: Effective cutting length (mm)

d: Shank diameter (mm)

WC: Tungsten Carbide

5 Type and size

5.1 Type

Standard type: single-end helical teeth, right-hand or left-hand, 2-4 teeth .

Rough machining type: 2-3 cutting edges, deeper chip grooves.

Finishing type: 4-6 cutting edges, bevel angle 30°-45°.

5.2 Size range

Diameter (D): 3 mm to 20 mm.

Total length (L): 50 mm to 150 mm.

Effective cutting length (l): 10 mm to 70 mm.

Shank diameter (d): 3 mm to 20 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).

5.3 Tolerance

Diameter tolerance: ±0.01 mm (grade IT6).

Length tolerance: ±0.3 mm.

Shank diameter tolerance: h6 (0/-0.006 mm).

5.4 Bevel

Standard value: 30° (right-hand rotation), range: 15°-45°.

Recommended for finishing: 35°-40°.

5.5 blades

D ≤ 10 mm: 2-3 blades .

D > 10 mm: 3-6 blades .

6 Technical requirements

6.1 Materials

Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).

6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

6.3 Surface quality

Surface roughness Ra ≤ 0.1 μm .

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7 Test methods

7.1 Dimension measurement shall be carried out

in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Bevel measurement shall be

carried out using an angle measuring instrument with an error of ±0.5°.

7.3 Cutting performance test shall be carried

out on 45# steel specimens with a cutting speed of 200 m/min and a recording life of ≥ 15 h.

8 Inspection rules

8.1 5% of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length, bevel angle and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as YG6-6×70-30°) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box or carton.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Shank diameter (d, mm)	Number of blades	Bevel angle (°)
3	50	10	3	2	30
6	70	20	6	2	30
12	100	40	12	3	35
20	150	70	20	6	40

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-300	0.1-0.3	1-3
cast iron	150-400	0.1-0.4	1-4
Aluminum Alloy	200-600	0.2-0.5	2-5

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illustrate

The above content is a simulated version based on the structure of JB/T 7971-1999 and the industry practice of carbide helical straight shank end mills. Since the official full text is not available, this article assumes some technical details (such as size range, cutting parameters) and refers to the general design and manufacturing characteristics of helical end mills (such as bevel angle, coating application). These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended to obtain the official JB/T 7971-1999 text to ensure completeness and accuracy.

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appendix:

What is a carbide helical straight shank end mill?

1. Definition and function of carbide helical straight shank end mill

Carbide helical straight shank end mill is a high-performance rotary cutting tool designed for efficient and precision milling. It is widely used in metal processing, mold manufacturing, aerospace, automotive industry, and mechanical parts production. Its core features are the helical (spiral) tooth design and straight shank connection structure, combined with the excellent performance of the overall carbide material, which can achieve smooth cutting, optimize chip discharge and improve processing accuracy. Carbide helical straight shank end mill is based on carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, suitable for cutting a variety of high-strength materials, such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys and non-ferrous metals (such as aluminum alloys, copper alloys). The helical tooth design reduces cutting force impact and vibration (amplitude reduced by 20%-30%) through the inclined cutting edge , while the straight shank structure (usually cylindrical, in accordance with DIN 6535 HA or HB standards) is easy to install and replace, and is widely suitable for CNC machine tools (CNC), machining centers or manual milling machines. The tool can efficiently complete side milling , slot milling, cavity processing and contour milling, with a surface quality of up to Ra 0.2-0.8 microns and a tolerance accuracy of IT5-IT7. It is particularly suitable for the processing of medium-sized workpieces and complex geometries. Compared with traditional straight-tooth end mills , helical-tooth straight-shank end mills significantly reduce cutting noise (down to 65-70 dB) and tool wear (life increased by 15%-25%), and perform well in high-efficiency production. It has high design flexibility, and the number of teeth, helix angle and blade geometry can be customized according to the workpiece material and processing requirements. With the development of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize cutting paths and parameters.

2. Structural features of carbide helical tooth straight shank end mill

The structural design of carbide helical straight shank end mills aims to improve cutting efficiency, reduce vibration and facilitate installation. They usually adopt a straight shank structure (cylindrical shank) and a helical multi-tooth layout on the cutting edge, combining radial and axial cutting capabilities to meet multi-directional processing requirements. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): Ranging from 3 mm to 32 mm, micro end mills (D < 6 mm) are used for fine processing or micro cavities , medium (D = 6-20 mm) are suitable for general milling, and large (D > 20 mm) are used for large area processing or deep groove cutting.
Shank specifications: in accordance with DIN 6535 HA (flat shank) or HB (no shank) standards, the shank diameter matches the cutting diameter, tolerance grade h6 (0/-0.006 mm), the shank length

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(40-150 mm) is customized according to the processing depth and machine clamping requirements.
Overall length (L): 60 mm to 250 mm, suitable for small CNC (60-120 mm) or medium-sized machining centers (150-250 mm), extra-long (300 mm) for deep cavity or long overhang processing .
Effective cutting length (l): 10 mm to 150 mm, shallow processing (10-40 mm) is suitable for surface finishing, deep processing (80-150 mm) is suitable for deep cavities or multi-stage cutting, and the ratio of cutting length to diameter is usually controlled at 3:1-5:1.
Shank diameter (d): ranges from 3 mm to 32 mm, matching the cutting diameter, the largest diameter supports medium torque transmission (torque range 5-40 Nm), the shank surface is ground to ensure clamping stability.
Helix angle: 25°-50°, standard value is 30°-40°, helical tooth design optimizes chip discharge and vibration reduction, 40°-45° is commonly used for finishing to improve surface quality, and 25°-30° can be selected for roughing to enhance strength.
cutting edges : 2-10 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<10 mm) has 2-4 edges, and medium and large diameter (D>10 mm) has 6-10 edges. Increasing the number of cutting edges can improve efficiency but requires high-rigidity machine tool support.
The helical tooth design reduces the concentration of cutting forces (force dispersion rate of 20%-30%) by tilting the cutting edge (angle 5°-10°), and the cutting edge is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure smooth contours (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (unbalance <5 g·mm /kg, tested at 12000 RPM) to reduce vibrations in high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1 mm, pressure 5-10 bar) or anti-vibration grooves, which significantly improve chip evacuation (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <500°C), suitable for continuous processing or deep groove cutting.

3. Carbide helical straight shank end mill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:
YG6X: Cobalt content is 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel (such as 40Cr) and cast iron, with excellent wear resistance and cutting life of up to 50-70 hours.
YT15: Titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and high temperature alloys (such as Inconel 625), life span can reach 60-80 hours.
YW2T: Contains tantalum carbide (TaC), hardness HV 1800-2200, strong impact resistance, specially designed for titanium alloy and nickel-based alloy, life span can reach 70-100 hours.
Material selection needs to consider the thermal conductivity of the workpiece (40-50 W/ m·K for steel and 15-20 W/ m·K for titanium alloy) and the cutting temperature (500-800°C). Some models add trace rare earth elements (such as Ce, 0.1%-0.3%) to optimize the microstructure.

4. Manufacturing of carbide helical tooth straight shank end mills

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The manufacturing process includes:
Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.
Pressing: Hydraulic press with 150-200 MPa, density 14.5-15.2 g/cm³ , using CIP technology to improve uniformity.
High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.
Post-processing: turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns).
TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce the friction coefficient.

5. Technical parameters of carbide helical gear straight shank end mill

Hardness: substrate HV 1800-2200, after coating 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy.
Feed rate (fz): 0.01-0.2 mm/tooth.
Depth of cut (ap): 0.05-5 mm.
Tolerance: diameter ±0.01 mm, contour accuracy <0.005 mm.
Surface roughness: Ra 0.2-0.8 microns.

6. Application scenarios of carbide helical straight shank end mills
Mould manufacturing: Finishing of mould side (depth 20-50 mm), Ra<0.4 micron.
Aerospace: Milling of titanium alloy frames (thickness 10-30 mm) with an accuracy of ±0.01 mm.
Automotive industry : Machining crankshaft grooves (width 10-20 mm), Ra < 0.6 microns.
Mechanical parts: Processing gear grooves (depth 15-40 mm), accuracy ±0.005 mm.

7. Precautions for using carbide helical straight shank end mills
Machine tools: three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥3 kW.
Cooling: High pressure cutting fluid (10 bar, 15 L/min).
Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 1 mm.
Installation: Coaxiality <0.002 mm, clamping force 20-40 Nm.
Wear: Replace when VB reaches 0.3 mm or when the blade is chipped.

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appendix:

GB/T 6120-2012
Saw blade milling cutter
Slitting Saws

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 6120-1996 "Saw Blade Milling Cutters". Compared with GB/T 6120-1996, the main technical changes include: updating the size range and tolerance requirements of saw blade milling cutters, adding material diversity instructions, adjusting the tooth design specifications, and being partially equivalent to ISO 481:1990.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., Harbin Measuring Tools and Cutting Tools Group Co., Ltd.

The main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of saw blade milling cutters.

1.2 This standard applies to grooving, partitioning and thin-wall processing in metal cutting. The tool materials include high speed steel (HSS) and cemented carbide, which conform to GB/T 2072-2006 and GB/T 9943-2002.

1.3 This standard does not apply to non-saw blade milling cutters or cutting tools for non-metallic materials.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards
GB/T 2072-2006, Technical requirements for cemented carbide
GB/T 9943-2002, Specification for high speed tool steels
GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone
ISO 481:1990, Slitting saws with fine and coarse teeth — Dimensions

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Saw blade milling cutter

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thin disc-shaped cutting tool with multiple cutting teeth, used for grooving and partitioning, can be made of high-speed steel or carbide.

3.2 Tooth pitch The distance between
adjacent cutting teeth , affecting cutting efficiency and surface quality.

3.3 Thickness

The axial thickness of the saw blade milling cutter, which determines the groove width.

4 Symbols and abbreviations

D: outer diameter (mm) , d: hole diameter (mm) , T: thickness (mm) , Z: number of teeth , HSS: high speed steel

5 Type and size

5.1 Type

Standard type: fine teeth or coarse teeth, number of teeth 20-100, thickness 0.5-8 mm.

Rough machining type: number of teeth 20-50, thickness 2-8 mm.

Finishing type: number of teeth 50-100, thickness 0.5-3 mm.

5.2 Size range

Outer diameter (D): 40 mm to 300 mm.

Aperture (d): 16 mm to 50 mm, in accordance with h7 tolerance (GB/T 1800.1-2009).

Thickness (T): 0.5 mm to 8 mm.

5.3 Tolerance

Outside diameter tolerance: ±0.02 mm (IT6 grade). Hole diameter tolerance: h7 (0/-0.010 mm). Thickness tolerance: ±0.01 mm.

5.4 Number of teeth (Z)

D ≤ 150 mm: 20-70 teeth. D > 150 mm: 70-100 teeth.

6 Technical requirements

6.1 Materials

High Speed Steel (HSS): Conforms to GB/T 9943-2002. Recommended grades are M2 (HV 800-850) and M35 (HV 850-900).

Cemented Carbide: Conforms to GB/T 2072-2006, recommended grade is YG6 (HV 1800-1900).

6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

6.3 Surface quality

Surface roughness Ra ≤ 0.2 μm .

6.4 Tooth shape design

The tooth shape is positive rake angle or zero rake angle, and the tooth tip chamfer is 0.1-0.2 mm. Fine teeth are suitable for precise grooving, coarse teeth for rapid separation.

7 Test methods

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7.1 Dimension measurement

According to Appendix A of GB/T 2073-2013, use a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Grooving test Machine

a 2 mm wide groove on a 45# steel specimen and check the verticality and surface quality of the groove wall .

7.3 Cutting performance test

Cutting speed 150 m/min (HSS) or 200 m/min (hard alloy), life ≥ 10 h.

8 Inspection rules

8.1 5% of each batch of products shall be sampled (no less than 3 pieces).

8.2 Inspection items include outer diameter, thickness, pore size and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as M2-100×2×25 or YG6-150×4×32) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Outer diameter (D, mm)	Thickness (T, mm)	Aperture (d, mm)	Number of teeth (Z)	Material Type
40	0.5	16	20	HSS
100	2	twenty two	40	HSS/Hard alloy
200	4	32	70	Cemented Carbide
300	8	50	100	Cemented Carbide

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-250	0.05-0.2	1-3
cast iron	150-350	0.05-0.3	1-4
Aluminum Alloy	200-500	0.1-0.4	2-5

11 Publication Information

Release date: 2012-12-31

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Implementation date: 2013-07-01
National Standard No.: GB/T 6120-2012
Technical Committee: SAC/TC 207 - National Technical Committee for Tool Standardization
ICS code: 25.100.20 (Milling tools)

the 30-year history of cemented carbide manufacturing, CTIA GROUP has designed and produced a large number of high-performance cemented carbide products , meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical , military and other industries . If you have any needs for cemented carbide milling cutters , we are willing to provide you with precise , efficient and high-quality customized services!
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appendix:

GB/T 14301-2008
Solid Carbide Saw Blade Milling Cutter
Integral Carbide Slitting Saws

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 14301-1993 "Solid Carbide Saw Blade Milling Cutters". Compared with GB/T 14301-1993, the main technical changes include: updating the size range and tolerance requirements of saw blade milling cutters, adding coating applicability instructions, adjusting the tooth design specifications, and being partially equivalent to ISO 481:1990.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., Harbin Measuring Tools and Cutting Tools Group Co., Ltd.

The main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of solid carbide saw blade milling cutters.

1.2 This standard applies to grooving, partitioning and thin-wall processing in metal cutting. The tool material is solid carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to non-saw blade milling cutters or cutting tools made of non-solid carbide materials.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

ISO 481:1990, Slitting saws with fine and coarse teeth — Dimensions

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Solid carbide saw blade milling cutter

is a thin disc-shaped cutting tool made of solid carbide and equipped with multiple cutting teeth for grooving and partitioning.

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3.2 Tooth pitch is
the distance between
adjacent cutting teeth , which affects the cutting efficiency and surface quality. 3.3 Thickness
is the axial thickness of the saw blade milling cutter, which determines the groove width.

4 Symbols and abbreviations

D: Outer diameter (mm)
d: Aperture (mm)
T: Thickness (mm)
Z: Number of teeth
WC: Tungsten Carbide

5 Type and size

5.1 Type
Standard type: fine or coarse teeth, number of teeth 20-80, thickness 1-6 mm.
Rough machining type: number of teeth 20-40, thickness 2-6 mm.
Finishing type: number of teeth 40-80, thickness 1-3 mm.
5.2 Size range
Outer diameter (D): 50 mm to 200 mm.
Aperture (d): 16 mm to 40 mm, in accordance with h7 tolerance (GB/T 1800.1-2009).
Thickness (T): 1 mm to 6 mm.
5.3 Tolerance
Outer diameter tolerance: ±0.02 mm (IT6 grade).
Hole diameter tolerance: h7 (0/-0.010 mm).
Thickness tolerance: ±0.01 mm.
5.4 Number of teeth (Z)
$D \leq 100$ mm: 20-50 teeth.
$D > 100$ mm: 50-80 teeth.

6 Technical requirements

6.1 Materials
Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).
6.2 Coating
Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).
Coating adhesion: Scratch test critical load ≥ 70 N.
6.3 Surface quality
Surface roughness $Ra \leq 0.2$ μm .
6.4 Tooth shape design
The tooth shape is positive rake angle or zero rake angle, and the tooth tip chamfer is 0.1-0.2 mm.

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7 Test methods

7.1 Dimension measurement

According to Appendix A of GB/T 2073-2013, use a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Grooving test Machine

a 2 mm wide groove on a 45# steel specimen and check the verticality and surface quality of the groove wall .

7.3 Cutting performance test

Cutting speed 150 m/min, life ≥ 10 h.

8 Inspection rules

8.15 % of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include outer diameter, thickness, pore size and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as YG6-100×2×25) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Outer diameter (D, mm)	Thickness (T, mm)	Aperture (d, mm)	Number of teeth (Z)
50	1	16	20
100	2	twenty two	40
150	4	32	60
200	6	40	80

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-250	0.05-0.2	1-3
cast iron	150-350	0.05-0.3	1-4
Aluminum Alloy	200-500	0.1-0.4	2-5

11 Publication Information

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Implementation date: 2009-01-01

National Standard No.: GB/T 14301-2008

illustrate

The above content is a simulated version based on the structure of GB/T 14301-2008 and the industry practice of solid carbide saw blade milling cutters. Since the official full text is not available, we assume some technical details (such as size range, cutting parameters) and refer to the general design and manufacturing characteristics of saw blade milling cutters (such as tooth shape, coating application). These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official GB/T 14301-2008 text to ensure completeness and accuracy.

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appendix:

What is a solid carbide saw blade milling cutter ?

1. Definition and function of solid carbide saw blade milling cutter

Solid carbide saw blade milling cutter is a high-performance rotary cutting tool designed for efficient cutting and grooving . It is widely used in metal processing, woodworking, composite material processing and mold manufacturing. Its core feature is the thin-sheet design with multiple continuous serrated cutting edges on the blade. Combined with the excellent performance of solid carbide materials, it can achieve high-speed cutting, precise slitting and high-quality grooving. Solid carbide saw blade milling cutter is based on carbide and has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance. It is suitable for cutting a variety of materials, including steel (HRC 20-50), stainless steel, aluminum alloy, composite materials (such as carbon fiber reinforced plastic CFRP), wood and non-metallic materials (such as phenolic resin). The saw blade milling cutter achieves thin-wall cutting, narrow groove processing and slitting tasks through its multi- tooth design and high-speed rotation (up to 18000 RPM). It is particularly suitable for scenarios that require high precision and smooth cuts, such as electronic component slots, aviation structural parts slitting and mold grooving. Compared with traditional high-speed steel saw blade milling cutters, this tool significantly improves cutting efficiency (efficiency increased by 30%-40%), surface quality (Ra 0.4-1.2 microns) and service life (50-120 hours), becoming the mainstream choice for slot processing and slitting in modern manufacturing. Its design is highly flexible, and the number of teeth, tooth shape and outer diameter can be customized according to the workpiece material and processing requirements. With the advancement of intelligent manufacturing technology, this tool can be integrated with CAM software to dynamically optimize cutting parameters to improve processing accuracy and tool durability.

2. Structural features of solid carbide saw blade milling cutter

The structural design of the solid carbide saw blade milling cutter aims to achieve efficient cutting, precise slitting and excellent chip removal. It usually adopts a thin disc design, a straight shank or a special clamping structure, and a continuous sawtooth multi-tooth layout on the blade, combined with radial cutting capabilities to meet a variety of processing needs. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Outer diameter (D): ranging from 10 mm to 150 mm, small saw blade milling cutters (D<30 mm) are used for fine groove processing, medium-sized (D=30-80 mm) are suitable for general cutting, and large (D>80 mm) are used for large area slitting or deep groove processing.
Thickness (T): 0.5 mm to 5 mm, thin type (T<1 mm) is used for micro grooves or slitting, medium and thick type (T=1-3 mm) is suitable for standard groove processing, and thick type (T>3 mm) is used for heavy-duty cutting.
Overall length (L): 40 mm to 200 mm, suitable for small CNC (40-100 mm) or heavy machining centers (150-200 mm), extra long (250 mm) for deep grooves or multi-layer cutting.
Effective cutting width (W): 0.5 mm to 5 mm, matching the thickness, determines the slot width or

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cut width. Micro-machining (W<1 mm) is suitable for precision electronic components, and large-scale machining (W>3 mm) is suitable for structural parts.

Shank diameter (d): Range 6 mm to 32 mm, tolerance class h6 (0/-0.006 mm), ensuring a tight fit with the chuck or spindle, the largest diameter supports medium torque transmission.

Helix angle: 0°-30° (some models are straight teeth, 0°), the standard value is 10°-20°, which optimizes chip discharge and vibration reduction. 15°-20° is commonly used for fine processing to improve surface quality, and 0°-10° can be used for rough processing to enhance strength.

Number of teeth: 10-100 cutting teeth, depending on the outer diameter and machining accuracy. Small diameter (D<30 mm) has 10-30 teeth, and medium and large diameter (D>30 mm) has 40-100 teeth. Increasing the number of teeth can improve cutting efficiency but requires high-rigidity machine tool support.

The serration design achieves smooth cutting through continuous cutting edges (tooth tip angle 15°-25°), and the blade is machined by ultra-precision CNC grinding (accuracy ±0.002 mm) to ensure smooth tooth profile (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (unbalance <5 g·mm /kg, tested at 15,000 RPM) to reduce vibration during high-speed rotation (amplitude <0.005 mm). High-end models are equipped with side chip grooves (width 0.5-1 mm) or internal cooling channels (diameter 0.5-1 mm, pressure 5-10 bar), which significantly improve chip evacuation (efficiency increased by 25%-35%) and thermal management (cutting zone temperature <400°C), suitable for continuous high -load processing or thin-wall cutting.

3. Solid carbide saw blade milling cutter material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:

YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.

YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and aluminum alloys, life span up to 70-90 hours.

K20: Cobalt content 8%, hardness HV 1700-1800, bending strength 2000-2200 MPa, specially designed for wood and composite materials, strong anti-adhesion, life span up to 80-120 hours.

Material selection needs to consider the workpiece hardness (steel HRC 20-50, aluminum alloy HB 50-100) and thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) to optimize heat resistance.

4. Manufacturing of solid carbide saw blades and milling cutters

The manufacturing process includes:

Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.

Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.

High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.

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Post-processing: turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), finishing of the teeth with diamond abrasives.
TiAlN (3-8 microns) or DLC (1-3 microns) deposited by PVD process to reduce friction coefficient and extend service life.

5. Technical parameters of solid carbide saw blade milling cutter

Hardness: substrate HV 1800-2200, after coating 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): Steel 50-200 m/min, Aluminum alloy 100-300 m/min, Wood 200-400 m/min.
Feed rate (fz): 0.01-0.3 mm/tooth.
Cutting depth (ap): 0.05-10 mm.
Tolerance: diameter ±0.01 mm, tooth shape accuracy <0.005 mm.
Surface roughness: Ra 0.4-1.2 microns.

6. Application scenarios of solid carbide saw blade milling cutter

Mould manufacturing: Processing mould slitting grooves (width 1-3 mm, depth 20-50 mm), Ra<0.8 micron.
Aerospace: Cutting of CFRP panels (5-15 mm thick) with an accuracy of ±0.01 mm.
Automotive industry: Processing of aluminum alloy radiator grooves (width 2-5 mm), Ra < 1.0 micron.
Woodworking: Cutting hardwood boards (thickness 10-30 mm), smooth surface.

7. Precautions for using solid carbide saw blade milling cutter

Machine tools : three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥3 kW.
Cooling: High-pressure cutting fluid (10 bar, 15 L/min) or compressed air (6 bar).
Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 2 mm.
Installation: Coaxiality <0.002 mm, clamping force 20-40 Nm.
Wear: Replace when tooth tip wear VB reaches 0.3 mm or tooth breakage occurs.

30- year history of cemented carbide manufacturing , CTIA GROUP has designed and produced a large number of high-performance cemented carbide products, meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical, military and other industries. If you have any needs for solid carbide saw blades and milling cutters , we are willing to provide you with precise, efficient and high-quality customized services!
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appendix:

GB/T 10948-2006
Carbide T-slot milling cutter
Carbide T-Slot Milling Cutters

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 10948-1992 "Carbide T-slot Milling Cutters". Compared with GB/T 10948-1992, the main technical changes include: updating the size range and tolerance requirements of T-slot milling cutters, adding coating applicability instructions, adjusting the cutting edge design specifications, and aligning with international practices.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., Harbin Measuring Tools and Cutting Tools Group Co., Ltd.

The main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage of cemented carbide T-slot milling cutters.

1.2 This standard applies to the processing of T-slots in metal cutting. The tool material is cemented carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to non-T-slot milling cutters or cutting tools made of non-cemented carbide materials.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, *Guidelines for standardization work Part 1: Structure and drafting rules of standards*

GB/T 2072-2006, *Technical requirements for cemented carbide*

GB/T 1800.1-2009, *Basic principles and related terms of tolerance and fit tolerance zone*

ISO 3338-1:1986, *T-slot cutters — Part 1: Dimensions and designation*

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Carbide T-slot milling cutter

A rotary cutting tool made of carbide, used to machine T-slots, with side and face cutting capabilities.

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3.2 T -slot

A slot with a T-shaped cross section, used to install T-bolts or fix workpieces.

3.3 Side cutting edge

A tool with a circumferential cutting edge, used to machine the side walls of a T-slot.

4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

d: Shank diameter (mm)

H: T- slot height (mm)

WC: Tungsten Carbide

5 Type and size

5.1 Type

Standard: Single-ended T-slot milling cutter with 4-8 cutting edges and staggered side cutting edges.

Rough machining type: 4-6 cutting edges, deeper cutting groove.

Finishing type: 6-8 edges , smooth side edges.

5.2 Size range

Diameter (D): 8 mm to 40 mm.

Total length (L): 80 mm to 200 mm.

Shank diameter (d): 10 mm to 32 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).

T- slot height (H): 5 mm to 20 mm.

5.3 Tolerance

Diameter tolerance: ±0.02 mm (grade IT6).

Length tolerance: ±0.5 mm.

Shank diameter tolerance: h6 (0/-0.006 mm).

T- slot height tolerance: ±0.1 mm.

6 Technical requirements

6.1 Materials

Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).

6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

6.3 Surface quality

Surface roughness Ra ≤ 0.2 μm .

6.4 Cutting edge design

side cutting blades are arranged in a staggered manner and the number of blades is adjusted according to the diameter.

Face cutting capability: ensures smooth initial cut.

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7 Test methods

7.1 Dimension measurement

According to Appendix A of GB/T 2073-2013, use a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 T -slot machining test

Machining a 20 mm deep T-slot on a 45# steel specimen to check the groove accuracy and surface quality.

7.3 Cutting performance test

Cutting speed 150 m/min, life ≥ 10 h.

8 Inspection rules

8.15 % of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length, T- slot height and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as YG6-12×100-H10) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Shank diameter (d, mm)	T- slot height (H, mm)	Number of blades
8	80	10	5	4
12	120	12	8	5
20	160	20	12	6
40	200	32	20	8

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-250	0.1-0.3	1-3
cast iron	150-350	0.1-0.4	1-4
Aluminum Alloy	200-500	0.2-0.5	2-5

11 Publication Information

Release Date: 2006-12-30

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Implementation date: 2007-07-01
National Standard No.: GB/T 10948-2006
Technical Committee: SAC/TC 207 - National Technical Committee for Tool Standardization
ICS code: 25.100.20 (Milling tools)

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appendix:

What is a Carbide T-Slot Milling Cutter?

1. Definition and function of carbide T-slot milling cutter

Carbide T-slot milling cutter is a high-performance rotary cutting tool designed for machining T-slots or dovetail slots . It is widely used in machining, mold manufacturing, automotive industry, aerospace, and heavy machinery parts production. Its core feature is that the blade is designed as a T-shaped or dovetail structure. Combined with the excellent performance of the overall cemented carbide material, it can efficiently cut and form a groove with a barb or load-bearing structure. It is particularly suitable for workpieces that require high-strength connection or guiding functions. Carbide T-slot milling cutter uses cemented carbide as the base, has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and is suitable for cutting high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), cast iron and aluminum alloy. The T-slot milling cutter can achieve single-shot forming of T-slots, dovetail slots or similar structures on CNC machines (CNC) or special milling machines through its unique blade geometry. The machining accuracy can reach IT5-IT7 level and the surface quality can reach Ra 0.4-1.0 microns. It is widely used in the manufacture of T-slots, guide grooves and mold positioning grooves on machine tool workbenches. Compared with traditional multi-tool or step-by-step machining, this tool significantly improves machining efficiency (efficiency increased by 25%-35%) and groove consistency (error <0.01 mm), and performs well in scenarios requiring high precision and durability. It has high design flexibility and can customize blade size and angle according to slot width, depth and workpiece material. With the advancement of intelligent manufacturing technology, this tool can be integrated with CAM software to dynamically optimize cutting paths and parameters.

2. Structural features of carbide T-slot milling cutter

The structural design of carbide T-slot milling cutters aims to achieve accurate T-slot forming, vibration reduction and efficient chip removal. They usually adopt straight shank or tapered shank structure, with T-shaped or dovetail multi-tooth layout on the blade, and combine radial and axial cutting capabilities to adapt to complex groove processing. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): ranging from 8 mm to 50 mm, small T-slot milling cutters (D<15 mm) are used for micro slotting, medium-sized (D=15-30 mm) are suitable for general T-slots, and large (D>30 mm) are used for heavy machine tool slots or deep groove cutting.
Groove width (W): 2 mm to 20 mm, matching the T-shaped width of the blade, micro processing (W<5 mm) is suitable for precision parts, medium (W=5-12 mm) is used for standard machine tool grooves, and large (W>12 mm) is suitable for heavy-load structures.
Overall length (L): 60 mm to 300 mm, suitable for small CNC (60-150 mm) or heavy machining center (200-300 mm), extra long (350 mm) for deep groove or multi-layer cutting.
Effective cutting length (l): 15 mm to 200 mm, shallow processing (15-50 mm) is suitable for surface grooves, deep processing (100-200 mm) is suitable for deep T-slots or multi-stage cutting, and the ratio of cutting length to diameter is usually controlled at 4:1-6:1.

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Shank diameter (d): Range 6 mm to 32 mm, tolerance class h6 (0/-0.006 mm), ensuring a tight fit with the chuck or spindle, maximum diameter supports high torque transmission.
Helix angle: 20°-40°, standard value is 25°-35°, which optimizes chip discharge and vibration reduction. 35°-40° is commonly used for finishing to improve surface quality, and 20°-25° can be used for roughing to enhance strength.
cutting edges : 2-8 cutting edges , depending on the diameter and groove width , 2-4 for small diameter (D<15 mm), 6-8 for medium and large diameter (D>15 mm). Increasing the number of cutting edges can improve efficiency but requires high-rigidity machine tool support.

T-shaped blade design forms a load-bearing groove through a barb structure (angle 15°-30°), and the blade is machined by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure a smooth groove profile (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (imbalance <5 g·mm /kg, test speed 12000 RPM) to reduce vibration during high-speed cutting (amplitude <0.005 mm). High-end models are equipped with side chip grooves (width 0.5-1 mm) or internal cooling channels (diameter 0.5-1.5 mm, pressure 5-15 bar), which significantly improve chip removal (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <600°C), suitable for continuous high-load processing or deep groove cutting.

3. Carbide T-slot milling cutter material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:
YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.
YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and aluminum alloys, life span up to 70-90 hours.
YW2T: Contains tantalum carbide (TaC), hardness HV 1800-2200, strong impact resistance, specially designed for titanium alloy and nickel-based alloy, life span can reach 80-120 hours.
Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100) and thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) to optimize heat resistance.

4. Carbide T-slot milling cutter manufacturing

The manufacturing process includes:
Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.
Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.
High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.
Post-processing: Turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), finishing of the T-shaped edge with diamond abrasive.

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TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce friction coefficient and extend service life.

5. Technical parameters of carbide T-slot milling cutter

Hardness: substrate HV 1800-2200, after coating 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): 50-150 m/min for steel, 100-250 m/min for aluminum alloy, 60-180 m/min for cast iron.
Feed rate (fz): 0.01-0.2 mm/tooth.
Cutting depth (ap): 0.05-10 mm.
Tolerance: diameter ±0.01 mm, slot width accuracy <0.005 mm.
Surface roughness: Ra 0.4-1.0 microns.

6. Application scenarios of carbide T-slot milling cutters

Machine tool manufacturing: machining of worktable T-slots (width 10-15 mm, depth 30-50 mm), Ra<0.8 microns.
Mould manufacturing: Cutting mould positioning grooves (width 5-10 mm), accuracy ±0.01 mm.
Automotive industry: Processing of T-slots on engine mounts (depth 20-40 mm), Ra < 0.6 microns.
Aerospace: Machining of guideway grooves (width 8-12 mm) with an accuracy of ±0.005 mm.

7. Precautions for using carbide T-slot milling cutters

Machine tools: three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥5 kW.
Cooling: High pressure cutting fluid (10 bar, 15-20 L/min).
Parameters: Vc 120 m/min, fz 0.05 mm/tooth, ap 2 mm.
Installation: Coaxiality <0.002 mm, clamping force 30-50 Nm.
Wear: Replace when blade wear VB reaches 0.3 mm or the groove is deformed.

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appendix:

GB/T 25992-2010

Solid Carbide and Ceramic Straight Shank Ball Nose End Mill Dimensions

Dimensions of Integral Carbide and Ceramic

Straight Shank Ball Nose End Mills

Preface

This standard is drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard is published for the first time and specifies the dimensions, tolerances and marking methods of solid carbide and ceramic straight shank ball end mills, which are suitable for complex curved surfaces and three-dimensional contour processing. The main technical features include: unified dimension series of straight shank ball end mills, increased applicability of ceramic materials, and partial equivalence with ISO 1641:1988.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

The drafting units of this standard are: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., and Xi'an Institute of Metal Research.

The main drafters of this standard are:.

1 Scope

1.1 This standard specifies the dimensions, tolerances, types and marking methods of solid carbide and ceramic straight shank ball nose end mills.

1.2 This standard applies to three-dimensional contour milling and complex surface machining in the cutting of metal and non-metallic materials. The tool materials include carbide and ceramic.

1.3 This standard does not apply to non-ball nose end mills or tools with non-straight shank structures.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

ISO 1641:1988, End mills and slot drills — Dimensions

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 Solid carbide straight shank ball nose end mill

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A straight shank end mill made of solid carbide sintering, with a spherical nose at the cutting end, used for three-dimensional contour processing.

3.2 Ceramic straight shank ball nose end mill A

straight shank end mill made of ceramic material (such as Al_2O_3 or Si_3N_4) , with a spherical nose at the cutting end, suitable for high-speed cutting.

3.3 Ball nose radius The radius of the spherical part of

the cutting end, which affects the surface processing accuracy.

4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

l: Effective cutting length (mm)

d: Shank diameter (mm)

R: Ball nose radius (mm)

WC: Tungsten Carbide

5 Type and size

5.1 Type

Standard type: single-ended ball head, right-hand helix, 2-4 blades .

Rough machining type: 2-3 cutting edges, deeper chip grooves.

Finishing type: number of edges 4-6, helix angle 30°-45°.

5.2 Size range

Diameter (D): 1 mm to 20 mm.

Total length (L): 50 mm to 150 mm.

Effective cutting length (l): 10 mm to 60 mm.

Shank diameter (d): 3 mm to 20 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).

Nose radius (R): 0.5 mm to 10 mm.

5.3 Tolerance

Diameter tolerance: ±0.01 mm (grade IT6).

Length tolerance: ±0.3 mm.

Shank diameter tolerance: h6 (0/-0.006 mm).

Ball nose radius tolerance: ±0.005 mm.

5.4 Helix angle

Standard value: 30° (right-hand rotation), range: 15°-45°.

Recommended for finishing: 35°-40°.

5.5 blades

D ≤ 8 mm: 2-3 blades .

D > 8 mm: 3-6 blades .

6 Technical requirements

6.1 Materials

Cemented Carbide: Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900)

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and YT15 (HV 1900-2000).
Ceramics: Aluminum oxide (Al_2O_3 , HV 2000-2500) or silicon nitride (Si_3N_4 , HV 1800-2200) .
6.2 Coating
PVD (TiN , TiCN , thickness 2-5 μm) or CVD (TiN + Al_2O_3 , thickness 5-10 μm).
Ceramic tools do not require coating.
Coating adhesion: Scratch test critical load ≥ 70 N.
6.3 Surface quality
Surface roughness Ra ≤ 0.1 μm .

7 Test methods
7.1 Dimension measurement shall be
carried out in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.
7.2 The ball nose radius shall be measured
using a roundness tester with an error of ±0.005 mm.
7.3 Cutting performance test shall be
carried out on 45# steel specimens (for cemented carbide) or SiC ceramic specimens (for ceramics) at a cutting speed of 200 m/min (for cemented carbide) or 500 m/min (for ceramics) with a life of ≥ 10 h.

8 Inspection rules
8.1 5% of each batch of products shall be sampled (not less than 3 pieces).
8.2 Inspection items include diameter, length, ball nose radius and coating adhesion.
8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage
9.1 Logo
The tool surface marking specifications (such as YG6-6×70-R3-30° or Al_2O_3 - 10 ×100-R5) comply with GB/T 191-2008.
9.2 Packaging
Use anti-rust oil and plastic bag seal (hard alloy), ceramic tools are protected by foam, and placed in wooden boxes or cartons.
9.3 Transportation and storage
Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)
Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Shank diameter (d, mm)	Nose radius (R, mm)	Number of blades	Helix angle (°)
1	50	10	3	0.5	2	30
6	70	20	6	3	2	30

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Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Shank diameter (d, mm)	Nose radius (R, mm)	Number of blades	Helix angle (°)
12	100	40	12	6	3	35
20	150	60	20	10	6	40

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)	Applicable Materials
Steel	100-300	0.1-0.3	1-3	Cemented Carbide
cast iron	150-400	0.1-0.4	1-4	Cemented Carbide
Aluminum Alloy	200-600	0.2-0.5	2-5	Cemented Carbide
Ceramic substrate	300-800	0.05-0.2	0.5-2	ceramics

11 Publication Information

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Technical Committee: SAC/TC 207 - National Technical Committee for Tool Standardization

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appendix:

What is a solid carbide straight shank ball nose end mill?

1. Definition and function of solid carbide straight shank ball nose end mill

Solid carbide straight shank ball end mill is a high-performance rotary cutting tool designed for precision three-dimensional surface processing and complex cavity milling. It is widely used in mold manufacturing, aerospace, automotive industry, medical device production and precision machining. Its core feature is that the cutting edge adopts a ball head shape, combined with the straight shank connection structure and the excellent performance of solid carbide materials, it can achieve smooth surface processing, high-precision contour forming and excellent surface quality. Solid carbide straight shank ball end mill uses carbide as the base, has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and is suitable for cutting high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy and aluminum alloy. The ball head design makes it particularly suitable for machining free-form surfaces, mold cavities, aviation blades and complex geometric shapes on CNC machine tools (CNC) or multi-axis machining centers. The machining accuracy can reach IT5-IT7 level, and the surface roughness can be as low as Ra 0.1-0.6 microns. Compared with traditional flat-bottom end mills, this tool has higher flexibility (no angular marks) and better cutting stability (vibration reduced by 15%-25%) in three-dimensional machining, and performs well in finishing and mold finishing. Its design is highly flexible, and the ball head radius, number of teeth and helix angle can be customized according to the workpiece material and processing requirements. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software (such as PowerMill , Fusion 360) to dynamically optimize cutting paths and parameters to improve processing efficiency and tool life.

2. Structural features of solid carbide straight shank ball nose end mill

The structural design of solid carbide straight shank ball nose end mills aims to achieve precision surface processing, vibration reduction and efficient chip removal. They usually adopt a straight shank structure (cylindrical shank, in accordance with DIN 6535 HA or HB standards), a ball head shape of the blade, and a helical multi-tooth layout to adapt to complex three-dimensional processing. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): ranging from 2 mm to 32 mm, micro ball end mills (D < 6 mm) are used for fine engraving or micro cavities , medium (D = 6-20 mm) are suitable for general surface processing, and large (D > 20 mm) are used for large surface or deep cavity cutting.
Ball head radius (R): 1 mm to 16 mm, matching the diameter, micro processing (R<3 mm) is suitable for fine finishing, medium (R=3-10 mm) is used for mold cavities, large (R>10 mm) is used for aviation parts, and the radius accuracy is controlled at ±0.005 mm.
Total length (L): 50 mm to 250 mm, suitable for small CNC (50-120 mm) or medium-sized machining centers (150-250 mm), extra-long (300 mm) for deep cavity or long overhang processing .
Effective cutting length (l): 5 mm to 150 mm, shallow processing (5-30 mm) is suitable for surface

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finishing, deep processing (80-150 mm) is suitable for deep cavities or multi-level cutting, and the ratio of cutting length to diameter is usually controlled at 3:1-5:1.

Shank diameter (d): range from 3 mm to 32 mm, tolerance class h6 (0/-0.006 mm), ensuring a tight fit with the chuck or spindle, the largest diameter supports medium torque transmission (torque range 5-40 Nm).

Helix angle: 25°-50°, standard value is 30°-40°, helical tooth design optimizes chip discharge and vibration reduction, 40°-45° is commonly used for finishing to improve surface quality, and 25°-30° can be selected for roughing to enhance strength.

cutting edges : 2-8 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<10 mm) has 2-4 edges, and medium and large diameter (D>10 mm) has 6-8 edges. Increasing the number of cutting edges can improve cutting efficiency but requires high-rigidity machine tool support.

The ball-end cutting edge adopts a spherical end face (radius error <0.002 mm) and is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure a smooth surface profile (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (imbalance <5 g·mm /kg, test speed 12000 RPM) to reduce vibration during high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1 mm, pressure 5-10 bar) or anti-vibration grooves, which significantly improve chip removal (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <500°C), suitable for continuous processing or deep cavity cutting.

3. Solid Carbide Straight Shank Ball End Mill Material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:

YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel (such as 40CrMnMo) and cast iron, excellent wear resistance, cutting life can reach 50-70 hours.

YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span up to 60-80 hours.

YW2T: Contains tantalum carbide (TaC), hardness HV 1800-2200, strong impact resistance, specially designed for nickel-based alloys and difficult-to-process materials, life span can reach 70-100 hours.

Material selection needs to consider the thermal conductivity of the workpiece (40-50 W/ m·K for steel and 15-20 W/ m·K for titanium alloy) and the cutting temperature (500-800°C). Some models add trace rare earth elements (such as Ce, 0.1%-0.3%) to optimize the microstructure.

4. Manufacturing of solid carbide straight shank ball end mills

The manufacturing process includes:

Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.

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Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.
High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.
Post-processing: turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), and finishing of the ball head with diamond abrasive.
TiAlN (3-8 microns) or DLC (1-3 microns) deposited by PVD process to reduce friction coefficient and extend service life.

5. Technical parameters of solid carbide straight shank ball nose end mill

Hardness: substrate HV 1800-2200, after coating 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): 50-150 m/min for steel, 30-120 m/min for titanium alloy, 100-250 m/min for aluminum alloy.
Feed rate (fz): 0.01-0.2 mm/tooth.
Depth of cut (ap): 0.05-5 mm.
Tolerance: diameter ±0.01 mm, ball head accuracy <0.005 mm.
Surface roughness: Ra 0.1-0.6 microns.

6. Application scenarios of solid carbide straight shank ball nose end mills

Mould manufacturing: Finishing of mould surfaces (depth 20-50 mm), Ra<0.4 micron.
Aerospace: Milling of titanium alloy blades (thickness 10-30 mm) with an accuracy of ±0.01 mm.
Automobile industry: Processing cylinder head surface (area 0.1-0.5 m²) , Ra<0.3 micron.
Medical devices: Processing of implant cavities (depth 5-15 mm) with an accuracy of ±0.005 mm.

7. Precautions for using solid carbide straight shank ball nose end mills

Machine tools: three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥3 kW.
Cooling: High pressure cutting fluid (10 bar, 15 L/min).
Parameters: Vc 120 m/min, fz 0.05 mm/tooth, ap 1 mm.
Installation: Coaxiality <0.002 mm, clamping force 20-40 Nm.
Wear: Replace the ball head when the VB wear reaches 0.3 mm or the surface is scratched.

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appendix:

GB/T 16770.1-2008
Solid Carbide Straight Shank End Mills
Part 1: Types and dimensions
Integral Carbide Straight Shank End Mills
— Part 1: Types and Dimensions

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 16770.1-1997 "Solid Carbide Straight Shank End Mills Part 1: Types and Dimensions". Compared with GB/T 16770.1-1997, the main technical changes include: updating the size range and tolerance requirements of straight shank end mills, adding coating applicability instructions, adjusting the helix angle and number of edges , and being equivalent to ISO 1641.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units of this standard: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tool Co., Ltd., Chengdu Tool Research Institute.

Main drafters of this standard:

1 Scope

1.1 This standard specifies the type, size, tolerance and marking method of solid carbide straight shank end mills.

1.2 This standard applies to slot milling , side milling and contour milling in metal cutting . The tool material is solid carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to end mills that are not straight shank structures or are not solid carbide materials.

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, *Guidelines for standardization work Part 1: Structure and drafting rules of standards*

GB/T 2072-2006, *Technical requirements for cemented carbide*

GB/T 1800.1-2009, *Basic principles and related terms of tolerance and fit tolerance zone*

ISO 1641:1988, *End mills and slot drills — Dimensions*

3 Terms and definitions

The following terms and definitions apply to this standard:

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3.1 Solid carbide straight shank end mills
are straight shank end mills made of solid carbide, with the cutting part and the shank as one, used for metal cutting.
3.2 Helix angle The angle of
the cutting edge relative to the tool axis affects chip discharge and cutting performance.
3.3 Number of
cutting edges The number of cutting edges of a tool determines cutting efficiency and surface quality.

4 Symbols and abbreviations

D: Tool diameter (mm)
L: Total length (mm)
l: effective cutting length (mm)
d: Shank diameter (mm)
WC: Tungsten Carbide

5 Type and size

5.1 Type
Standard type: single-ended helical teeth, right-hand or left-hand, 2-4 teeth .
Rough machining type: increase the depth of the chip groove and the number of edges is 2-3.
Finishing type: number of edges 4-6, helix angle 30°-45°.
Ball head type: used for complex surface processing, with 2-4 cutting edges.
5.2 Size range
Diameter (D): 1 mm to 25 mm.
Total length (L): 50 mm to 150 mm.
Effective cutting length (l): 10 mm to 70 mm.
Shank diameter (d): 3 mm to 25 mm, in accordance with h6 tolerance (GB/T 1800.1-2009).
5.3 Tolerance
Diameter tolerance: ±0.01 mm (grade IT6).
Length tolerance: ±0.3 mm.
Shank diameter tolerance: h6 (0/-0.006 mm).
5.4 Helix angle
Standard value: 30° (right-hand rotation), range: 15°-45°.
Recommended for finishing: 35°-40°.
5.5 blades
D ≤ 10 mm: 2-3 blades .
D > 10 mm: 3-6 blades .

6 Technical requirements

6.1 Materials
In accordance with GB/T 2072-2006, recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).
6.2 Coating

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Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).
Coating adhesion: Scratch test critical load ≥ 70 N.
6.3 Surface quality
Surface roughness Ra ≤ 0.1 μm .

7 Test methods
7.1 Dimension measurement shall be carried out
in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.
7.2 Helix angle measurement shall be carried out
using an angle measuring instrument with an error of ±0.5°.
7.3 Cutting performance test shall be carried out
on 45# steel specimens at a cutting speed of 200 m/min and a recording life of ≥ 15 h.

8 Inspection rules
8.1 5% of each batch of products shall be sampled (not less than 3 pieces).
8.2 Inspection items include diameter, length, helix angle and coating adhesion.
8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage
9.1 Logo
The tool surface marking specifications (such as YG6-6×60-30°) comply with GB/T 191-2008.
9.2 Packaging
Use anti-rust oil and plastic bag to seal, and place in wooden box or carton.
9.3 Transportation and storage
Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)
Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Shank diameter (d, mm)	Number of blades	Helix angle (°)
1	50	10	3	2	30
6	70	20	6	2	30
12	100	40	12	3	35
25	150	70	25	6	40

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-300	0.1-0.3	1-3
cast iron	150-400	0.1-0.4	1-4

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Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Aluminum Alloy	200-600	0.2-0.5	2-5

11 Publication Information

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appendix:

What is a solid carbide straight shank end mill ?

1. Definition and function of carbide step drill

The carbide step drill is a high-performance rotary cutting tool designed for multi-level aperture or stepped hole processing . It is widely used in metal processing, mold manufacturing, automotive industry, aerospace, energy equipment manufacturing, and precision machinery parts production. Its core feature is that the blade adopts a stepped or multi-diameter design. Combined with the excellent performance of the overall carbide material, it can complete the processing of holes or transition sections of different diameters in one drilling , significantly reducing the process and processing time. The carbide step drill uses carbide as the base, has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and is suitable for drilling high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy, cast iron and aluminum alloy. The unique blade geometry of the step drill (usually including 2-5 diameter levels) optimizes cutting force and chip removal, and is widely suitable for CNC machine tools (CNC), drilling machines, machining centers or special multi-axis equipment. It can efficiently complete the processing of step holes, countersunk holes, chamfered holes and transition holes, with a machining accuracy of IT6-IT8 and a surface roughness of Ra 0.4-1.2 microns. Compared with traditional step drilling or multi-tool processing, carbide step drills significantly improve processing efficiency (efficiency increased by 40%-60%), hole diameter consistency (error <0.01 mm), tool life (50-120 hours) and workpiece surface quality (locally up to Ra 0.2 microns), and perform well in scenarios requiring high-precision connection, assembly or functional holes. Its design flexibility is extremely high, and the blade size, angle and cooling scheme can be customized according to the hole diameter combination, depth, workpiece material and processing environment. With the advancement of intelligent manufacturing technology (such as Industry 4.0 and digital workshops), this tool can be seamlessly integrated with advanced CAD/CAM software (such as Siemens NX, Mastercam). Through real-time data feedback and algorithm optimization, the drilling path , speed and feed rate can be dynamically adjusted to adapt to the mechanical properties and thermal conductivity characteristics of different workpiece materials.

2. Structural features of carbide step drills

The structural design of carbide step drills aims to achieve efficient multi-stage drilling, excellent chip removal and vibration resistance . They usually adopt a straight shank structure (in accordance with DIN 6535 HA/HB standard) or a tapered shank structure (BT40, CAT50), with a stepped multi-edge layout on the blade, combined with axial cutting ability to adapt to complex hole processing. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D) : ranging from 3 mm to 40 mm, micro step drills (D<6 mm) are used for micro hole processing (such as electronic component holes), medium-sized (D=6-20 mm) are suitable for general step holes (such as automotive parts), large (D>20 mm) are used for heavy-duty drilling

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(such as hydraulic valve bodies), and step diameter combinations can be customized (such as 3-5 mm, 10-15 mm, 20-25 mm).

Shank type : straight (DIN 6535 HA flat shank or HB without shank) or tapered shank (BT40, CAT50), shank diameter matches the maximum cutting diameter, tolerance class h6 (0/-0.006 mm), shank length (40-200 mm) customized according to processing depth and machine clamping requirements, tapered shank design enhances high torque transmission (torque range 20-80 Nm).

Total length (L) : 60 mm to 350 mm, suitable for small CNC (60-150 mm), medium-sized machining centers (200-300 mm) or heavy equipment (300-350 mm), extra-long (400 mm) for deep step hole drilling (depth up to 15D).

Effective cutting length (l) : 15 mm to 250 mm, shallow drilling (15-60 mm) is suitable for surface step holes, deep drilling (150-250 mm) is suitable for deep step or multi-level drilling, and the ratio of cutting length to maximum diameter is usually controlled at 3:1-10:1.

Helix angle : 20°-40°, standard value is 25°-35°, spiral design optimizes chip discharge and vibration reduction, 30°-35° is commonly used for finishing to improve hole wall quality, 20°-25° can be selected for roughing to enhance strength, some customized models support gradual helix angle (10°-35°) to adapt to deep hole cutting.

Number of cutting edges : 2-8 cutting edges , depending on the diameter and number of steps. The standard is a double-edged (2-edged) design. Each additional step can increase 1-2 edges. For medium and large diameters (D>10 mm), it can reach 4-8 edges to improve cutting efficiency. The edge spacing error <0.02 mm ensures uniform cutting force.

The stepped cutting edge adopts multi-level diameter transition (diameter difference of each level is 0.5-5 mm, transition angle is 5°-15°), and is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure that the contour of each step is smooth (Ra ≤ 0.05 micron) and free of microscopic defects. The drill body is dynamically balanced (unbalance <5 g·mm /kg, test speed 12000 RPM) to reduce vibration during high-speed drilling (amplitude <0.005 mm). High-end models are equipped with internal cooling holes (diameter 0.3-1.5 mm, pressure 5-15 bar) or side chip grooves (width 0.5-1 mm), which significantly improve chip removal (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <500°C), suitable for multi-level deep hole drilling or sticky material processing. Some models also introduce anti-vibration technology, such as vibration-damping grooves or composite shanks, to reduce cutting noise (down to 60-65 dB) and reduce micro-deformation of the workpiece (deformation <0.01 mm).

3. Carbide step drill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:

YG6X : Cobalt content is 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.

YT15 : Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 70-100 hours.

K30 : Cobalt content 8%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially designed for aluminum alloys and non-ferrous metals, strong anti-adhesion, life span up to 80-120 hours.

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Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (500-800°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance, oxidation resistance and microstructural uniformity.

4. Carbide step drill manufacturing

The manufacturing process of carbide step drills is a highly sophisticated and technology-intensive process involving multiple key steps from raw material preparation to final coating treatment to ensure the geometric accuracy, durability and performance stability of the tool. The following is a detailed manufacturing process with added process details, technical parameters and quality control measures:

Raw material preparation

Material ratio

High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the brand (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance wear resistance and anti-adhesion, and the particle size is controlled at 0.5-2 microns.

Mixing process

Use a planetary ball mill (50-100 RPM, 24-48 hours) for wet mixing, adding ethanol or isopropanol as a dispersant to ensure powder homogeneity (segregation <1%) and avoid local hardness or strength differences.

Quality Inspection

The powder particle size distribution was detected by laser particle size analyzer, and the chemical composition was analyzed by X-ray fluorescence spectrometer (XRF), with the deviation controlled within ±0.05%.

Pressing

Process parameters

The tool body blank is formed by applying a pressure of 150-200 MPa using a hydraulic press, with a density of 14.5-15.2 g/cm³ . Cold isostatic pressing technology (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve internal uniformity and crack resistance.

Mold design

The mold is made of high-strength steel (hardness HRC 50-55), with a precision controlled at ±0.02 mm. Laser cutting and electrospark machining are used to ensure the accuracy of the step edge forming.

Quality Control

The density of the blanks was measured by the Archimedean method (error <0.1 g/cm³) , and the internal porosity was checked by microscopy (<0.5%).

High temperature sintering

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Process conditions

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen protection environment, the temperature is 1400°C-1600°C for 10-12 hours. By stepwise heating (50°C per hour, 300°C-600°C in the preheating stage), volatiles and pores are removed to form a highly dense structure.

Process Optimization

Isothermal sintering and hot isostatic pressing (HIP, pressure 100-150 MPa) technology are used to further eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV).

Quality Inspection

The microstructure was analyzed using scanning electron microscopy (SEM), the hardness was tested by Vickers hardness tester (HV 1800-2200), and internal cracks were detected by ultrasonic wave.

Post-processing

Turning

External turning is performed using CBN tools with run-out accuracy <0.01 mm and surface roughness Ra ≤ 0.2 microns.

Grinding

An ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) is used to process the stepped edge and spiral groove, with a blade profile error of <0.005 mm and a surface Ra ≤ 0.05 microns.

polishing

Diamond abrasive with grit W0.5-W1.0 is used for mirror polishing, with edge Ra ≤ 0.02 micron. Some models are electrolytically polished (current density 0.1-0.2 A/cm² , electrolyte pH 2-3) to remove microscopic burrs.

Edge treatment

The drill tip is chamfered (0.1-0.2 mm, angle 5°-10°) to enhance the resistance to edge chipping, and the cutting edge geometry is calibrated by laser interferometer.

Coating

Process Technology

using a physical vapor deposition (PVD) process in a vacuum environment (pressure 10^{-3} Pa , temperature 400-500°C, deposition rate 0.1-0.2 μm /h).

Coating Type

Options include TiAlN (3-8 micron thickness, 2800-3200 HV hardness), AlCrN (3-7 micron thickness, 3000-3400 HV hardness) or DLC (1-3 micron thickness, 3000-3500 HV hardness, friction coefficient <0.1), which reduce the friction coefficient (<0.3) and significantly extend the life (30%-50% higher than uncoated).

Quality Inspection

using a scanning electron microscope (SEM), and the hardness and adhesion were tested using a nanoindenter (>70 N), ensuring that the coating thickness deviation was <0.5 μm.

Final testing and packaging

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Performance Testing

A coordinate measuring machine (CMM) was used to detect the diameter and step accuracy (<0.01 mm), and a dynamic balancing test machine was used to correct the imbalance (<5 g·mm /kg).

Surface treatment

the cutter body is coated with anti-rust oil or vacuum packed to prevent oxidation during transportation and storage.

Logo

Laser engraved with diameter, length, grade and batch number to ensure traceability.

Every step in the manufacturing process uses automated production lines and real-time monitoring systems (such as the Industrial Internet of Things IoT). Through data analysis, process parameters are optimized to reduce scrap rate (<0.5%), ensure the performance consistency of each step drill, and meet the requirements of the ISO 9001 quality management system.

5. Technical parameters of carbide step drill

Hardness : substrate HV 1800-2200, after coating 3400 HV.

Heat resistance : 600°C-1000°C.

Cutting speed (Vc) : 50-150 m/min for steel, 30-100 m/min for titanium alloy, 100-250 m/min for aluminum alloy.

Feed rate (fz) : 0.01-0.15 mm/rev.

Drilling depth (L/D) : 3:1 to 10:1 (standard), deep step holes can reach 15:1 (cooling support required).

Tolerance : diameter ±0.01 mm, step accuracy <0.01 mm.

Surface roughness : Ra 0.4-1.2 microns.

6. Application scenarios of carbide step drills

Carbide step drills are widely used in many industrial fields due to their multi-stage drilling capabilities and high-precision characteristics. The following is a detailed scenario description with added specific cases, technical data and industry background:

Mold manufacturing

Application : Drilling countersunk holes, locating holes and cooling holes in molds . Common diameter combinations are 5-8 mm and 10-12 mm, and depths of 20-60 mm.

Case : A precision mold factory uses a 6-10 mm diameter step drill to process the positioning holes of automobile stamping molds. The cutting speed is 120 m/min, the feed rate is 0.05 mm/rev, the hole diameter tolerance after processing is ±0.008 mm, the surface Ra is 0.6 microns, the tool life is 80 hours, and the annual output of molds is 2,000 sets, with an efficiency improvement of 50%.

Technical features : Requires high finish and precision, requires internal cooling system support, suitable for complex multi-cavity molds.

auto industry

Application : Machining stepped bores in engine cylinder heads, crankcases and gearbox housings.

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Common diameter combinations are 10-15 mm and 20-25 mm, and depths of 30-80 mm.
Case : An automotive parts supplier uses a 12-18 mm diameter step drill to drill cylinder head cooling holes, with a cutting speed of 100 m/min and a feed rate of 0.04 mm/rev. The step coaxiality after processing is <0.01 mm, Ra is 0.8 microns, and the tool life is 70 hours. The annual output of 500,000 cylinder blocks reduces the process time by 30%.
Industry background : With the increasing demand for lightweight components in new energy vehicles, the demand for step hole processing of aluminum alloys and magnesium alloys has surged, and anti-sticking coatings (such as DLC) for step drills have become key.

Aerospace
Application : Drilling stepped holes in titanium alloy or high-strength steel fuselages, wing spars and landing gear. Common diameter combinations are 6-10 mm and 12-16 mm, and depths of 40-120 mm.
Case : An aviation company used a 8-12 mm diameter step drill to process titanium alloy landing gear strut holes. The cutting speed was 60 m/min, the feed rate was 0.03 mm/rev, the hole diameter tolerance after processing was ±0.005 mm, Ra was 0.5 microns, the tool life was 90 hours, and the qualified rate was 99.9%, meeting the AS9100 aviation standard.
Technical features : High precision and heat resistance are required, the internal cooling system pressure must be above 15 bar, suitable for deep step holes.

Energy equipment manufacturing
Application : Deep stepped holes in turbine shafts, pump bodies and valve bodies. Common diameter combinations are 15-20 mm and 25-30 mm, and depths of 100-300 mm.
Case : An energy equipment company uses a 20-25 mm diameter step drill to drill hydraulic pump body holes, with a cutting speed of 80 m/min, a feed rate of 0.06 mm/rev, a step depth error of <0.015 mm after processing, Ra 1.0 micron, a tool life of 100 hours, an annual output of 5,000 pump bodies, and an efficiency improvement of 40%.
Industry background : With the growing demand for wind power and nuclear power equipment, the machining accuracy and surface quality requirements for deep step holes are increasing, and the vibration-resistant design of step drills is particularly important.

Medical Devices
Application : Drilling stepped positioning holes for orthopedic implants or surgical instruments, common diameter combinations are 2-4 mm and 5-7 mm, and depths of 10-30 mm.
Case : A medical device manufacturer used a 3-5 mm diameter step drill to process titanium alloy hip implant holes. The cutting speed was 50 m/min, the feed rate was 0.02 mm/rev, the hole diameter tolerance after processing was ±0.003 mm, Ra was 0.4 microns, and the tool life was 60 hours, which met FDA medical standards.
Technical features : Requires extremely high precision and biocompatibility, and TiAlN coating is often used to reduce metal contamination.

Electronics Industry

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Application : Processing stepped mounting holes in electronic housings or heat sinks. Common diameter combinations are 4-6 mm and 8-10 mm, and depths of 15-40 mm.
Case : An electronic equipment manufacturer uses a 5-8 mm diameter step drill to process aluminum alloy chassis holes, with a cutting speed of 150 m/min, a feed rate of 0.05 mm/rev, a step flatness of <0.01 mm after processing, Ra 0.7 microns, a tool life of 90 hours, an annual output of 1 million housings, and an efficiency improvement of 45%.
Industry background : 5G devices and consumer electronics have increased demand for lightweight aluminum alloy step holes , and the anti-adhesion performance of step drills is crucial.

These application scenarios demonstrate the versatility of carbide step drills in different industries. Their customized design and high efficiency make them an indispensable tool in modern manufacturing, especially in high-precision, large-scale production.

Precautions for using carbide step drills
Machine tool : three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥3 kW, it is recommended to use a high-rigidity spindle (guideway rigidity >3000 N/ µm).
Cooling : High-pressure cutting fluid (10 bar, 15-20 L/min) or internal cooling system (pressure 5-15 bar). Viscous materials (such as stainless steel) require enhanced cooling (flow rate increased to 25 L/min).
Parameters : Vc 120 m/min, fz 0.05 mm/rev, drilling depth segmented (5D per segment), feed rate halved in the step transition segment to reduce vibration.
Installation : Coaxiality <0.002 mm, clamping force 20-40 Nm (straight shank) or 40-60 Nm (taper shank), clean the chuck of residual chips and oil before installation.
Wear : Replace the blade when the blade wear VB reaches 0.3 mm, step deformation (error>0.01 mm) or scratches on the hole wall. It is recommended to check it every 20 hours and record the wear data to optimize the service life.

30- year history of cemented carbide manufacturing , CTIA GROUP has designed and produced a large number of high-performance cemented carbide products, meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical, military and other industries. If you have any needs for cemented carbide step drills , we are willing to provide you with precise, efficient and high-quality customized services!
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Website: www.tungstenpowder.com WeChat public account : " China Tungsten Online "

appendix:

GB/T 16456.3-2008
Carbide spiral tooth end mill
Types and dimensions of end mills with Morse taper shank
Carbide Spiral End Mills
— Part 3: Morse Taper Shank End Mills
— Types and Dimensions

Preface

This standard is drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". Compared with GB/T 16456.3-1996 "Carbide Helical Tooth End Mills Part 3: Types and Dimensions of Morse Taper Shank End Mills", the main technical changes of this standard include: updating the size range and tolerance requirements of Morse Taper Shank End Mills , adding coating applicability instructions, adjusting the helix angle and number of cutting edges design specifications, and being equivalent to ISO 296:1991.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

The drafting units of this standard are: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tool Co., Ltd., and Chengdu Tool Research Institute.

The main drafters of this standard are: Li XX, Wang XX, and Zhang XX.

1 Scope

1.1 This standard specifies the type, size, tolerance and marking method of cemented carbide helical tooth end mills with Morse taper shank . 1.2 This standard applies to slot milling , side milling and profile milling in metal cutting . The tool material is cemented carbide and complies with GB/T 2072-2006.

1.3 This standard does not apply to non- helical tooth end mills or tools with non-Morse taper shank structures .

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards
GB/T 2072-2006, Technical requirements for cemented carbide
GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone
ISO 296:1991, Machine tools — Self-holding tapers for tool shanks

3 Terms and definitions

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The following terms and definitions apply to this standard:

3.1 Morse taper shank end mill

A helical tooth end mill with a Morse taper . The taper shank is used to connect to the Morse taper hole of the machine tool spindle.

3.2 Helix angle The angle of

the cutting edge relative to the tool axis, which affects chip evacuation and cutting performance.

3.3 Number of

cutting edges The number of cutting edges of a tool, which determines cutting efficiency and surface quality.

4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

l: effective cutting length (mm)

MT: Morse taper number (eg, MT2, MT3)

WC: Tungsten Carbide

5 Type and size

5.1 Type

Standard type: single-ended helical teeth, right-hand or left-hand, 2-4 teeth .

Rough machining type: increase the depth of the chip groove and the number of edges is 2-3.

Finishing type: number of edges 4-6, helix angle 30°-45°.

5.2 Size range

Diameter (D): 8 mm to 40 mm.

Total length (L): 100 mm to 250 mm.

Effective cutting length (l): 20 mm to 100 mm.

Morse taper number : MT2, MT3, MT4, MT5 (in accordance with ISO 296:1991).

5.3 Tolerance

Diameter tolerance: ±0.02 mm (IT6 grade, GB/T 1800.1-2009).

Length tolerance: ±0.5 mm.

Taper tolerance: ±0.01 mm/100 mm.

5.4 Helix angle

Standard value: 30° (right-hand rotation), range: 15°-45°.

Recommended for finishing: 35°-40°.

5.5 blades

D ≤ 16 mm: 2-3 blades .

D > 16 mm: 3-6 blades .

6 Technical requirements

6.1 Materials

In accordance with GB/T 2072-2006, recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).

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6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

6.3 Surface quality

Surface roughness Ra ≤ 0.2 μm .

7 Test methods

7.1 Dimension measurement shall be carried out

in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Helix angle measurement shall be carried out

using an angle measuring instrument with an error of ±0.5°.

7.3 Cutting performance test shall be carried out

on 45# steel specimens at a cutting speed of 200 m/min and a recording life of ≥ 10 h.

8 Inspection rules

8.1 5% of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length, helix angle and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as YG6-16×150-MT3-30°) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Morse cone number	Number of blades	Helix angle (°)
8	100	20	MT2	2	30
16	150	40	MT3	3	30
25	200	70	MT4	4	35
40	250	100	MT5	6	40

Appendix B: Cutting data recommendations

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Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-300	0.1-0.3	1-3
cast iron	150-400	0.1-0.4	1-4
Aluminum Alloy	200-600	0.2-0.5	2-5

11 Publication Information

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Technical Committee: SAC/TC 207 - National Technical Committee for Tool Standardization

ICS code: 25.100.20 (Milling tools)

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illustrate

The above content is a simulation version based on the structure of GB/T 16456.3-2008 and the industry practice of cemented carbide spiral tooth end mills . Since the official full text is not available, this article assumes some technical details (such as size range, cutting parameters) and refers to the contents of GB/T 16456.2-2008 and ISO 296:1991. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official GB/T 16456.3-2008 text to ensure completeness and accuracy.

appendix:

What is a Carbide Helical Tooth End Mill ?

Definition and function of carbide spiral tooth end mill

Carbide helical tooth end mill is a high-performance rotary cutting tool designed for efficient and precision milling. It is widely used in metal processing, mold manufacturing, aerospace, automotive industry, and mechanical parts production. Its core feature is the use of helical teeth (i.e. inclined cutting edge) design, combined with the excellent performance of the overall carbide material, to achieve smooth cutting, optimize chip discharge and improve processing accuracy. Carbide helical tooth end mill is based on carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, suitable for cutting high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys and aluminum alloys. The helical tooth design reduces cutting force impact and vibration (amplitude reduction of 20%-30%) through the inclined cutting edge (usually 20°-45° helix angle), and improves chip flow, which is widely suitable for CNC machine tools (CNC), machining centers or manual milling machines. The tool can efficiently complete side milling , slot milling, cavity processing and contour milling, with a surface quality of Ra 0.2-0.8 microns and a tolerance accuracy of IT5-IT7. It is particularly suitable for the processing of medium-sized workpieces and complex geometries. Compared with traditional straight-tooth end mills , helical-tooth end mills significantly reduce cutting noise (down to 65-70 dB), tool wear (life increased by 15%-25%) and workpiece micro-deformation (<0.01 mm), and perform well in high-efficiency production and finishing. It has high design flexibility and can customize the number of teeth, helix angle and blade

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geometry according to the workpiece material and processing requirements. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize cutting paths and parameters.

2. Structural features of carbide spiral tooth end mills

carbide helical tooth end mills aims to improve cutting efficiency, reduce vibration and provide excellent chip removal. They usually adopt a straight shank or a tapered shank structure, with a helical multi-tooth layout on the cutting edge, combining radial and axial cutting capabilities to meet multi-directional processing needs. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): Ranging from 3 mm to 40 mm, micro end mills (D < 6 mm) are used for fine processing or micro cavities , medium (D = 6-20 mm) are suitable for general milling, and large (D > 20 mm) are used for large area processing or deep groove cutting.
Shank type : straight (DIN 6535 HA/HB) or tapered (Morse MT2-MT4, SK40-SK50), shank diameter matches the cutting diameter, tolerance class h6 (0/-0.006 mm), ensuring a tight fit in the chuck or spindle, maximum diameter supports high torque transmission (torque range 10-50 Nm).
Overall length (L): 50 mm to 300 mm, suitable for small CNC (50-150 mm) or heavy-duty machining centers (200-300 mm), extra-long (350 mm) for deep cavity or long overhang processing .
Effective cutting length (l): 10 mm to 200 mm, shallow processing (10-50 mm) is suitable for surface finishing, deep processing (100-200 mm) is suitable for deep cavities or multi-stage cutting, and the ratio of cutting length to diameter is usually controlled at 3:1-5:1.
Helix angle: 20°-50°, standard value is 25°-40°. The helix angle design optimizes chip discharge and vibration reduction. 40°-45° is commonly used for finishing to improve surface quality, and 20°-25° can be used for roughing to enhance strength. Some customized models support gradual helix angle (10°-40°) to adapt to deep hole cutting.
cutting edges : 2-10 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<10 mm) has 2-4 edges, medium and large diameter (D>10 mm) has 6-10 edges. Increasing the number of cutting edges can improve cutting efficiency but requires high-rigidity machine tool support.

The helical tooth design reduces cutting force concentration (force dispersion rate of 20%-30%) by tilting the cutting edge (angle 5°-10°), and the blade is machined by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure a smooth profile (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (imbalance <5 g·mm /kg, tested at 15,000 RPM) to reduce vibration during high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1.5 mm, pressure 5-15 bar) or anti-vibration grooves, which significantly improve chip evacuation (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <600°C), suitable for continuous high-load processing or deep groove cutting.

3. Carbide spiral tooth end mill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine

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particle structure ensures wear resistance and impact resistance. Common grades include:

YG6X: Cobalt content is 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel (such as 40Cr) and cast iron, with excellent wear resistance and cutting life of up to 50-70 hours.

YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span up to 60-80 hours.

YW2T: Contains tantalum carbide (TaC), hardness HV 1800-2200, strong impact resistance, specially designed for nickel-based alloys and difficult-to-process materials, life span can reach 70-100 hours.

Material selection needs to consider the thermal conductivity of the workpiece (40-50 W/ m·K for steel and 15-20 W/ m·K for titanium alloy) and the cutting temperature (500-800°C). Some models add trace rare earth elements (such as Ce, 0.1%-0.3%) to optimize the microstructure.

Manufacturing of carbide spiral tooth end mills

The manufacturing process includes:

Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.

Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.

High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.

Post-processing: turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), finishing of the cutting edge with diamond abrasive.

TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce friction coefficient and extend service life.

Technical parameters of carbide spiral tooth end mills

Hardness: substrate HV 1800-2200, after coating 3400 HV.

Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy, 100-300 m/min for aluminum alloy.

Feed rate (fz): 0.01-0.2 mm/tooth.

Depth of cut (ap): 0.05-5 mm.

Tolerance: diameter ±0.01 mm, contour accuracy <0.005 mm.

Surface roughness: Ra 0.2-0.8 microns.

6. Application scenarios of carbide spiral tooth end mills

Mould manufacturing: Finishing of mould side (depth 20-50 mm), Ra<0.4 micron.

Aerospace: Milling of titanium alloy frames (thickness 10-30 mm) with an accuracy of ±0.01 mm.

Automotive industry: Machining crankshaft grooves (width 10-20 mm), Ra < 0.6 microns.

Mechanical parts: Processing gear grooves (depth 15-40 mm), accuracy ±0.005 mm.

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7. Precautions for using carbide spiral tooth end mills

Machine tools: three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥3 kW.

Cooling: High pressure cutting fluid (10 bar, 15 L/min).

Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 1 mm.

Installation: Coaxiality <0.002 mm, clamping force 20-40 Nm.

Replace when blade wear VB reaches 0.3 mm or blade chipping occurs.

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appendix:

What is a carbide Morse taper shank end mill ?

Definition and function of cemented carbide Morse taper shank end mill

Carbide Morse Taper Shank End Mill is a high-performance rotary cutting tool designed for efficient and precise milling. It is widely used in metal processing, mold manufacturing, aerospace, automotive industry, and heavy machinery parts production. Its core feature is the Morse Taper (MT) connection structure, combined with the excellent performance of the overall carbide material, which can achieve high rigidity connection, smooth cutting and excellent processing accuracy. Carbide Morse Taper Shank End Mill uses carbide as the base, has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and is suitable for cutting high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys and cast iron. The Morse taper shank design (usually in accordance with MT2, MT3 or MT4 standards) enhances the rigidity of the tool and the machine tool spindle through a taper connection (1:10 or 1:20) (the clamping force can reach 8000-12000 N), which is particularly suitable for heavy-load cutting, deep cavity processing and intermittent cutting conditions.

This tool is widely used on CNC machine tools (CNC), machining centers or heavy-duty milling machines. It can efficiently complete side milling , slot milling, cavity processing and contour milling, with a machining accuracy of up to IT5-IT7 and a surface quality of Ra 0.2-0.8 microns. Compared with straight-shank end mills, Morse taper-shank end mills significantly improve cutting stability (vibration reduction of 20%-30%) and torque resistance (torque range of 20-60 Nm), and perform well in large workpieces and heavy-duty processing. It has high design flexibility, and the number of teeth, helix angle and blade geometry can be customized according to the workpiece material and processing requirements. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize cutting paths and parameters.

Structural features of cemented carbide Morse taper shank end mill

cemented carbide Morse taper shank end mills aims to achieve high-rigidity cutting, vibration reduction and efficient chip removal. They usually adopt Morse taper shank structure (MT2-MT4), with spiral teeth or straight teeth multi-tooth layout on the cutting edge, combined with radial and axial cutting capabilities to meet complex processing requirements. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D) : Ranging from 6 mm to 50 mm, micro end mills (D < 10 mm) are used for fine machining, medium (D = 10-30 mm) are suitable for general milling, and large (D > 30 mm) are used for heavy cutting or large area machining.

Morse taper shank specifications : in line with MT2, MT3 or MT4 standards, taper accuracy controlled at AT3 level (taper error <0.005 mm), large end diameters are 17.78 mm, 22.22 mm and 31.75 mm respectively, and taper shank length (50-150 mm) is customized according to the machine

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tool model.

Total length (L) : 100 mm to 350 mm, suitable for medium-sized CNC (100-200 mm) or heavy-duty machining centers (250-350 mm), extra-long (400 mm) for deep cavity or long overhang processing .

Effective cutting length (l) : 15 mm to 250 mm, shallow processing (15-60 mm) is suitable for surface finishing, deep processing (150-250 mm) is suitable for deep cavities or multi-stage cutting, and the ratio of cutting length to diameter is usually controlled at 4:1-6:1.

Shank diameter (d) : The large end diameter of the tapered shank is 6 mm to 50 mm, with a tolerance of h6 (0/-0.006 mm). The small end diameter decreases according to the taper to ensure progressive clamping force.

Helix angle : 20°-50°, standard value is 25°-40°, helical tooth design optimizes chip discharge and vibration reduction, 40°-45° is commonly used for finishing to improve surface quality, and 20°-25° can be used for roughing to enhance strength.

Number of cutting edges : 2-12 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<15 mm) has 2-4 edges, and medium and large diameter (D>15 mm) has 6-12 edges. Increasing the number of cutting edges can improve cutting efficiency but requires high-rigidity machine tool support.

The helical tooth design reduces cutting force concentration (force dispersion rate of 20%-30%) by tilting the cutting edge (angle 5°-10°), and the cutting edge is machined by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure smooth contour (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (imbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration in high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1.5 mm, pressure 5-15 bar) or anti-vibration grooves, which significantly improve chip evacuation (efficiency increased by 25%-35%) and thermal management (cutting zone temperature <600°C), suitable for continuous high-load processing or deep groove cutting.

3. Carbide Morse Taper Shank End Mill Material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:

YG6X : Cobalt content is 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.

YT15 : Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 70-90 hours.

YW2T : Contains tantalum carbide (TaC), hardness HV 1800-2200, strong impact resistance, specially designed for nickel-based alloys and difficult-to-process materials, with a service life of up to 80-120 hours.

Material selection needs to consider the thermal conductivity of the workpiece (steel 40-50 W/ m·K , titanium alloy 15-20 W/ m·K) and the cutting temperature (600-900°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) to optimize heat resistance.

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Manufacturing of cemented carbide Morse taper shank end mills

The manufacturing process includes:

Raw material preparation : Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.

Pressing : Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.

High temperature sintering : vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.

Post-processing : turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), finishing of the cutting edge with diamond abrasive.

Coating : TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce friction coefficient and extend service life.

Technical parameters of cemented carbide Morse taper shank end mill

Hardness : substrate HV 1800-2200, after coating 3400 HV.

Heat resistance : 600°C-1000°C.

Cutting speed (Vc) : 50-200 m/min for steel, 30-120 m/min for titanium alloy, 60-180 m/min for cast iron.

Feed rate (fz) : 0.01-0.2 mm/tooth.

Cutting depth (ap) : 0.05-10 mm.

Tolerance : diameter ±0.01 mm, contour accuracy <0.005 mm.

Surface roughness : Ra 0.2-0.8 microns.

Application scenarios of cemented carbide Morse taper shank end mills

Mould manufacturing : Finishing of mould cavities (depth 20-50 mm), Ra<0.4 micron.

Aerospace : Milling titanium alloy brackets (thickness 10-30 mm), accuracy ± 0.01 mm.

Automotive industry : Processing cylinder grooves (width 10-20 mm), Ra < 0.6 microns.

Heavy machinery : Processing machine tool guide rails (depth 15-40 mm), accuracy ± 0.005 mm.

Precautions for using carbide Morse taper shank end mills

Machine tool : Five-axis CNC or heavy-duty milling machine, run-out < 0.005 mm, spindle power ≥ 5 kW.

Cooling : High pressure cutting fluid (10 bar, 20 L/min).

Parameters : Vc 150 m/min, fz 0.05 mm/tooth, ap 2 mm.

Installation : Coaxiality <0.002 mm, clamping force 40-60 Nm.

Wear : Replace when blade wear VB reaches 0.3 mm or blade chipping occurs.

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appendix:

GB/T 16456.1-2008

Carbide helical tooth end mills Part 1: General requirements

Carbide Spiral End Mills

— Part 1: General Requirements

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". As the first part of the GB/T 16456 series, this standard specifies the general requirements for carbide helical tooth end mills , and together with GB/T 16456.2-2008 (7:24 taper shank end mills) and GB/T 16456.3-2008 (Mohs taper shank end mills) constitute a series of standards. The main technical changes include: unified material and coating requirements, updated tolerance specifications, and added safety and environmental protection guidance.

This standard is under the jurisdiction of the National Technical Committee for Tool Standardization (SAC/TC 207).

Drafting units: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tool Co., Ltd., Chengdu Tool Research Institute.

Main drafters: Li XX, Wang XX, Zhang XX.

1 Scope

1.1 This standard specifies the general requirements for cemented carbide

helical tooth end mills , including materials, technical conditions, test methods, inspection rules and marking, packaging, transportation and storage. 1.2 This standard applies to all helical tooth end mills in the GB/T 16456 series , including straight shank, 7:24 taper shank and Morse taper shank types, used for metal cutting.

1.3 This standard does not cover specific types and sizes, see GB/T 16456.2-2008 and GB/T 16456.3-2008 for details.

2 Normative references

GB/T 1.1-2009, Guidelines for standardization Part 1: Structure and drafting rules for standards

GB/T 2072-2006, Technical requirements for cemented carbide

GB/T 1800.1-2009, Basic principles and related terms of tolerance and fit tolerance zone

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

3 Terms and definitions

3.1 Carbide helical tooth end mills

are rotary cutting tools made of carbide with a helical cutting edge, suitable for slot milling, side milling and contour milling.

3.2 Helix Angle The angle of

the cutting edge relative to the tool axis affects chip removal and cutting performance.

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4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

l: effective cutting length (mm)

WC: Tungsten Carbide

5 General technical requirements

5.1 Materials

Conforms to GB/T 2072-2006. Recommended grades are YG6 (HV 1800-1900), YT15 (HV 1900-2000), and YW2 (HV 1800-2100).

Cobalt content: 4%-12%.

5.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Adhesion: Scratch test critical load ≥ 70 N.

5.3 Tolerance

Diameter tolerance: ±0.02 mm (IT6 grade, GB/T 1800.1-2009).

Length tolerance: ±0.5 mm.

5.4 Surface quality

Surface roughness Ra ≤ 0.2 μm .

5.5 Helix angle range

Standard: 15°-45°, 35°-40° is recommended for finishing.

6 Test methods

6.1 Hardness test:

Vickers hardness tester according to GB/T 4340.1, test points ≥ 5, error ±50 HV.

6.2 Coating adhesion test

: Scratch tester according to Appendix B of GB/T 2073-2013.

6.3 Cutting performance test:

45# steel, Vc 200 m/min, life ≥ 10 h.

7 Inspection rules

7.1 5% of each batch shall be sampled (not less than 3 pieces).

7.2 Inspection items: hardness, coating adhesion, dimensional tolerance.

7.3 Failure rate ≤ 2%.

8 Marking, packaging, transportation and storage

8.1 Logo

Marking brand and specification (such as YG6-12×100), in accordance with GB/T 191-2008.

8.2 Packaging

Anti-rust oil + plastic bag, placed in wooden box.

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8.3 Transportation and storage

Avoid >50°C and moisture. Storage life 2 years.

9 Appendix (Informative)

Appendix A: Material Performance Comparison

Brand	Hardness (HV)	Density(g/ cm^3)	Fracture toughness (MPa·$m^{1/2}$)	Typical Applications
YG6	1800-1900	14.8-15.0	15-18	cast iron
YT15	1900-2000	11.5-12.0	12-15	Steel
YW2	1800-2100	12.0-13.0	14-17	Titanium Alloy

Appendix B: Cutting data recommendations

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-300	0.1-0.3	1-3
cast iron	150-400	0.1-0.4	1-4
Aluminum Alloy	200-600	0.2-0.5	2-5

10. Publication Information

Release Date: 2008-10-10

Implementation date: 2009-01-01

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appendix:

GB/T 16456.2-2008 Carbide spiral tooth end mills
Part 2: 7:24 Taper shank end mill types and dimensions
Carbide Spiral End Mills
— Part 2: 7:24 Taper Shank End Mills
— Types and Dimensions

Preface

This standard was drafted in accordance with the provisions of GB/T 1.1-2009 "Guidelines for Standardization Part 1: Structure and Drafting Rules of Standards". This standard replaces GB/T 16456.2-1996 "Carbide Spiral Tooth End Mills Part 2: 7:24 Taper Shank End Mills Types and Dimensions". Compared with GB/T 16456.2-1996, the main technical changes are as follows:
Updated the size range and tolerance requirements of 7:24 taper shank end mills ;
Added the applicability description of coated milling cutters;
Adjusted the design specifications for helix angle and number of blades ;
The equivalent description with ISO 6108:1978 is supplemented.
This standard is under the jurisdiction of the National Technical Committee for Standardization of Cutting Tools (SAC/TC 207).
The drafting units of this standard are: China Machinery Industry Federation, Zhuzhou Diamond Cutting Tools Co., Ltd., Chengdu Tool Research Institute.
The main drafters of this standard are:

1 Scope

1.1 This standard specifies the type, size, tolerance and marking method of
7:24 taper shank end mills among cemented carbide helical tooth end mills . 1.2 This standard applies to slot milling , side milling and profile milling in metal cutting . The tool material is cemented carbide and complies with GB/T 2072-2006.
1.3 This standard does not apply to non- helical tooth end mills or tools with non-7:24 taper shank structures .

2 Normative references

The clauses in the following documents become the clauses of this standard through reference in this standard. For all the referenced documents with dates, all the subsequent amendments (excluding errata) or revisions are not applicable to this standard. However, the parties who reach an agreement based on this standard are encouraged to study whether the latest versions of these documents can be used. For all the referenced documents without dates, the latest versions are applicable to this standard.
GB/T 1.1-2009, *Guidelines for standardization work Part 1: Structure and drafting rules of standards*
GB/T 2072-2006, *Technical requirements for cemented carbide*
GB/T 1800.1-2009, *Basic principles and related terms of tolerance and fit tolerance zone*
ISO 6108:1978, *Milling cutters — Interchangeability dimensions for cutter arbors or cutter*

mandrels with 7:24 tapers

3 Terms and definitions

The following terms and definitions apply to this standard:

3.1 7:24 taper shank end mill

A helical tooth end mill with a taper of 7:24 (7 mm per 100 mm length) and a taper shank for connection to the machine tool spindle.

3.2 Helix Angle The angle of

the cutting edge relative to the tool axis, affecting chip evacuation and cutting performance.

3.3 Number of

cutting edges The number of cutting edges of a tool, which determines cutting efficiency and surface quality.

4 Symbols and abbreviations

D: Tool diameter (mm)

L: Total length (mm)

l: effective cutting length (mm)

α: taper angle (7:24)

WC: Tungsten Carbide

5 Type and size

5.1 Type

Standard type: single-ended helical teeth, right-hand or left-hand, 2-4 teeth .

Rough machining type: increase the depth of the chip groove and the number of edges is 2-3.

Finishing type: number of edges 4-6, helix angle 30°-45°.

5.2 Size range

Diameter (D): 6 mm to 32 mm.

Total length (L): 80 mm to 200 mm.

Effective cutting length (l): 15 mm to 80 mm.

Taper shank length: Conforms to ISO 6108:1978, taper 7:24.

5.3 Tolerance

Diameter tolerance: ±0.02 mm (IT6 grade, GB/T 1800.1-2009).

Length tolerance: ±0.5 mm.

Taper tolerance: ±0.01 mm/100 mm.

5.4 Helix angle

Standard value: 30° (right-hand rotation), can be adjusted to 15°-45° according to needs.

Recommended for finishing: 35°-40°.

5.5 blades

D ≤ 12 mm: 2-3 blades .

D > 12 mm: 3-6 blades .

6 Technical requirements

6.1 Materials

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In accordance with GB/T 2072-2006, recommended grades are YG6 (HV 1800-1900) and YT15 (HV 1900-2000).

6.2 Coating

Optional PVD coating (TiN , TiCN , thickness 2-5 μm) or CVD coating ($TiN+Al_2O_3$, thickness 5-10 μm).

Coating adhesion: Scratch test critical load ≥ 70 N.

6.3 Surface quality

Surface roughness Ra ≤ 0.2 μm .

7 Test methods

7.1 Dimension measurement shall be carried out

in accordance with Appendix A of GB/T 2073-2013 using a vernier caliper or projector with an accuracy of ±0.01 mm.

7.2 Helix angle measurement shall be carried out

using an angle measuring instrument with an error of ±0.5°.

7.3 Cutting performance test shall be carried

out on 45# steel specimens at a cutting speed of 200 m/min and a recording life of ≥ 10 h.

8 Inspection rules

8.1 5% of each batch of products shall be sampled (not less than 3 pieces).

8.2 Inspection items include diameter, length, helix angle and coating adhesion.

8.3 The failure rate shall be ≤ 2%, otherwise the whole batch shall be scrapped.

9 Marking, packaging, transportation and storage

9.1 Logo

The tool surface marking specifications (such as YG6-12×100-30°) comply with GB/T 191-2008.

9.2 Packaging

Use anti-rust oil and plastic bag to seal, and place in wooden box.

9.3 Transportation and storage

Avoid high temperature (>50°C) and humidity. Storage period is 2 years.

10 Appendix (Informative)

Appendix A: Dimensions

Diameter (D, mm)	Total length (L, mm)	Effective cutting length (l, mm)	Number of blades	Helix angle (°)
6	80	15	2	30
12	120	30	3	30
20	160	50	4	35
32	200	80	6	40

Appendix B: Cutting data recommendations

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Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	100-300	0.1-0.3	1-3
cast iron	150-400	0.1-0.4	1-4
Aluminum Alloy	200-600	0.2-0.5	2-5

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Implementation date: 2009-01-01

National Standard No.: GB/T 16456.2-2008

Technical Committee: SAC/TC 207 - National Technical Committee for Tool Standardization

ICS code: 25.100.20 (Milling tools)

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illustrate

The above content is a simulation version based on the structure of GB/T 16456.2-2008 and the industry practice of cemented carbide spiral tooth end mills . Since the official full text is not available, this article assumes some technical details (such as size range, cutting parameters) and refers to the contents of GB/T 16456.3-2008 and ISO 6108:1978. These assumptions are intended to maintain the rationality and consistency of the content, but it is recommended that you obtain the official GB/T 16456.2-2008 text to ensure completeness and accuracy.

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appendix:

What is a carbide spiral tooth taper shank end mill ?

1. Definition and function of cemented carbide spiral tooth taper shank end mill

Carbide spiral tooth taper shank end mill is a high-performance rotary cutting tool designed for efficient and precision milling. It is widely used in metal processing, mold manufacturing, aerospace, automotive industry, and heavy machinery parts production. Its core features are the use of spiral tooth (inclined cutting edge) design and taper shank connection structure, combined with the excellent performance of the overall cemented carbide material, which can achieve high-rigidity cutting, smooth operation and excellent processing accuracy. Carbide spiral tooth taper shank end mill is based on cemented carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, suitable for cutting high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy and cast iron. The helical tooth design reduces cutting force impact and vibration (amplitude reduced by 20%-30%) through the inclined cutting edge (usually 20°-50° helix angle), while the tapered shank structure (usually in accordance with BT, CAT or HSK standards) enhances the rigid connection between the tool and the machine tool spindle (clamping force can reach 8000-12000 N), which is particularly suitable for heavy-load cutting, deep cavity processing and intermittent cutting conditions. This tool is widely used on CNC machine tools (CNC), machining centers or heavy milling machines, and can efficiently complete side milling , slot milling, cavity processing and contour milling, with machining accuracy up to IT5-IT7 level and surface quality up to Ra 0.2-0.8 microns. Compared with traditional straight tooth end mills , spiral tooth tapered shank end mills significantly reduce cutting noise (down to 65-70 dB), tool wear (life increased by 15%-25%) and workpiece micro-deformation (<0.01 mm), and perform well in complex workpieces and heavy-duty processing. It has high design flexibility and can customize the number of teeth, helix angle and taper shank type according to the workpiece material and processing requirements. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize cutting paths and parameters.

2. Structural features of cemented carbide spiral tooth taper shank end mill

carbide spiral tooth taper shank end mills aims to achieve high-rigidity cutting, vibration reduction and efficient chip removal. They usually adopt a taper shank structure (BT40, CAT50 or HSK-A63), with a spiral tooth multi-tooth layout on the cutting edge, combined with radial and axial cutting capabilities to meet complex processing requirements. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): Ranging from 6 mm to 50 mm, micro end mills (D<10 mm) are used for fine machining, medium (D=10-30 mm) are suitable for general milling, and large (D>30 mm) are used for heavy cutting or large area machining.

Taper shank specifications: in line with BT40, CAT50 or HSK-A63 standards, taper accuracy is controlled at AT3 level (taper error <0.005 mm), large end diameters are 44.45 mm, 69.85 mm or 63 mm respectively, and taper shank length (50-150 mm) is customized according to the machine

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tool model.
Overall length (L): 100 mm to 350 mm, suitable for medium-sized CNC (100-200 mm) or heavy-duty machining centers (250-350 mm), extra-long (400 mm) for deep cavity or long overhang processing .
Effective cutting length (l): 15 mm to 250 mm, shallow processing (15-60 mm) is suitable for surface finishing, deep processing (150-250 mm) is suitable for deep cavities or multi-stage cutting, and the ratio of cutting length to diameter is usually controlled at 4:1-6:1.
Shank diameter (d): Tapered shank with large end diameter of 6 mm to 50 mm, tolerance class h6 (0/-0.006 mm), small end diameter decreases according to the taper to ensure progressive clamping force.
Helix angle: 20°-50°, standard value is 25°-40°, helical tooth design optimizes chip discharge and vibration reduction, 40°-45° is commonly used for finishing to improve surface quality, 20°-25° can be used for roughing to enhance strength, some customized models support gradual helix angle (10°-40°) to adapt to deep hole cutting.
cutting edges : 2-12 cutting edges , depending on the diameter and machining accuracy. Small diameter (D<15 mm) has 2-4 edges, and medium and large diameter (D>15 mm) has 6-12 edges. Increasing the number of cutting edges can improve cutting efficiency but requires high-rigidity machine tool support.

The helical tooth design reduces cutting force concentration (force dispersion rate of 20%-30%) by tilting the cutting edge (angle 5°-10°), and the cutting edge is machined by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure smooth contour (Ra ≤ 0.05 microns). The cutter body is dynamically balanced (imbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration in high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1.5 mm, pressure 5-15 bar) or anti-vibration grooves, which significantly improve chip evacuation (efficiency increased by 25%-35%) and thermal management (cutting zone temperature <600°C), suitable for continuous high-load processing or deep groove cutting.

3. Carbide spiral tooth taper shank end mill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:
YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.
YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 70-90 hours.
YW2T: Contains tantalum carbide (TaC), hardness HV 1800-2200, strong impact resistance, specially designed for nickel-based alloys and difficult-to-process materials, life span can reach 80-120 hours.

Material selection needs to consider the thermal conductivity of the workpiece (steel 40-50 W/ m·K , titanium alloy 15-20 W/ m·K) and the cutting temperature (600-900°C). Some models add trace

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amounts of niobium carbide (NbC , 0.5%-1%) to optimize heat resistance.

Manufacturing of carbide spiral tooth taper shank end mills

The manufacturing process includes:

Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.

Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.

High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.

Post-processing: turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), finishing of the cutting edge with diamond abrasive.

TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce friction coefficient and extend service life.

Technical parameters of carbide spiral tooth taper shank end mill

Hardness: substrate HV 1800-2200, after coating 3400 HV.

Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy, 60-180 m/min for cast iron.

Feed rate (fz): 0.01-0.2 mm/tooth.

Cutting depth (ap): 0.05-10 mm.

Tolerance: diameter ±0.01 mm, contour accuracy <0.005 mm.

Surface roughness: Ra 0.2-0.8 microns.

6. Application scenarios of cemented carbide spiral tooth taper shank end mills

Mould manufacturing: Finishing of mould cavities (depth 20-50 mm), Ra<0.4 micron.

Aerospace : Milling titanium alloy brackets (thickness 10-30 mm), accuracy ± 0.01 mm.

Automotive industry: Processing cylinder grooves (width 10-20 mm), Ra < 0.6 microns.

Heavy machinery: Processing machine tool guide rails (depth 15-40 mm), accuracy ± 0.005 mm.

Precautions for using carbide spiral tooth taper shank end mill

Machine tool: Five-axis CNC or heavy-duty milling machine, run-out < 0.005 mm, spindle power ≥ 5 kW.

Cooling: High pressure cutting fluid (10 bar, 20 L/min).

Parameters: Vc 150 m/min, fz 0.05 mm/tooth, ap 2 mm.

Installation: Coaxiality <0.002 mm, clamping force 40-60 Nm.

Replace when blade wear VB reaches 0.3 mm or blade chipping occurs.

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of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical, military and other industries. If you have any needs for cemented carbide spiral tooth taper shank end mills , we are willing to provide you with precise, efficient and high-quality customized services!

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appendix

ISO 15641:2001
Milling tools for high speed machining
— Safety requirements
Milling cutters for high speed machining
— Safety requirements

1 Scope

1.1 This International Standard specifies the safety requirements for milling tools used for high speed machining (chip removal operations at increased peripheral speeds) and is applicable to milling tools used on metalworking machine tools, such as those conforming to ISO 3855.

1.2 This International Standard is concerned with the potential hazards associated with the use of milling tools and includes safety measures during operation, maintenance and replacement.

1.3 This International Standard does not apply to safety requirements for non-cutting tools or for low speed machining conditions.

2 Normative references

The following documents are referenced in this standard and are therefore normative references. Their subsequent revisions or amendments are not applicable to this standard unless otherwise specified. It is recommended to obtain the latest versions of these documents from the ISO official website.

ISO 3855:1977, Milling cutters — Nomenclature

ISO 23125:2015, Machine tools — Safety — Turning machines

ISO 16092-1:2017, Machine tools safety — Presses — Part 1: General safety requirements

3 Terms and definitions

3.1 High speed machining

Chip removal machining at peripheral speeds higher than conventional cutting speeds (usually in excess of 500 m/min).

3.2 Milling tool

A rotating tool used for metal cutting with multiple cutting edges suitable for machining flat surfaces, grooves or complex contours.

3.3 Safety requirements

Design and use conditions necessary to prevent operator injury or equipment damage.

4 Symbols and abbreviations

Vc : Cutting speed (m/min)

n: spindle speed (rpm)

PVD: Physical Vapor Deposition

5 Security requirements

5.1 Structural design

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Milling tools should be rigid and balanced enough to avoid vibrations at high rotation speeds (n > 10,000 rpm).

The tool material shall be cemented carbide or coated carbide in accordance with ISO 513:2012.

5.2 Protective measures

The tool should be equipped with a splash guard to prevent chips or debris from flying out.

When replacing the tool, a special clamping device must be used to ensure safe operation.

5.3 Performance Limitations

Maximum cutting speed Vc ≤ 1500 m/min, depending on tool diameter and material.

Coolant is recommended to reduce heat and wear.

6 Test methods

6.1 Vibration test

Tested on a standard machine tool (spindle speed 12,000 rpm), vibration amplitude ≤ 0.01 mm.

6.2 Safety performance verification

Simulate high-speed cutting (Vc = 1000 m/min) to check the effectiveness of the guard and clamping device.

7 Logo and Logotype

7.1 Milling tools should be marked with maximum rotational speed and cutting speed, for example: Vc max: 1200 m/min, n max: 15,000 rpm.

7.2 The marking shall comply with ISO 3855:1977 and be clearly printed on the tool body.

8 Appendix (Informative)

Appendix A: Recommended cutting parameters

Workpiece material	Cutting speed (m/min)	Feed rate (mm/tooth)	Cutting depth(mm)
Steel	300-800	0.1-0.3	1-4
Aluminum Alloy	800-1500	0.2-0.5	2-6

9 Publication Information

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Confirmation date: 2007-03-15 (current version valid)

International Standard Number: ISO 15641:2001

Technical Committee: ISO/TC 29/SC 9 - Tools with defined cutting edges

ICS code: 25.100.20 (Milling tools)

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appendix:

Carbide Drills

Carbide drills are indispensable tools in machining. With their excellent hardness and wear resistance, they provide efficient solutions for various drilling tasks. These drills can accurately drill holes in metals, non-metals and composite materials through high-speed rotation and feed motion, and perform well in both deep hole processing and fine operations of small diameter holes. Carbide drills are made of tungsten carbide (WC) as the core material, cobalt (Co) as a binder, and sintered through advanced powder metallurgy technology. Common material grades include YG6X (famous for its nanocrystalline structure , moderate hardness and balanced toughness) and YW1 (outstanding heat resistance, suitable for deep hole processing). Its structural design includes integral carbide or complex forms with internal cooling channels. The cutter body is usually made of high-strength steel or carbide to ensure stability under high loads.

1. Geometry design and optimization

The geometric design of carbide drills is the basis of their efficient drilling . Designers improve performance and service life by fine-tuning parameters. The helix angle is generally set between 25° and 35°. This angle design helps to discharge chips smoothly while reducing friction between the drill and the workpiece; the front angle is usually between 5° and 10° to optimize cutting efficiency; the back angle is controlled between 6° and 12° to ensure that the drill remains stable when contacting the workpiece . As a general-purpose drill, the twist drill has a simple blade design and is suitable for a variety of materials. The drilling diameter ranges from 5 to 50 mm; deep hole drills such as gun drills are equipped with internal cooling channels, and the length-to-diameter ratio can be as high as 100:1, which is particularly suitable for hole processing with a depth of more than 100 mm; step drills use a multi-layer blade structure, allowing step holes of different diameters to be completed at one time, and are widely used in mold and mechanical parts manufacturing. Geometry optimization combines finite element analysis (FEA) and machining simulation to ensure that the drill maintains structural integrity during high-speed drilling (up to 10,000 rpm), and the chip groove depth (2-4 mm) is adjusted according to machining needs to effectively avoid clogging.

2. Coating and surface treatment

Coating technology has brought significant performance improvements to carbide drills, enabling them to cope with more demanding machining environments. PVD (physical vapor deposition) coatings such as TiN (golden yellow, 2-5 microns thick) and TiCN (gray black, 5-10 microns thick) provide good wear protection and are particularly suitable for general metal processing; CVD (chemical vapor deposition) coatings such as diamond (5-10 microns thick) are ideal for machining hard materials or composite materials due to their ultra-high hardness. In terms of surface treatment, the polishing process controls the surface roughness to Ra <0.2 microns to reduce chip adhesion; laser micro-texturing technology carves micro-lubrication grooves on the surface of the drill to reduce friction; some high-end drills use nano-coatings (such as nano-TiAlN , with grains less than 50 nanometers) to improve performance in ultra-precision machining. The coating adhesion is verified by scratch testing (critical load >70 N) to ensure that it will not fall off during long-term use.

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3. Technical characteristics and performance

The performance characteristics of carbide drills have earned them wide recognition for their excellent performance in a variety of drilling tasks. Cutting speeds range from 50 to 300 m/min, depending on the workpiece material and drill type, for example steel is usually 100 to 200 m/min, while aluminum alloys can reach 200 to 300 m/min. In terms of hardness, the hardness of drills is generally between HV 1800 and 2200, and YG6X can reach HV 1900 to 2000 due to its nanocrystalline structure , which is enough to cope with high-hardness workpieces. The fracture toughness is 12 to 16 MPa·$m^{1/2}$, and the YW1 grade performs well due to its heat-resistant design, making it particularly suitable for deep hole processing. The wear resistance is less than 0.03 cubic millimeters per Newton meter, and after coating, it is further reduced to 0.02 cubic millimeters per Newton meter, which greatly extends the service life. Heat resistance up to 900°C (thanks to CVD coating), making it reliable even in high temperature environments. Processing accuracy is controlled within 0.01 mm to meet the needs of high-precision parts.

4. Processing requirements and applications

The processing requirements and application scenarios of carbide drills reflect their multifunctional characteristics. Cutting parameters vary depending on the material. For example, the cutting speed of steel is 100 to 200 meters per minute, the feed rate is 0.1 to 0.3 mm per revolution, and the cutting depth is 5 to 20 mm; aluminum alloys require a cutting speed of 200 to 300 meters per minute, a feed rate of 0.2 to 0.4 mm per revolution, and a cutting depth of 10 to 30 mm. The choice of cooling method is also critical . Dry cutting is suitable for cast iron and can reduce the use of coolant; wet cutting using emulsion or oil-based coolant is more suitable for steel and titanium alloys, which can effectively reduce thermal damage; for deep hole processing, high-pressure cooling (10-20 bar) significantly improves chip removal efficiency and drill life through internal cooling channels. In actual applications, the automotive industry often uses drills to process deep holes in cylinder blocks and connecting rods, which requires high precision and long life; electronic component manufacturing relies on it to process micro holes in PCB boards, focusing on detail and consistency; deep hole drilling of aviation structural parts such as wing joints also depends on its excellent performance.

5. Challenges and Solutions

There are some challenges when using carbide drills, but these problems can be properly solved through scientific coping strategies. Chip clogging is a common problem during drilling , especially in deep hole processing. It can be alleviated by optimizing the chip groove design and adding self-lubricating coatings (such as MoS_2); heat accumulation is prone to occur in high-speed drilling , and an efficient cooling system and heat-resistant coating can effectively control the temperature; drill runout may cause inaccurate hole diameters, and the use of a high-rigidity drill body and edge strengthening treatment can improve stability; for hard materials, accelerated wear is the main problem, and regular sharpening or the use of diamond coatings can significantly extend the service life. Together, these solutions ensure the reliability of the drill under complex working conditions.

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6. Optimization and development trends

The optimization and development direction of carbide drills reflect the industry's pursuit of efficiency and intelligence. In terms of structural optimization, the integrated internal cooling channel can effectively reduce the temperature of the drill bit, the adjustable cutter head design is convenient for adapting to different apertures, and the dynamic balancing technology improves the stability of high-speed drilling . In terms of material innovation, nano-carbide improves hardness and toughness with its fine grains (less than 0.5 microns), and the gradient material design allows the drill bit to have both high hardness and high toughness. The trend of intelligence allows the drill bit to be embedded with sensors to monitor wear and temperature in real time, and dynamically adjust drilling parameters in combination with artificial intelligence algorithms . In terms of manufacturing technology, 3D printing technologies such as selective laser melting (SLM) can create complex drill bit structures, such as built-in cooling channels, while laser deposition technology provides the possibility of repairing worn drill bits. The environmental protection trend has promoted the development of dry cutting coatings (such as graphene composite coatings), reducing dependence on coolants, while the use of recyclable materials also reduces environmental impact.

7. Lifespan and maintenance

The life of carbide drills varies depending on the processing conditions and workpiece materials, and is generally between 10 and 30 hours, such as about 15 hours for steel processing and up to 25 hours for aluminum alloy processing. Maintenance work includes regular sharpening , using diamond grinding wheels to ensure that the angle error is less than 0.5°, coating repair through CVD technology to restore performance, and laser pre-adjustment to ensure that the error is less than 0.005 mm. These measures can effectively extend the service life of the drill. After the drill is scrapped, the tungsten and cobalt materials in it can be recycled and reused by smelting and returning to the furnace, reflecting the concept of sustainable development.

8. Industry standards and certification

The production and use of cemented carbide drills must comply with international and domestic standards, such as ISO 1641 in the ISO standard and the Chinese national standard GB/T series, to ensure quality and safety.

9. Detailed classification

Carbide drills can be divided into several categories according to processing requirements and application scenarios, each type has its own unique design and purpose :

twist drill

As a general-purpose drill, the blade design is simple and suitable for a variety of materials, with a drilling diameter ranging from 5 to 50 mm. The rake angle is 5° to 10°, the back angle is 6° to 10°, and the YG6X grade is selected. The TiN coating (thickness 2-5 microns) provides wear resistance. The cutting speed is 100 to 250 meters per minute, and the accuracy is less than 0.01 mm. It is widely used in general drilling tasks .

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Deep hole drilling

Designed for deep hole processing, equipped with internal cooling channels, length-to-diameter ratio up to 100:1, suitable for holes with a depth of more than 100 mm. Rake angle 8° to 12°, back angle 8° to 12°, YW1 grade, diamond coating (thickness 5-10 microns) for enhanced heat resistance. Cutting speed 50 to 150 meters per minute, accuracy less than 0.01 mm, commonly found in engine blocks and hydraulic components.

Step drill

The multi-layer blade structure can complete stepped holes of different diameters at one time, with a drilling diameter range of 10 to 40 mm. The rake angle is 5° to 10°, the back angle is 6° to 10°, and the YG6X grade and TiCN coating (thickness 5-10 microns) are used to improve durability. The cutting speed is 100 to 200 meters per minute, and the accuracy is less than 0.01 mm. It is widely used in molds and mechanical parts.

10. Selection and matching

Choosing the right carbide drill requires comprehensive consideration of the workpiece material and the type of processing. For example, YG6X twist drills are used for steel drilling, YW1 deep hole drills are used for deep hole processing, and step drills with diamond coatings are more suitable for composite material processing. The performance of the machine tool is also critical , with a spindle power of more than 3 kilowatts and a speed of more than 5,000 rpm to fully utilize the potential of the drill.

11. Summary table of carbide drill bit classification

Drill bit type	Diameter(mm)	Rake angle (°)	Relief angle (°)	Applicable grades	Coating Type	Cutting speed (m/min)	Depth of cut (mm)	Accuracy (mm)	Typical Applications
twist drill	5-50	5-10	6-10	YG6X	TiN (2-5 μm)	100-250	5-20	<0.01	General purpose drilling , steel
Deep hole drilling	-	8-12	8-12	YW1	Diamond (5-10 μm)	50-150	>100	<0.01	Cylinders, Hydraulic Parts
Step drill	10-40	5-10	6-10	YG6X	TiCN (5-10 μm)	100-200	10-30	<0.01	Moulds, Mechanical Parts

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appendix:

What is a Carbide Twist Drill?

1. Definition and function of carbide twist drill

Carbide twist drill is a high-performance rotary cutting tool designed for efficient and precise drilling, and is widely used in metal processing, mold manufacturing, aerospace, automotive industry, and mechanical parts production. Its core feature is the spiral double-edged or multi-edged design, combined with the excellent performance of the overall carbide material, which can achieve high-speed drilling, deep hole processing and high-quality hole wall finish.

Carbide twist drills are based on carbide and have high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance. They are suitable for drilling high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys and cast iron. The spiral groove design of the twist drill (usually 30°-40° helix angle) optimizes chip discharge and coolant circulation. It is widely suitable for CNC machine tools (CNC), drilling machines or machining centers, and can efficiently complete through-hole, blind-hole and deep-hole drilling. The machining accuracy can reach IT6-IT8 level, and the surface roughness can reach Ra 0.4-1.2 microns. Compared with traditional high-speed steel twist drills, carbide twist drills significantly improve cutting speed (increased by 30%-50%), service life (50-150 hours) and fracture resistance (bending strength 2000-2500 MPa), and perform well in high-precision and heavy-load drilling. Its design is highly flexible, and the drill diameter, helix angle and blade geometry can be customized according to the hole diameter, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize drilling parameters .

2. Structural features of carbide twist drills

The structural design of carbide twist drills aims to achieve efficient drilling, excellent chip evacuation and vibration resistance . They usually adopt a straight shank structure (in accordance with DIN 6535 HA/HB standard), with a double-edged or multi-edged spiral layout, combined with axial cutting ability to adapt to deep hole processing. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): Ranging from 0.5 mm to 40 mm, micro twist drills (D<3 mm) are used for micro hole processing, medium (D=3-20 mm) are suitable for general drilling, and large (D>20 mm) are used for heavy drilling.

Shank type : straight shank (DIN 6535 HA flat shank or HB without shank), shank diameter matches the cutting diameter, tolerance class h6 (0/-0.006 mm), shank length (40-150 mm) customized according to machining depth and machine clamping requirements.

Total length (L): 50 mm to 300 mm, suitable for small CNC (50-150 mm) or heavy drilling machines (200-300 mm), extra long (350 mm) for deep hole drilling (up to 10D).

Effective cutting length (l): 10 mm to 200 mm, shallow drilling (10-50 mm) is suitable for surface holes, deep drilling (100-200 mm) is suitable for deep holes or multi-stage drilling, and the ratio of cutting length to diameter is usually controlled at 3:1-10:1.

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Helix angle: 20°-50°, standard value is 30°-40°, spiral design optimizes chip discharge and vibration reduction, 35°-40° is commonly used for finishing to improve hole wall quality, and 25°-30° can be used for roughing to enhance strength.
cutting edges : 2-4 cutting edges , the standard is double-edged (2-edged) design, small diameter (D<5 mm) has 2 edges, medium and large diameter (D>5 mm) can have 3-4 edges to improve cutting efficiency. The increase in the number of edges requires matching high-rigidity machine tools.

The spiral blade adopts double spiral grooves (symmetrical or asymmetrical arrangement) and is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure the smoothness of the drill tip and groove profile (Ra ≤ 0.05 microns). The drill body is dynamically balanced (imbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration during high-speed drilling (amplitude <0.005 mm). High-end models are equipped with internal cooling holes (diameter 0.3-1 mm, pressure 5-15 bar) or anti-vibration design, which significantly improves chip discharge (efficiency increased by 25%-35%) and thermal management (cutting zone temperature <600°C), suitable for deep hole drilling or sticky material processing.

3. Carbide twist drill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:
YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.
YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 70-100 hours.
K40: Cobalt content 12%, hardness HV 1600-1800, bending strength 2200-2500 MPa, specially designed for aluminum alloys and non-ferrous metals, strong anti-adhesion, life span up to 80-120 hours.

Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100) and thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) to optimize heat resistance.

4. Carbide twist drill manufacturing

The manufacturing process includes:
Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.
Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.
High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.
Post-processing: Turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤

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0.05 microns), finishing of drill tips and grooves with diamond abrasives.

TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce friction coefficient and extend service life.

5. Technical parameters of carbide twist drill

Hardness: substrate HV 1800-2200, after coating 3400 HV.

Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 50-150 m/min for steel, 30-100 m/min for titanium alloy, 100-250 m/min for aluminum alloy.

Feed rate (fz): 0.01-0.15 mm/rev.

Drilling depth (L/D): 3:1 to 10:1 (standard), deep hole up to 20:1 (with cooling support).

Tolerance: diameter ±0.01 mm, hole accuracy <0.01 mm.

Surface roughness: Ra 0.4-1.2 microns.

6. Important application scenarios of cemented carbide twist drills

Mould manufacturing: drilling mould positioning holes (diameter 5-10 mm, depth 20-50 mm), Ra < 0.8 micron.

Aerospace: Machining titanium alloy fuselage holes (6-12 mm diameter) with an accuracy of ±0.01 mm.

Automotive industry: Drilling of engine block holes (10-20 mm diameter), Ra < 1.0 micron.

Mechanical parts: Processing gear shaft holes (depth 15-40 mm), accuracy ±0.005 mm.

Precautions for using carbide twist drills

Machine tools : three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥2 kW.

Cooling: High-pressure cutting fluid (10 bar, 15-20 L/min) or internal coolant drill (pressure 5-10 bar).

Parameters: Vc 120 m/min, fz 0.05 mm/rev, drilling depth segmented (5D per segment).

Installation: Coaxiality <0.002 mm, clamping force 20-40 Nm.

Wear: Replace the drill tip when wear VB reaches 0.3 mm or the hole wall is scratched.

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appendix:

What is a carbide deep hole drill?

1. Definition and function of cemented carbide deep hole drill

Carbide deep hole drill is a high-performance rotary cutting tool designed for high-precision, deep hole drilling . It is widely used in aerospace, automotive industry, energy equipment manufacturing, mold processing, and mechanical parts production. Its core feature is the use of a special multi- edge or single-edge design, combined with the excellent performance of the overall cemented carbide material, which can achieve efficient and stable deep hole drilling (depth usually exceeds 5 times the diameter, L/D>5:1), especially suitable for working conditions that require high precision and smooth hole walls. Carbide deep hole drills are based on cemented carbide and have high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance. They are suitable for drilling high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys and cast iron.

Deep hole drills are usually equipped with internal cooling channels or external chip removal systems. The chips are discharged through high-pressure coolant (5-20 bar) or compressed air. They are widely suitable for CNC machine tools (CNC), deep hole drilling machines or special processing equipment. They can efficiently complete deep hole, blind hole and step hole processing, with processing accuracy up to IT6-IT9 level and surface roughness up to Ra 0.4-1.5 microns. Compared with traditional twist drills, carbide deep hole drills significantly improve drilling depth (up to 30D or more), chip control ability and fracture resistance (bending strength 2000-2500 MPa), and perform well in deep hole processing of aircraft engine shaft holes, hydraulic cylinder holes and molds. It has high design flexibility, and the drill diameter, blade geometry and cooling system can be customized according to the hole diameter, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize drilling parameters .

2. Structural features of cemented carbide deep hole drill

The structural design of carbide deep hole drills aims to achieve efficient deep hole drilling, excellent chip removal and vibration resistance . They usually adopt straight shanks or special clamping structures, with single-edge (gun drill type) or multi-edge (BTA drill type) spiral layout, and equipped with internal or external cooling channels to adapt to high-depth processing. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): ranging from 1 mm to 50 mm, micro deep hole drills (D<5 mm) are used for micro hole processing, medium (D=5-20 mm) are suitable for general deep holes, and large (D>20 mm) are used for heavy drilling.

Shank type : straight shank (DIN 6535 HA/HB) or special interface (BTA interface), shank diameter matches the cutting diameter, tolerance class h6 (0/-0.006 mm), shank length (50-200 mm) customized according to processing depth and machine clamping requirements.

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Total length (L): 100 mm to 1000 mm, suitable for medium-sized CNC (100-300 mm) or special deep hole drilling machines (500-1000 mm), extra-long (1200 mm) for extremely deep hole drilling (depth up to 30D).
Effective cutting length (l): 50 mm to 800 mm, shallow drilling (50-150 mm) is suitable for medium depth holes, deep drilling (400-800 mm) is suitable for deep holes or multi-stage drilling, and the ratio of cutting length to diameter is usually controlled at 5:1-30:1.
Helix angle: 20°-40°, standard value is 25°-35°, spiral design optimizes chip discharge and vibration reduction, 30°-35° is commonly used for finishing to improve hole wall quality, and 20°-25° can be selected for roughing to enhance strength.
cutting edges : 1-3 cutting edges , mainly single-edge (gun drill) design, small diameter (D<10 mm) has 1 edge, medium and large diameter (D>10 mm) can have 2-3 edges to improve cutting efficiency. The increase in the number of edges requires matching high-rigidity machine tools and cooling systems.

The deep hole drill blade is usually designed with a single blade or an asymmetric multi- blade . The drill tip angle (118°-150°) can be customized. The blade is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure that the drill tip and groove profile are smooth (Ra ≤ 0.05 microns). The drill body is equipped with internal cooling holes (diameter 0.3-2 mm, pressure 5-20 bar) or external chip grooves, which significantly improve chip removal (efficiency increased by 30%-40%) and thermal management (cutting zone temperature <600°C), suitable for deep hole drilling or sticky material processing. The tool body is dynamically balanced (unbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration during high-speed drilling (amplitude <0.005 mm).

3. Carbide deep hole drill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:
YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 70-100 hours.
YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 80-120 hours.
K40: Cobalt content 12%, hardness HV 1600-1800, bending strength 2200-2500 MPa, specially designed for aluminum alloys and non-ferrous metals, strong anti-adhesion, life span up to 100-150 hours.

Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100) and thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) to optimize heat resistance and oxidation resistance.

4. Carbide deep hole drill manufacturing

The manufacturing process includes:

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Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.
Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.
High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.
Post-processing: Turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), finishing of drill tips and cooling holes with diamond abrasives.
TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce friction coefficient and extend service life.

5. Technical parameters of carbide deep hole drill

Hardness: substrate HV 1800-2200, after coating 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): steel 40-120 m/min, titanium alloy 20-80 m/min, aluminum alloy 80-200 m/min.
Feed rate (fz): 0.01-0.15 mm/rev.
Drilling depth (L/D): 5:1 to 30:1 (standard), deep hole up to 50:1 (with internal coolant support).
Tolerance: diameter ±0.01 mm, hole accuracy <0.01 mm.
Surface roughness: Ra 0.4-1.5 microns.

6. Application scenarios of cemented carbide deep hole drills

Aerospace: Drilling engine shaft holes (diameter 10-20 mm, depth 200-500 mm) with an accuracy of ±0.01 mm.
Automotive industry: Processing hydraulic cylinder bores (diameter 15-30 mm), Ra < 1.0 micron.
Energy equipment: Drilling deep holes on turbine shafts (depth 300-800 mm), accuracy ±0.015 mm.
Mould manufacturing : Processing mould cooling holes (diameter 5-10 mm), Ra<0.8 micron.

Precautions for using carbide deep hole drills

Machine tool: Special deep hole drilling machine or five-axis CNC, runout <0.005 mm, spindle power ≥5 kW.
Cooling: High pressure internal cooling system (10-20 bar, 20-30 L/min) or external spray coolant.
Parameters: Vc 100 m/min, fz 0.05 mm/rev, drilling depth segmented (5-10D per segment).
Installation: Coaxiality <0.002 mm, clamping force 40-60 Nm.
Wear: Replace the drill tip when wear VB reaches 0.3 mm or the hole wall is scratched.

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appendix:

What is a Carbide Step Drill?

1. Definition and function of carbide step drill

high-performance rotary cutting tool designed for multi-level aperture or stepped hole processing . It is widely used in metal processing, mold manufacturing, automotive industry, aerospace, and mechanical parts production. Its core feature is that the blade adopts a stepped or multi-diameter design. Combined with the excellent performance of the overall carbide material, it can complete the processing of holes or transition sections of different diameters in one drilling , reducing the process and processing time. The carbide step drill uses carbide as the base, has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and is suitable for drilling high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys and aluminum alloys.

The unique blade geometry of the step drill (usually including 2-5 diameter levels) optimizes cutting force and chip evacuation. It is widely suitable for CNC machine tools, drilling machines or machining centers, and can efficiently complete the processing of stepped holes, countersunk holes and chamfered holes. The processing accuracy can reach IT6-IT8 level and the surface roughness can reach Ra 0.4-1.2 microns. Compared with traditional step drilling, carbide step drills significantly improve processing efficiency (efficiency increased by 40%-60%), hole diameter consistency (error <0.01 mm) and tool life (50-120 hours), and perform well in scenarios requiring high-precision connection or assembly. It has high design flexibility and can customize the blade size and angle according to the hole diameter combination, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize drilling parameters .

2. Structural features of carbide step drills

The structural design of carbide step drills aims to achieve efficient multi-stage drilling, excellent chip evacuation and vibration resistance . They usually adopt a straight shank structure (in accordance with DIN 6535 HA/HB standard), with a stepped multi-edge layout on the blade, combined with axial cutting ability to adapt to complex hole processing. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): ranging from 3 mm to 40 mm, micro step drills (D<6 mm) are used for micro hole processing, medium size (D=6-20 mm) is suitable for general step holes, large size (D>20 mm) is used for heavy drilling, step diameter combinations can be customized (such as 3-5 mm, 10-15 mm).
Shank type : straight shank (DIN 6535 HA flat shank or HB without shank), shank diameter matches the maximum cutting diameter, tolerance class h6 (0/-0.006 mm), shank length (40-150 mm) customized according to processing depth and machine clamping requirements.
Total length (L): 60 mm to 300 mm, suitable for small CNC (60-150 mm) or medium-sized machining centers (200-300 mm), extra long (350 mm) for deep step hole drilling (depth up to 10D).

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Effective cutting length (l): 15 mm to 200 mm, shallow drilling (15-50 mm) is suitable for surface step holes, deep drilling (100-200 mm) is suitable for deep step or multi-level drilling, and the ratio of cutting length to maximum diameter is usually controlled at 3:1-8:1.
Helix angle: 20°-40°, standard value is 25°-35°, spiral design optimizes chip discharge and vibration reduction, 30°-35° is commonly used for finishing to improve hole wall quality, and 20°-25° can be selected for roughing to enhance strength.
cutting edges : 2-6 cutting edges , depending on the diameter and number of steps. The standard is a double-edged (2-edged) design. Each additional step can increase 1-2 edges. For medium and large diameters (D>10 mm), it can reach 4-6 edges to improve cutting efficiency.

The stepped cutting edge adopts multi-level diameter transition (diameter difference of each level is 0.5-5 mm, angle is 5°-15°), and is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure the smoothness of each step profile (Ra ≤ 0.05 microns). The drill body is dynamically balanced (imbalance <5 g·mm /kg, test speed 12000 RPM) to reduce vibration during high-speed drilling (amplitude <0.005 mm). High-end models are equipped with internal cooling holes (diameter 0.3-1 mm, pressure 5-10 bar) or anti-vibration design, which significantly improves chip discharge (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <500°C), suitable for multi-level deep hole drilling or sticky material processing.

3. Carbide step drill material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:
YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.
YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 70-100 hours.
K30: Cobalt content 8%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially designed for aluminum alloys and non-ferrous metals, strong anti-adhesion, life span up to 80-120 hours.
Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100) and thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) to optimize heat resistance.

4. Carbide step drill manufacturing

The manufacturing process includes:
Raw material preparation: Tungsten carbide powder is mixed with cobalt powder (accuracy ±0.1%), TiC or NbC is added , particle size is 0.5-2 microns, ball milled for 24-48 hours, and ethanol dispersant is added to ensure uniformity.
Pressing: Hydraulic press applies 150-200 MPa, density 14.5-15.2 g/cm³ , CIP technology is used to improve uniformity, and the mold accuracy is controlled within ±0.02 mm.
High temperature sintering: vacuum or hydrogen protection, 1400°C-1600°C, 10-12 hours, step-by-step heating to eliminate pores.

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Post-processing: Turning (runout < 0.01 mm), grinding (accuracy ± 0.002 mm), polishing (Ra ≤ 0.05 microns), finishing of the step edge with diamond abrasive.

TiAlN (3-8 microns) or AlCrN (3-7 microns) deposited by PVD process to reduce friction coefficient and extend service life.

5. Technical parameters of carbide step drill

Hardness: substrate HV 1800-2200, after coating 3400 HV.

Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 50-150 m/min for steel, 30-100 m/min for titanium alloy, 100-250 m/min for aluminum alloy.

Feed rate (fz): 0.01-0.15 mm/rev.

Drilling depth (L/D): 3:1 to 10:1 (standard), deep step holes up to 15:1 (with cooling support).

Tolerance: diameter ±0.01 mm, step accuracy <0.01 mm.

Surface roughness: Ra 0.4-1.2 microns.

6. Important application scenarios of carbide step drills

Mould manufacturing: Drilling mould countersinks (5-10 mm in diameter, 20-40 mm in depth), Ra<0.8 micron.

Automotive industry: Machining of cylinder head stepped holes (diameter 10-15 mm) with an accuracy of ±0.01 mm.

Aerospace: Drilling titanium alloy connection holes (depth 30-60 mm), Ra < 1.0 micron.

Mechanical parts: Processing of stepped holes in bearing seats (diameter 12-20 mm), accuracy ±0.005 mm.

7. Precautions for using carbide step drills

Machine tools: three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥3 kW.

Cooling: High pressure cutting fluid (10 bar, 15-20 L/min) or internal cooling system.

Parameters: Vc 120 m/min, fz 0.05 mm/rev, drilling depth segmented (5D per segment).

Installation: Coaxiality <0.002 mm, clamping force 20-40 Nm.

Wear: Replace when blade wear VB reaches 0.3 mm or step deformation occurs.

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appendix:

What are Carbide Boring Tools ?

Carbide boring tools are special tools used for precision hole enlargement and finishing in mechanical processing. With its excellent hardness and wear resistance, it provides an efficient and accurate solution for the processing of internal holes of various workpieces. These boring tools are widely used in manufacturing scenarios that require high precision and high quality by rotating at low speed and accurately feeding on lathes or boring machines to complete the enlargement, calibration and surface finish of the inner hole. Carbide boring tools are based on tungsten carbide (WC), adding cobalt (Co) as a binder, and sintered by precision powder metallurgy. Common material grades include YG8 (high toughness, suitable for intermittent cutting), YT15 (strong heat resistance, suitable for steel processing) and YW2 (excellent comprehensive performance, suitable for complex working conditions). Its design forms are diverse, with both integral carbide structure and flexible configuration of adjustable or replaceable blades. The tool body is usually made of high-strength steel to ensure stability in high-load and long-stroke processing.

1. Geometry design and optimization

carbide boring cutters is the key to their efficient operation. Designers carefully adjust parameters to meet different processing requirements. The front angle of the tool is generally set between 5° and 10°. This angle design helps to reduce cutting force and improve chip formation; the back angle is usually between 6° and 12° to ensure smooth contact between the boring cutter and the inner wall of the workpiece to avoid excessive wear; the chamfer of the cutting edge (0.1-0.2 mm) enhances the ability to resist chipping by dispersing stress , especially in intermittent cutting. Single-edge boring cutters are suitable for finishing of small holes, with a diameter range of 5 to 30 mm and a length of up to 200 mm; multi- edge boring cutters are used for large diameter holes, with the number of blades ranging from 2 to 6 and a diameter of up to 50 to 200 mm, suitable for heavy-duty machining; adjustable boring cutters achieve aperture accuracy through a fine-tuning device and are widely used in multi-process machining. Geometry optimization combines computer-aided design (CAD) and simulation analysis to ensure that the boring tool remains stable during low-speed, high-precision machining (up to 3000 rpm), and the chip groove depth (1-3 mm) is adjusted according to the hole depth to ensure smooth chip discharge.

2. Coating and surface treatment

Coating technology has given carbide boring tools additional performance advantages, enabling them to cope with more complex machining environments. PVD (physical vapor deposition) coatings such as TiN (golden yellow, 2-5 microns thick) provide primary wear protection and are particularly suitable for machining non-ferrous metals; CVD (chemical vapor deposition) coatings such as TiAlN (purple black, 10-20 microns thick) are ideal for machining steel and cast iron with their heat resistance up to 1000°C. In terms of surface treatment, the polishing process controls the surface roughness to Ra <0.2 microns to reduce chip adhesion; laser micro-texturing technology forms micro-lubricating grooves on the tool surface to reduce the friction coefficient; some high-end boring tools use nano-coatings (such as nano- TiAlN , with grains less than 50 nanometers), which significantly improves performance in ultra-precision machining. Coating adhesion is

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verified by scratch testing (critical load >70 N) to ensure that the coating will not peel off during long-term use.

3. Technical characteristics and performance

cemented carbide boring cutters makes them a powerful assistant for precision machining and has won high recognition in the industry. The cutting speed ranges from 50 to 200 meters per minute, depending on the workpiece material. For example, steel is usually 100 to 150 meters per minute, while cast iron can reach 150 to 200 meters per minute. In terms of hardness, the hardness of boring cutters is generally between HV 1800 and 2100. YT15 can reach HV 2000 to 2100 due to titanium carbide, which is enough to cope with high-hardness workpieces. The fracture toughness is 12 to 18 MPa· $m^{1/2}$. The YG8 grade has a higher toughness due to its high cobalt content (8%), which is particularly suitable for intermittent cutting. The wear resistance is less than 0.03 cubic millimeters per Newton meter, and it is further reduced to 0.02 cubic millimeters per Newton meter after coating, which greatly extends the service life. The heat resistance can reach up to 1000°C (thanks to the CVD coating), making it stable in high temperature environments . The processing accuracy is controlled within 0.005 mm, meeting the requirements of high-precision inner hole processing.

4. Processing requirements and applications

cemented carbide boring tools reflect their unique value in precision manufacturing. Cutting parameters vary depending on the material. For example, the cutting speed of steel is 100 to 150 meters per minute, the feed rate is 0.05 to 0.2 mm per revolution, and the cutting depth is 0.5 to 2 mm; cast iron requires a cutting speed of 150 to 200 meters per minute, a feed rate of 0.1 to 0.3 mm per revolution, and a cutting depth of 1 to 3 mm. The choice of cooling method is also critical . Dry cutting is suitable for cast iron and can reduce the use of coolant; wet cutting using emulsion or oil-based coolant is more suitable for steel and titanium alloys, which can effectively reduce thermal damage; for deep hole boring , high-pressure cooling (10-15 bar) significantly improves chip removal efficiency through internal cooling channels. In practical applications, the automotive industry often uses boring cutters to process the inner holes of cylinder liners and crankshafts, which require high precision and long life; mold manufacturing relies on it to fine-tune the guide holes of stamping dies, focusing on surface quality; the aviation industry, such as expanding the inner holes of engine casings, also relies on its excellent performance.

5. Challenges and Solutions

using carbide boring tools, but these problems can be properly solved through scientific coping strategies. During the boring process , poor chip removal is a common problem in deep hole processing, which can be alleviated by optimizing the chip groove design and adding self-lubricating coatings (such as MoS_2); heat accumulation is prone to occur in low-speed and high -load processing, and an efficient cooling system and heat-resistant coating can effectively control the temperature; boring tool runout may cause aperture errors, and the use of a high-rigidity tool body and edge strengthening treatment can improve stability; for hard materials, accelerated wear is the main problem, and regular sharpening or the use of diamond coatings can significantly extend the service life. These solutions together ensure the reliability of boring tools under complex

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working conditions.

6. Optimization and development trends

cemented carbide boring tools reflect the industry's pursuit of efficiency and intelligence. In terms of structural optimization, the integrated internal cooling channel can effectively reduce the temperature of the boring tool, the adjustable tool head design is convenient for adapting to different apertures, and the dynamic balancing technology improves the stability of low-speed and high-precision processing. In terms of material innovation, nano-cemented carbide improves hardness and toughness with its fine grains (less than 0.5 microns), and the gradient material design allows the boring tool to have both high hardness and high toughness. The trend of intelligence allows boring tools to be embedded with sensors to monitor wear and temperature in real time, and dynamically adjust boring parameters in combination with artificial intelligence algorithms. In terms of manufacturing technology, 3D printing technologies such as selective laser melting (SLM) can create complex boring tool structures, such as built-in cooling channels, while laser deposition technology provides the possibility of repairing worn boring tools . The environmental protection trend has promoted the development of dry cutting coatings (such as graphene composite coatings), reducing dependence on coolants, while the use of recyclable materials also reduces environmental impact.

7. Lifespan and maintenance

carbide boring tools varies depending on the processing conditions and workpiece materials, and is generally between 15 and 30 hours, such as about 20 hours for steel processing and up to 25 hours for cast iron processing. Maintenance work includes regular sharpening , using diamond grinding wheels to ensure that the angle error is less than 0.5°, coating repair through CVD technology to restore performance, and laser pre-adjustment to ensure that the error is less than 0.005 mm. These measures can effectively extend the service life of boring tools. After the boring tool is scrapped, the tungsten and cobalt materials in it can be recycled and reused by smelting and returning to the furnace, reflecting the concept of sustainable development.

8. Industry standards and certification

cemented carbide boring tools must comply with international and domestic standards, such as ISO 13399 in the ISO standard and the Chinese national standard GB/T series, to ensure quality and safety. In terms of certification, CE safety certification and RoHS environmental certification are essential. If necessary, you can contact CTIA GROUP to obtain relevant technical data . CTIA GROUP provides users with professional guidance in selection and operation.

9. Detailed classification of carbide boring tools

Carbide boring tools can be divided into several categories according to processing requirements and application scenarios, each type has its own unique design and purpose:

Single-edge boring tool : Suitable for finishing of small holes, with diameters ranging from 5 to 30 mm and lengths up to 200 mm. Rake angle 5° to 8°, back angle 6° to 10°, YG8 grade, TiN coating

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(thickness 2-5 microns) for wear resistance. Cutting speed 100 to 150 m/min, accuracy below 0.005 mm, widely used for small shaft holes and bearing seat processing.

Multi- edge boring tool : used for roughing and finishing of large diameter holes, with 2 to 6 edges and diameters of 50 to 200 mm. Rake angle 5° to 10°, back angle 6° to 12°, YT15 grade, TiAlN coating (thickness 10-20 microns) for enhanced heat resistance. Cutting speed 100 to 200 m/min, accuracy less than 0.01 mm, commonly used in heavy machinery and engine housings.

Adjustable boring tool : A fine-tuning device is used to achieve hole diameter accuracy, and the drilling diameter range is 20 to 150 mm. The front angle is 5° to 10°, the back angle is 6° to 12°, and the YW2 grade is selected. Multi-layer coating (such as $TiN+Al_2O_3$) provides comprehensive performance. The cutting speed is 80 to 150 meters per minute, and the accuracy is less than 0.005 mm. It is widely used in multi-process and complex internal hole processing.

10. Selection and matching

Choosing the right carbide boring tool requires comprehensive consideration of the workpiece material and the type of processing. For example, YT15 multi- edge boring tools are used for finishing steel, YG8 single-edge boring tools are used for roughing cast iron, and YW2 adjustable boring tools with multi-layer coatings are more suitable for complex internal hole processing. The performance of the machine tool is also critical , with a spindle power of more than 5 kilowatts and a speed of 1,000 to 3,000 rpm to fully utilize the potential of the boring tool.

11. Classification summary table

Boring tool type	Number of blades	diameter (mm)	Front Angle (°)	Rear Angle (°)	Applicable Brand	Coating Type	Cutting speed (m/min)	Depth of cut (mm)	Accuracy(mm)	Typical Applications
Single edge boring tool	1	5-30	5-8	6-10	YG8	TiN (2-5 μm)	100-150	0.5-2	<0.005	Small shaft bore, bearing housing
Multi-edge boring tool	2-6	50-200	5-10	6-12	YT15	TiAlN (10-20 μm)	100-200	1-3	<0.01	Heavy machinery, housing
Adjustable boring tool	-	20-150	5-10	6-12	YW2	$TiN + Al_2O_3$	80-150	0.5-2	<0.005	Complex inner hole, multiple processes

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appendix:

What is a carbide single-edge boring tool？

1. Definition and function of carbide single-edge boring tool

Carbide single-edge boring tool is a high-performance cutting tool designed for precision internal hole processing and boring operations . It is widely used in mechanical processing, mold manufacturing, aerospace, automotive industry, energy equipment production and other fields. Its core feature is the single cutting edge design, combined with the excellent performance of the overall cemented carbide material, which can achieve high-precision internal hole finishing, hole diameter adjustment and surface finish optimization. Carbide single-edge boring tool is based on cemented carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, suitable for boring high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy and cast iron. The single-edge design reduces cutting force fluctuations (force dispersion rate <10%) through a single cutting point, and combined with an adjustable tool bar structure, it is widely compatible with CNC machine tools (CNC), boring machines or machining centers. It can efficiently complete hole expansion, fine boring , chamfering and inner surface processing, with a machining accuracy of up to IT5-IT7 level and a surface roughness of Ra 0.1-0.6 microns.

Compared with multi- edge boring tools, carbide single-edge boring tools have higher flexibility (adjustment accuracy ±0.005 mm) and better chip control (chip removal efficiency increased by 15%-25%) in small diameter holes (<10 mm) or high precision requirements, and are particularly suitable for processing that requires fine adjustment of hole diameter or complex internal hole shapes. Its design is highly flexible, and the blade size, angle and shank length can be customized according to the hole diameter, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software to dynamically optimize cutting parameters to improve processing quality and tool life.

2. Structural features of carbide single-edge boring cutters

carbide single-edge boring tools aims to achieve high-precision boring, excellent chip removal and adjustability. They usually adopt a straight shank or a tapered shank structure, with a single cutting edge layout at the blade, combined with an adjustable tool bar to adapt to different hole diameters and depths. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): ranging from 2 mm to 50 mm, micro single-edge boring tools (D<6 mm) are used for micro-hole fine boring, medium-sized (D=6-20 mm) are suitable for general internal hole processing, and large (D>20 mm) are used for heavy boring. The cutting edge diameter can be fine-tuned by the tool arbor.

Shank type : straight shank (DIN 6535 HA/HB) or tapered shank (BT40, CAT50, HSK-A63), shank diameter matches the maximum cutting diameter, tolerance class h6 (0/-0.006 mm), shank length (50-300 mm) customized according to processing depth and machine tool clamping requirements,

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tapered shank enhances high torque transmission (torque range 20-100 Nm).
Total length (L): 100 mm to 500 mm, suitable for small CNC (100-200 mm) or heavy boring machines (300-500 mm), extra long (600 mm) for deep hole boring (depth up to 20D).
Effective cutting length (l): 20 mm to 400 mm, shallow boring (20-80 mm) is suitable for surface finishing, deep boring (200-400 mm) is suitable for deep holes or multi-stage boring, and the ratio of cutting length to diameter is usually controlled at 5:1-15:1.
Helix angle: 0°-30° (straight edge or micro helix), standard value is 10°-20°, optimize chip removal and vibration reduction, 15°-20° is commonly used for finishing to improve surface quality, and 0°-10° can be used for roughing to enhance strength.
The blade adjustment range is 0.01-5 mm (fine adjustment). The aperture can be precisely controlled through the shank thread or eccentric adjustment mechanism, with an adjustment accuracy of ±0.005 mm.

The single-edge adopts a single-point cutting design (edge angle 90°-120°) and is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure smooth cutting edges (Ra ≤ 0.02 microns) and geometric accuracy. The cutter body is dynamically balanced (imbalance <5 g·mm /kg, test speed 12000 RPM) to reduce vibration during high-speed boring (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.3-1.5 mm, pressure 5-15 bar) or external chip flutes, which significantly improve chip removal (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <500°C), suitable for deep hole boring or sticky material processing. Some models introduce a replaceable cutter head design, and the cutter head and tool bar are connected by high-precision threads (tolerance 6H/6g), which is convenient for quick replacement and blade re-grinding.

3. Carbide single-edge boring tool material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:

YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 60-80 hours.
YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 70-100 hours.
K20: Cobalt content 8%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially designed for aluminum alloys and non-ferrous metals, strong anti-adhesion, life span up to 80-120 hours.
Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (500-800°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance and microstructure.

Manufacturing of carbide single-edged boring tools

The manufacturing process includes multiple precision steps from raw material preparation to final

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coating treatment to ensure the geometric accuracy, durability and performance stability of the tool. The following is a detailed manufacturing process:

Raw materials preparation:

Material ratio: High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the brand (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance performance, and the particle size is controlled at 0.5-2 microns.

Mixing process: Wet mixing is performed using a planetary ball mill (50-100 RPM, 24-48 hours), with ethanol added as a dispersant to ensure powder homogeneity (segregation <1%).

Quality inspection: Laser particle size analyzer is used to detect particle size distribution, and X-ray fluorescence spectrometer (XRF) is used to analyze chemical composition. The deviation is controlled within ±0.05%.

Compression Molding:

Process parameters: Hydraulic press with 150-200 MPa pressure to form the tool body blank with a density of 14.5-15.2 g/cm^3 , cold isostatic pressing (CIP, 150-200 MPa, 10-15 minutes) to improve uniformity.

Mold Design: The mold is made of high-strength steel (hardness HRC 50-55), with a precision of ±0.02 mm. Laser cutting and EDM are used to ensure the blade forming accuracy.

Quality Control: Density of the blanks is measured by Archimedean method (error < 0.1 g/cm^3) , internal porosity is checked by microscopy (< 0.5%).

High temperature sintering:

Process conditions: vacuum furnace (pressure 10 $^{-2}$ Pa) or hydrogen protection, temperature 1400°C-1600°C, lasting 10-12 hours, staged heating (50°C per hour, preheating stage 300°C-600°C) to remove volatiles.

Process optimization : Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV).

Quality inspection: Scanning electron microscope (SEM) to analyze the microstructure, Vickers hardness tester to test the hardness (HV 1800-2200).

Post-processing:

Turning: External turning with CBN tools, run-out accuracy <0.01 mm, surface roughness Ra ≤ 0.2 microns.

Grinding: Ultra- precision five-axis CNC grinding machine for cutting edge (accuracy ±0.002 mm), cutting edge profile error <0.005 mm, surface Ra ≤ 0.02 microns.

Polishing: Diamond abrasive with grain size W0.5-W1.0, edge Ra ≤ 0.01 micron, electrolytic polishing (current density 0.1 A/cm^2) to remove microscopic burrs.

Edge treatment: Drill tip chamfer (0.1-0.2 mm, angle 5°-10°) to enhance chipping resistance, edge geometry calibrated by laser interferometer.

Coating treatment:

Process technology: Coating is achieved by PVD process (pressure 10 $^{-3}$ Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h).

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Coating type: TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), reduce friction coefficient (<0.3), increase service life by 30%-50%.
Quality inspection: SEM to check coating uniformity, nanoindenter to test hardness and adhesion (>70 N), thickness deviation <0.5 micron.

Final inspection and packaging:

Performance testing: Coordinate measuring machine (CMM) checks diameter and blade accuracy (<0.01 mm), dynamic balancing machine corrects imbalance (<5 g·mm /kg).
Surface treatment: Anti-rust oil coating or vacuum packaging to prevent oxidation.
Marking: Laser engraved with diameter, length, grade and batch number to ensure traceability.

5. Technical parameters of carbide single-edge boring tool

Hardness: substrate HV 1800-2200, after coating 3400 HV.
Heat resistance: 600°C-1000°C.
Cutting speed (Vc): 50-150 m/min for steel, 30-100 m/min for titanium alloy, 100-250 m/min for aluminum alloy.
Feed rate (fz): 0.01-0.15 mm/rev.
Depth of cut (ap): 0.05-5 mm.
Tolerance: diameter ±0.01 mm, hole accuracy <0.005 mm.
Surface roughness: Ra 0.1-0.6 microns.

scenarios of cemented carbide single-edge boring cutters

Carbide single-edge boring tools are widely used in various industrial fields due to their high precision and adjustability. The following is a detailed scenario description, covering specific cases, technical data and industry background:

Mould manufacturing:

Application: Fine boring of mold inner holes, guide holes and positioning holes, common diameters are 6-20 mm and depths are 20-100 mm.
Case: A mold factory uses a 10 mm diameter single-edge boring tool to fine bore the guide post hole of the stamping die. The cutting speed is 100 m/min, the feed rate is 0.05 mm/rev, the hole diameter tolerance after processing is ±0.003 mm, Ra is 0.2 microns, the tool life is 80 hours, and the annual output is 1,500 sets of molds, with an efficiency improvement of 35%.
Technical features : High finish and coaxiality are required, and the internal cooling system (10 bar) supports deep hole processing.

auto industry:

Application: Processing of engine cylinder bores, connecting rod bores and gearbox housing bores, with typical diameters of 15-30 mm and depths of 30-150 mm.
Case: An automotive parts company uses a 20 mm diameter single-edge boring tool to process cylinder bores, with a cutting speed of 80 m/min and a feed rate of 0.04 mm/rev. The hole roundness after processing is <0.005 mm, Ra is 0.3 microns, and the tool life is 90 hours. It produces 600,000 cylinders per year, reducing processes by 20%.

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Industry background: With the increasing demand for electric vehicle motor housings, precision boring of aluminum alloys and magnesium alloys has become a focus, and the demand for anti-adhesion coatings (such as DLC) for single-edge boring tools has increased.

Aerospace:

Application: boring titanium alloy or high-strength steel fuselage connection holes and landing gear strut holes, common diameter 10-25 mm, depth 50-200 mm.

Case: An airline company used a 15 mm diameter single-edge boring tool to process titanium alloy landing gear holes. The cutting speed was 50 m/min, the feed rate was 0.03 mm/rev, the hole diameter tolerance after processing was ±0.004 mm, Ra was 0.2 microns, the tool life was 100 hours, and it met the AS9100 standard.

Technical features: Requires heat resistance and high precision, and internal cooling pressure must be above 15 bar.

Energy equipment manufacturing:

Application: Processing turbine shaft holes, pump body inner holes and valve body holes, common diameters are 20-40 mm and depths are 100-300 mm.

Case: An energy equipment manufacturer uses a 25 mm diameter single-edge boring tool to process hydraulic pump body holes. The cutting speed is 70 m/min, the feed rate is 0.06 mm/rev, the hole diameter error after processing is <0.01 mm, Ra is 0.5 microns, the tool life is 110 hours, and the annual output is 4,000 pump bodies, with an efficiency improvement of 30%.

Industry background: As wind power and nuclear power equipment have higher requirements for deep hole accuracy, the vibration-resistant design and cooling channel of single-edge boring cutters have become key.

Medical Devices:

Application: Boring inner holes of orthopedic implants or positioning holes of surgical instruments, with common diameters of 4-10 mm and depths of 10-50 mm.

Case: A medical company used a 6 mm diameter single-edge boring tool to process the inner hole of a titanium alloy hip joint. The cutting speed was 40 m/min, the feed rate was 0.02 mm/rev, the hole diameter tolerance after processing was ±0.002 mm, Ra was 0.1 micron, the tool life was 60 hours, and it met the FDA biocompatibility standards.

Technical features: Requires extremely high precision and surface quality, often uses TiAlN coating to reduce metal contamination.

Mechanical parts:

Application: Processing bearing seat holes, gear shaft holes and pump housing inner holes, common diameters are 12-30 mm and depths are 50-150 mm.

Case: A machinery manufacturing company uses a single-edge boring tool with a diameter of 18 mm to process bearing seat holes. The cutting speed is 90 m/min, the feed rate is 0.05 mm/rev, the hole roundness after processing is <0.006 mm, Ra is 0.4 microns, the tool life is 85 hours, and the annual output of 100,000 bearing seats is 25% higher.

Industry background: As the demand for large-diameter deep hole processing in heavy machinery increases, the rigidity and durability of single-edge boring tools become a competitive advantage.

Precautions for using carbide single-edge boring tools

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Machine tool: three-axis or five-axis CNC, runout <0.005 mm, spindle power ≥3 kW, it is recommended to use a high-rigidity boring machine (guideway rigidity >3000 N/ μm).
Cooling: High-pressure cutting fluid (10 bar, 15-20 L/min) or internal cooling system (pressure 5-15 bar). Viscous materials (such as stainless steel) require enhanced cooling (flow rate increased to 25 L/min).
Parameters: Vc 100 m/min, fz 0.05 mm/rev, cutting depth segment (5D per segment), feed in the boring transition segment is halved to reduce vibration.
Installation : Coaxiality <0.002 mm, clamping force 20-40 Nm (straight shank) or 40-60 Nm (taper shank), calibrate the coaxiality of the tool shank before installation.
Wear: Replace when blade wear VB reaches 0.3 mm, hole diameter is out of tolerance (>0.01 mm), or surface scratches occur. It is recommended to check every 20 hours and record wear data to optimize the usage cycle.

30- year history of cemented carbide manufacturing , CTIA GROUP has designed and produced a large number of high-performance cemented carbide products, meeting the stringent needs of tens of thousands of customers in the machinery, aviation, energy, mining, electronics, automobile, chemical, military and other industries. If you have any needs for cemented carbide single-edge boring tools , we are willing to provide you with precise, efficient and high-quality customized services!
Contact us to get the latest industry information and customize exclusive solutions :
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appendix:

What is a carbide multi- edge boring tool?

1. Definition and function of cemented carbide multi -edge boring tool

Carbide multi- edge boring cutters are high-performance cutting tools designed for efficient and precise internal hole processing and boring operations . They are widely used in machining, mold manufacturing, aerospace, automotive industry, energy equipment production, and heavy machinery manufacturing. Its core feature is the use of multiple cutting edge design (usually 2-6 edges), combined with the excellent performance of the overall cemented carbide material, which can achieve high-efficiency rough boring, semi-finishing boring and finishing boring, especially suitable for large diameter or deep hole processing. Carbide multi-edge boring cutters are based on cemented carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, suitable for boring high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys, cast iron and aluminum alloys. The multi- blade design shares the cutting force through multiple cutting points (force dispersion rate 20%-40%), improving processing efficiency and stability. It is widely suitable for CNC machine tools (CNC), boring machines, machining centers or special boring equipment, and can efficiently complete hole expansion, fine boring, chamfering and inner surface processing. The processing accuracy can reach IT5-IT7 level, and the surface roughness can reach Ra 0.2-0.8 microns.

Carbide multi- edge boring tools have higher cutting speed (increased by 30%-50%) and vibration resistance (reduced by 15%-25%) in medium to large diameter holes (>10 mm) or high metal removal rate scenarios, and are particularly suitable for heavy loads and mass production environments. Its design is highly flexible, and the number of edges, edge geometry, and shank length can be customized according to the hole diameter, depth, and workpiece material . With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software (such as HyperMill and Edgecam) to dynamically optimize cutting parameters to improve processing efficiency and tool life.

2. Structural features of cemented carbide multi- edge boring cutters

carbide multi- edge boring cutters aims to achieve efficient boring, high rigidity and excellent chip evacuation. They usually adopt straight shank, tapered shank or modular tool bar structure, with multi-edge spiral or straight edge layout, combining radial and axial cutting capabilities to adapt to complex internal hole processing. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): ranging from 10 mm to 100 mm, micro multi- edge boring tools (D<15 mm) are used for fine boring of small holes, medium-sized (D=15-50 mm) are suitable for general internal hole processing, and large (D>50 mm) are used for heavy boring or large diameter holes. The cutting edge diameter can be fine-tuned by the tool arbor.

Shank type : straight shank (DIN 6535 HA/HB), taper shank (BT40, CAT50, HSK-A63) or modular

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shank, shank diameter matches the maximum cutting diameter, tolerance class h6 (0/-0.006 mm), shank length (100-500 mm) customized according to processing depth and machine clamping requirements , taper shank or modular design supports high torque transmission (torque range 50-200 Nm).

Overall length (L): 150 mm to 800 mm, suitable for medium-sized CNC (150-300 mm) or heavy-duty boring machines (400-800 mm), extra-long (1000 mm) for deep hole boring (depth up to 25D).

Effective cutting length (l): 30 mm to 600 mm, shallow boring (30-100 mm) is suitable for surface finishing, deep boring (300-600 mm) is suitable for deep holes or multi-stage boring, and the ratio of cutting length to diameter is usually controlled at 5:1-20:1.

Helix angle: 10°-40°, standard value is 15°-30°, the spiral design optimizes chip discharge and vibration reduction, 25°-30° is commonly used for finishing to improve surface quality, 10°-20° can be selected for roughing to enhance strength, some customized models support gradual helix angle (10°-35°) to adapt to deep hole cutting.

cutting edges : 2-6 cutting edges , depending on the diameter and processing requirements. Small diameter (D<20 mm) has 2-3 edges, medium and large diameter (D>20 mm) has 4-6 edges. Increasing the number of edges can improve cutting efficiency but requires high-rigidity machine tools and cooling support. The edge spacing error <0.02 mm ensures uniform cutting force.

The multi-edge adopts symmetrical or asymmetrical multi-point cutting design (edge angle 90°-120°), which is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure the smoothness of the cutting edge (Ra ≤ 0.02 microns) and geometric accuracy. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration (amplitude <0.005 mm) in high-speed boring . High-end models are equipped with internal cooling channels (diameter 0.5-2 mm, pressure 5-20 bar) or external chip grooves (width 1-2 mm), which significantly improve chip removal (efficiency increased by 25%-35%) and thermal management (cutting zone temperature <600°C), suitable for deep hole boring or sticky material processing. Some models introduce modular cutter head design, which is connected to the cutter head and the tool bar by high-precision threads or bayonet (tolerance 6H/6g), which is convenient for quick replacement and blade re-grinding, and the modular length can reach 500 mm.

3. Carbide multi- edge boring tool material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:

YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 70-100 hours.

YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 80-120 hours.

K40: Cobalt content 12%, hardness HV 1600-1800, bending strength 2200-2500 MPa, specially designed for aluminum alloys and non-ferrous metals, strong anti-adhesion, life span up to 100-150 hours.

Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB

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50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (500-900°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance, oxidation resistance and microstructural uniformity.

4. Manufacturing of cemented carbide multi- edge boring tools

The manufacturing process includes multiple precision steps from raw material preparation to final coating treatment to ensure the geometric accuracy, durability and performance stability of the tool. The following is a detailed manufacturing process:

Raw materials preparation:

Material ratio: High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the brand (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance performance, and the particle size is controlled at 0.5-2 microns.

Mixing process: Wet mixing is performed using a planetary ball mill (50-100 RPM, 24-48 hours), with ethanol added as a dispersant to ensure powder homogeneity (segregation <1%).

Quality inspection: Laser particle size analyzer is used to detect particle size distribution, and X-ray fluorescence spectrometer (XRF) is used to analyze chemical composition. The deviation is controlled within ±0.05%.

Compression Molding:

Process parameters: Hydraulic press with 150-200 MPa pressure to form the tool body blank with a density of 14.5-15.2 g/cm³ , cold isostatic pressing (CIP, 150-200 MPa, 10-15 minutes) to improve uniformity.

Mould design: The mould is made of high-strength steel (hardness HRC 50-55), with a precision of ±0.02 mm. Laser cutting and EDM are used to ensure the forming accuracy of multiple blades.

Quality Control : Density of the blanks is measured by Archimedean method (error < 0.1 g/cm³) , internal porosity is checked by microscopy (< 0.5%).

High temperature sintering:

Process conditions: vacuum furnace (pressure 10^{-2} Pa) or hydrogen protection, temperature 1400°C-1600°C, lasting 10-12 hours, staged heating (50°C per hour, preheating stage 300°C-600°C) to remove volatiles.

Process optimization: Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV).

Quality inspection: Scanning electron microscope (SEM) to analyze the microstructure, Vickers hardness tester to test the hardness (HV 1800-2200).

Post-processing:

Turning: External turning with CBN tools, run-out accuracy <0.01 mm, surface roughness Ra ≤ 0.2 microns.

Grinding: Ultra- precision five-axis CNC grinding machine processes multiple cutting edges (accuracy ±0.002 mm), cutting edge profile error <0.005 mm, surface Ra ≤ 0.02 microns.

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Polishing: Diamond abrasive with grain size W0.5-W1.0, edge Ra ≤ 0.01 micron, electrolytic polishing (current density 0.1 A/cm²) to remove microscopic burrs.

Edge treatment: Chamfered blade tip (0.1-0.2 mm, angle 5°-10°) to enhance chipping resistance, blade geometry calibrated by laser interferometer.

Coating treatment:

Process technology: Coating is achieved by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h).

Coating type: TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), reduce friction coefficient (<0.3), increase service life by 30%-50%.

Quality inspection: SEM to check coating uniformity, nanoindenter to test hardness and adhesion (>70 N), thickness deviation <0.5 micron.

Testing and packaging:

Performance testing: Coordinate measuring machine (CMM) checks diameter and blade accuracy (<0.01 mm), dynamic balancing machine corrects imbalance (<5 g·mm /kg).

Surface treatment: Anti-rust oil coating or vacuum packaging to prevent oxidation.

Marking: Laser engraved with diameter, length, number of flutes , grade and batch number to ensure traceability.

5. Technical parameters of cemented carbide multi- edge boring cutters

Hardness: substrate HV 1800-2200, after coating 3400 HV.

Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy, 100-300 m/min for aluminum alloy.

Feed rate (fz): 0.02-0.25 mm/rev.

Cutting depth (ap): 0.1-10 mm.

Tolerance: diameter ±0.01 mm, hole accuracy <0.005 mm.

Surface roughness: Ra 0.2-0.8 microns.

6. Application scenarios of cemented carbide multi- edge boring cutters

Carbide multi- edge boring cutters are widely used in many industrial fields due to their high efficiency and the characteristics of multi-edge sharing cutting force. The following is a detailed scenario description, covering specific cases, technical data and industry background:

Mould manufacturing:

Application : Rough and fine boring of mold cavities, guide bushings and cooling holes, typical diameters are 20-50 mm and depths are 50-200 mm.

Case: A mold factory uses a 30 mm diameter, 4- edge boring tool to rough bore the inner cavity of the stamping mold. The cutting speed is 150 m/min, the feed rate is 0.15 mm/rev, the hole diameter tolerance after processing is ±0.008 mm, Ra is 0.5 microns, the tool life is 100 hours, and the annual output is 1,200 sets of molds, with an efficiency improvement of 40%.

Technical features: High metal removal rate and stability are required, and the internal cooling system (15 bar) supports deep hole processing.

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auto industry:

Application: Processing of engine cylinder bores, crankshaft spindle bores and gearbox housing bores, with typical diameters of 30-70 mm and depths of 80-250 mm.

Case: An automotive parts company uses a 50 mm diameter, 6- edge boring tool to fine bore the main shaft hole of the cylinder block. The cutting speed is 120 m/min, the feed rate is 0.10 mm/rev, the hole roundness after processing is <0.006 mm, Ra is 0.3 microns, the tool life is 120 hours, and the annual output is 800,000 cylinder blocks, and the process time is reduced by 25%.

Industry background: The demand for processing large-diameter holes in electric vehicle motor housings and transmission systems has increased, and the high efficiency of multi- edge boring tools has become an advantage.

Aerospace:

Application: boring titanium alloy or high-strength steel fuselage connection holes and landing gear strut holes, common diameter 25-60 mm, depth 100-300 mm.

Case: An airline company used a 40 mm diameter, 4- edge boring tool to process titanium alloy landing gear holes. The cutting speed was 80 m/min, the feed rate was 0.08 mm/rev, the hole diameter tolerance after processing was ±0.005 mm, Ra was 0.2 microns, the tool life was 130 hours, and it met the AS9100 standard.

Technical features: Requires heat resistance and high precision, and internal cooling pressure must be above 20 bar.

Energy equipment manufacturing:

Application: Processing turbine shaft holes, pump body large holes and valve body holes, common diameters are 40-100 mm and depths are 200-500 mm.

Case: An energy equipment manufacturer uses a 60 mm diameter, 6- edge boring tool to process hydraulic pump body holes. The cutting speed is 100 m/min, the feed rate is 0.12 mm/rev, and the hole diameter error after processing is <0.01 mm, Ra is 0.6 microns, and the tool life is 150 hours. The annual output is 3,000 pump bodies, and the efficiency is improved by 35%.

Industry background: Wind power and nuclear power equipment have higher requirements on the machining accuracy and surface quality of large-diameter deep holes, and the vibration resistance and cooling design of multi- edge boring cutters are crucial.

Heavy Machinery:

Application: Processing machine tool spindle holes, gear box inner holes and large casting holes, common diameters are 50-100 mm and depths are 200-600 mm.

Case: A machinery manufacturing company uses a 80 mm diameter, 5- edge boring tool to process the spindle hole of a machine tool. The cutting speed is 90 m/min, the feed rate is 0.10 mm/rev, and the hole roundness after processing is <0.008 mm, Ra 0.5 microns, and the tool life is 140 hours. The annual output of 5,000 machine tool parts has increased efficiency by 30%.

Industry background: As the demand for large-diameter deep hole processing in heavy machinery increases, the rigidity and durability of multi- edge boring tools become a competitive advantage.

Shipbuilding:

Application: Processing of marine engine cylinder bores and propeller shaft holes, common diameters are 70-120 mm and depths are 300-800 mm.

Case: A shipyard uses a 100 mm diameter, 6- edge boring tool to process the thruster shaft hole. The

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cutting speed is 80 m/min, the feed rate is 0.15 mm/rev, the hole diameter tolerance after processing is ±0.01 mm, Ra is 0.7 microns, the tool life is 160 hours, and the annual output is 200 thrusters, which improves the efficiency by 40%.
Technical features: High rigidity and deep hole processing capability are required, and the internal cooling system requires high pressure support (20 bar).

Precautions for using carbide multi- edge boring tools
Machine tool : five-axis CNC or heavy-duty boring machine, runout <0.005 mm, spindle power ≥5 kW, it is recommended to use a high-rigidity spindle (guideway rigidity >4000 N/ µm).
Cooling: High-pressure cutting fluid (10-20 bar, 20-30 L/min) or internal cooling system (pressure 5-20 bar). Viscous materials (such as stainless steel) require enhanced cooling (flow rate increased to 35 L/min).
Parameters: Vc 120 m/min, fz 0.10 mm/rev, depth of cut segmented (5D per segment), feed halved in multi- edge transition segment to reduce vibration.
Installation: Coaxiality <0.002 mm, clamping force 40-80 Nm (taper shank or modular), calibrate the coaxiality of the tool arbor and spindle before installation.
Wear: Replace when blade wear VB reaches 0.3 mm, hole diameter is out of tolerance (>0.01 mm), or surface scratches occur. It is recommended to check every 30 hours and record wear data to optimize the usage cycle.

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appendix:

What is a Carbide Adjustable Boring Tool?

Definition and function of carbide adjustable boring tool

The carbide adjustable boring tool is a high-performance cutting tool designed for high-precision internal hole processing and flexible boring operations . It is widely used in mechanical processing, mold manufacturing, aerospace, automotive industry, energy equipment production, and precision instrument manufacturing. Its core feature is the combination design of adjustable tool bar and carbide cutting edge . It can accurately adjust the cutting diameter through the fine-tuning mechanism to meet the needs of different hole diameters and achieve high-precision processing. The carbide adjustable boring tool uses carbide as the blade material, has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and is suitable for boring high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy, cast iron and aluminum alloy. The adjustable design achieves diameter adjustment through precision threads, eccentric adjustment or hydraulic mechanism (adjustment range 0.01-10 mm, accuracy ±0.002 mm). It is widely compatible with CNC machine tools (CNC), boring machines, machining centers or special boring equipment. It can efficiently complete hole expansion, fine boring, chamfering, inner surface processing and aperture repair. The processing accuracy can reach IT4-IT6 level and the surface roughness can reach Ra 0.1-0.5 microns.

Carbide adjustable boring tools have higher flexibility (adaptability increased by 50%-70%) and economy (reduced tool replacement frequency) in small-batch production, multi-specification hole processing or aperture fine-tuning scenarios, and are particularly suitable for complex workpiece processing that requires high precision and dynamic adjustment. Its design flexibility is extremely high, and the blade geometry, adjustment mechanism and tool bar length can be customized according to the aperture range, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software and sensor systems to dynamically optimize cutting parameters through real-time data feedback.

features of carbide adjustable boring cutter

carbide adjustable boring tools aims to achieve high-precision boring, adjustability and excellent chip evacuation. They usually adopt straight shank, tapered shank or modular tool bar structure, single-edge or multi-edge layout of the blade, and are equipped with precision adjustment mechanism to meet different hole diameter requirements. The following are its detailed structural features, covering geometric parameters, processing technology and functional optimization:

Diameter (D): ranging from 5 mm to 150 mm, micro adjustable boring tools (D<15 mm) are used for fine boring of small holes, medium (D=15-50 mm) are suitable for general internal hole processing, large (D>50 mm) are used for heavy boring or large diameter holes, adjustment range 0.01-10 mm, accuracy ±0.002 mm.
Shank type : straight shank (DIN 6535 HA/HB), tapered shank (BT40, CAT50, HSK-A63) or modular shank, shank diameter matches the maximum cutting diameter, tolerance class h6 (0/-0.006

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mm), shank length (100-600 mm) customized according to processing depth and machine clamping requirements , modular design supports high torque transmission (torque range 50-300 Nm).
Total length (L): 150 mm to 1000 mm, suitable for medium-sized CNC (150-300 mm) or heavy-duty boring machines (400-1000 mm), extra-long (1200 mm) for deep hole boring (depth up to 30D).
Effective cutting length (l): 30 mm to 800 mm, shallow boring (30-100 mm) is suitable for surface finishing, deep boring (400-800 mm) is suitable for deep holes or multi-stage boring, and the ratio of cutting length to diameter is usually controlled at 5:1-25:1.
Helix angle: 10°-40°, standard value is 15°-30°, the spiral design optimizes chip discharge and vibration reduction, 25°-30° is commonly used for finishing to improve surface quality, 10°-20° can be selected for roughing to enhance strength, some customized models support gradual helix angle (10°-35°) to adapt to deep hole cutting.
cutting edges : 1-4 cutting edges , depending on the diameter and processing requirements. Small diameter (D<20 mm) has 1-2 edges, medium and large diameter (D>20 mm) has 2-4 edges. Increasing the number of edges can improve cutting efficiency but requires high-rigidity machine tool support. The edge spacing error is <0.02 mm.

The adjustable blade is designed with single or multiple blades . The adjustment mechanism includes precision thread (pitch 0.5-1 mm), eccentric adjustment (eccentricity 0.01-5 mm) or hydraulic fine adjustment (pressure 0.1-1 bar). It is processed by ultra- precision five-axis CNC grinding machine (accuracy ± 0.002 mm) to ensure the smoothness of the cutting edge (Ra ≤ 0.02 microns) and geometric accuracy. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration in high-speed boring (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-2.5 mm, pressure 5-25 bar) or external chip grooves (width 1-2.5 mm), which significantly improve chip removal (efficiency increased by 25%-40%) and thermal management (cutting zone temperature <600°C), suitable for deep hole boring or sticky material processing. Some models introduce a modular cutter head design. The cutter head and tool rod are connected by high-precision threads or bayonet connections (tolerance 6H/6g), which supports quick replacement and blade regrinding. The modular length can reach 800 mm.

3. Carbide adjustable boring tool material

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include:
YG6X: Cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 70-100 hours.
YT15: Contains titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span can reach 80-120 hours.
K30: Cobalt content 8%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially designed for aluminum alloys and non-ferrous metals, strong anti-adhesion, life span up to 100-150 hours.
Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting

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temperature (500-900°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance, oxidation resistance and microstructural uniformity.

4. Manufacturing of carbide adjustable boring cutters

The manufacturing process includes multiple precision steps from raw material preparation to final coating treatment, ensuring the geometric accuracy, durability and adjustable performance of the tool. The following is a detailed manufacturing process:

Raw materials preparation:

Material ratio: High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the brand (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance performance, and the particle size is controlled at 0.5-2 microns.

Mixing process: Wet mixing is performed using a planetary ball mill (50-100 RPM, 24-48 hours), with ethanol added as a dispersant to ensure powder homogeneity (segregation <1%).

Quality inspection: Laser particle size analyzer is used to detect particle size distribution, and X-ray fluorescence spectrometer (XRF) is used to analyze chemical composition. The deviation is controlled within ±0.05%.

Compression Molding:

Process parameters: Hydraulic press with 150-200 MPa pressure to form the tool body blank with a density of 14.5-15.2 g/cm³ , cold isostatic pressing (CIP, 150-200 MPa, 10-15 minutes) to improve uniformity.

Mould design: The mould is made of high-strength steel (hardness HRC 50-55), with a precision of ±0.02 mm. Laser cutting and EDM are used to ensure the forming accuracy of the blade and adjustment mechanism.

Quality Control: Density of the blanks is measured by Archimedean method (error < 0.1 g/cm³) , internal porosity is checked by microscopy (< 0.5%).

High temperature sintering :

Process conditions: vacuum furnace (pressure 10^{-2} Pa) or hydrogen protection, temperature 1400°C-1600°C, lasting 10-12 hours, staged heating (50°C per hour, preheating stage 300°C-600°C) to remove volatiles.

Process optimization: Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV).

Quality inspection: Scanning electron microscope (SEM) to analyze the microstructure, Vickers hardness tester to test the hardness (HV 1800-2200).

Post-processing:

Turning: External turning with CBN tools, run-out accuracy <0.01 mm, surface roughness Ra ≤ 0.2 microns.

Grinding: Ultra- precision five-axis CNC grinding machine for cutting edge and adjustment mechanism (accuracy ±0.002 mm), cutting edge profile error <0.005 mm, surface Ra ≤ 0.02 microns.

Polishing: Diamond abrasive with grain size W0.5-W1.0, edge Ra ≤ 0.01 micron, electrolytic

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polishing (current density 0.1 A/cm²) to remove microscopic burrs.

Edge treatment: Chamfered blade tip (0.1-0.2 mm, angle 5°-10°) to enhance chipping resistance, adjustment mechanism thread accuracy 6H/6g, geometry calibrated by laser interferometer.

Coating treatment:

Process technology: Coating is achieved by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h).

Coating type: TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), reduce friction coefficient (<0.3), increase service life by 30%-50%.

Quality inspection: SEM to check coating uniformity, nanoindenter to test hardness and adhesion (>70 N), thickness deviation <0.5 micron.

Testing packaging:

Performance testing: Coordinate measuring machine (CMM) checks diameter, blade accuracy and adjustment range (<0.01 mm), dynamic balancing machine corrects imbalance (<5 g·mm /kg).

Surface treatment: Anti-rust oil coating or vacuum packaging to prevent oxidation.

Marking: Laser engraved with diameter range, length, grade and batch number to ensure traceability.

Technical parameters of carbide adjustable boring tool

Hardness: substrate HV 1800-2200, after coating 3400 HV.

Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy, 100-300 m/min for aluminum alloy.

Feed rate (fz): 0.01-0.20 mm/rev.

Cutting depth (ap): 0.05-10 mm.

Tolerance: Diameter adjustment accuracy ±0.002 mm, hole diameter accuracy <0.005 mm.

Surface roughness: Ra 0.1-0.5 microns.

scenarios of carbide adjustable boring cutters

Carbide adjustable boring tools are widely used in many industrial fields due to their high precision and flexible adjustable characteristics. The following is a detailed scenario description, covering specific cases, technical data and industry background:

Mould manufacturing:

Application: Fine boring of guide holes , cooling holes and inner holes in molds , with diameters ranging from 10 to 30 mm and depths from 50 to 150 mm.

Case: A mold factory uses an adjustable boring tool with a diameter of 15-25 mm to fine bore the guide sleeve hole of the stamping die . The cutting speed is 120 m/min, the feed rate is 0.05 mm/rev, the adjustment accuracy is ±0.002 mm, the hole diameter tolerance after processing is ±0.003 mm, Ra is 0.2 microns, the tool life is 90 hours, and the annual output is 1,000 sets of molds, reducing tool replacement by 50%.

Technical features: High finish and coaxiality are required, and the internal cooling system (10 bar) supports deep hole processing.

auto industry:

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Application: Processing of engine cylinder bores, connecting rod bores and gearbox housing bores, with typical diameters ranging from 20-50 mm and depths of 80-200 mm.

Case: An automotive parts company uses a 30-40 mm diameter adjustable boring tool to process cylinder bores, with a cutting speed of 100 m/min, a feed rate of 0.08 mm/rev, an adjustment accuracy of ±0.002 mm, a hole roundness of <0.005 mm after processing, Ra 0.3 microns, a tool life of 110 hours, an annual output of 700,000 cylinders, and a 30% reduction in process time.

Industry background: The demand for processing multi-specification holes in electric vehicle motor housings has increased, and the flexibility of adjustable boring tools has become the key.

Aerospace:

Application: boring titanium alloy or high-strength steel fuselage connection holes and landing gear strut holes, common diameter range 15-40 mm, depth 100-300 mm.

Case: An airline company used a 20-30 mm diameter adjustable boring tool to process titanium alloy landing gear holes. The cutting speed was 60 m/min, the feed rate was 0.04 mm/rev, the adjustment accuracy was ±0.002 mm, the hole diameter tolerance after processing was ±0.004 mm, Ra was 0.2 microns, the tool life was 120 hours, and it met the AS9100 standard.

Technical features: Requires heat resistance and high precision, and internal cooling pressure must be above 15 bar.

Energy equipment manufacturing:

Application: Processing turbine shaft holes, pump body large holes and valve body holes, common diameter range is 40-80 mm, depth 200-500 mm.

Case: An energy equipment manufacturer uses a 50-70 mm diameter adjustable boring tool to process hydraulic pump body holes. The cutting speed is 90 m/min, the feed rate is 0.10 mm/rev, the adjustment accuracy is ±0.002 mm, the hole diameter error after processing is <0.01 mm, Ra is 0.4 microns, the tool life is 140 hours, and the annual output is 2,500 pump bodies, which improves efficiency by 35%.

the vibration resistance and cooling design of adjustable boring cutters are particularly important.

Heavy Machinery:

Application: Processing machine tool spindle holes, gear box inner holes and large casting holes, common diameter range is 60-120 mm, depth 300-800 mm.

Case: A machinery manufacturing company uses an adjustable boring cutter with a diameter of 80-100 mm to process the spindle hole of a machine tool. The cutting speed is 80 m/min, the feed rate is 0.12 mm/rev, the adjustment accuracy is ±0.002 mm, the hole roundness after processing is <0.008 mm, Ra is 0.5 microns, the tool life is 150 hours, and the annual output of 4,000 machine tool parts has increased efficiency by 30%.

and the rigidity and adjustability of adjustable boring tools have become a competitive advantage.

Precision instruments:

Application: boring optical instrument shaft holes, precision bearing seat holes and sensor mounting holes, common diameter range 5-20 mm, depth 20-100 mm.

Case: A precision instrument manufacturer uses a 10-15 mm diameter adjustable boring tool to process optical lens shaft holes, with a cutting speed of 70 m/min, a feed rate of 0.03 mm/rev, an adjustment accuracy of ±0.002 mm, a hole diameter tolerance of ±0.001 mm after processing, Ra 0.1 micron, a tool life of 80 hours, and an annual output of 500,000 instruments, in line with ISO

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2768 standards.

Technical features: Requires extremely high precision and surface quality, often uses DLC coating to reduce friction.

Precautions for using carbide adjustable boring tools

Machine tool: five-axis CNC or heavy-duty boring machine, runout <0.005 mm, spindle power ≥5 kW, it is recommended to use a high-rigidity spindle (guideway rigidity >4000 N/ µm).

Cooling: High-pressure cutting fluid (10-20 bar, 20-30 L/min) or internal cooling system (pressure 5-25 bar). Viscous materials (such as stainless steel) require enhanced cooling (flow rate increased to 35 L/min).

Parameters: Vc 100 m/min, fz 0.05-0.10 mm/rev, depth of cut segmented (5D per segment), recalibrate cutting parameters after adjustment to reduce vibration.

Installation: Coaxiality <0.002 mm, clamping force 40-80 Nm (taper shank or modular), calibrate the tool arbor and adjust the coaxiality of the mechanism before installation.

Wear: Replace when blade wear VB reaches 0.3 mm, hole diameter is out of tolerance (>0.01 mm) or surface scratches occur. Maintenance is required when the adjustment mechanism is worn (clearance >0.01 mm). It is recommended to check every 20 hours and record wear data to optimize the usage cycle.

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appendix:

What are Carbide Reamers ?

Carbide reamers are precision tools used for finishing holes in machining. With their excellent hardness and wear resistance, they provide reliable guarantees for the surface finish and dimensional accuracy of workpieces. These reamers can carefully trim pre-drilled holes through slow rotation and small feed movements to make the hole diameter meet the design requirements. They are widely used in manufacturing fields that require high precision and high quality. Carbide reamers are based on tungsten carbide (WC), with cobalt (Co) added as a binder, and sintered through advanced powder metallurgy processes. Common material grades include YG6 (moderate hardness, suitable for general processing), YT10 (excellent heat resistance, suitable for steel) and YW1 (strong comprehensive performance, suitable for complex materials). Its design forms are diverse, with both integral carbide structures and adjustable or multi- blade configurations. The cutter body is usually made of high-strength steel or carbide to ensure stability during precision machining.

1. Geometry design and optimization

The geometric design of carbide reamers is the core of high-precision machining. Designers carefully adjust parameters to improve performance and service life. The front angle is usually set between 0° and 5°. This small angle design helps to reduce cutting force and ensure surface finish; the back angle is generally between 5° and 10° to ensure smooth contact between the reamer and the hole wall to avoid excessive wear; the chamfer of the cutting edge (0.05-0.1 mm) enhances durability by dispersing stress, especially in finishing. Straight- blade reamers are suitable for standard hole processing, with a diameter range of 5 to 50 mm and a number of blades from 4 to 8; spiral- blade reamers use a helix angle of 15° to 30° to improve chip discharge, especially for deep holes or sticky materials; adjustable reamers achieve fine adjustment of the aperture through a fine-tuning mechanism, and are widely used in multi-process and strict tolerance processing. Geometry optimization combines computer-aided design (CAD) and machining simulation to ensure that the reamer remains stable during slow finishing (up to 2000 rpm), and the chip flute width (1-2 mm) is adjusted according to the hole diameter and material to ensure smooth chip evacuation.

2. Coating and surface treatment

Coating technology has given carbide reamers additional performance advantages, enabling them to adapt to more complex machining environments. PVD (physical vapor deposition) coatings such as TiN (golden yellow, 2-5 microns thick) provide good wear protection and are particularly suitable for machining aluminum alloys and copper; CVD (chemical vapor deposition) coatings such as TiAlN (purple black, 5-15 microns thick) are ideal for finishing steel and cast iron with their heat resistance up to 1000°C. In terms of surface treatment, the polishing process controls the surface roughness to Ra <0.1 microns to ensure a smooth and delicate surface inside the hole; laser micro-texturing technology carves micro-lubrication grooves on the surface of the reamer to reduce the friction coefficient; some high-end reamers use nano-coatings (such as nano- TiAlN , with grains less than 50 nanometers), which significantly improves performance in ultra-precision machining. The coating adhesion is verified by scratch testing (critical load >70 N) to ensure that the coating

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will not peel off during long-term use.

3. Technical characteristics and performance

The technical performance of carbide reamers makes them the best in the field of finishing and has won a wide range of applications. The cutting speed ranges from 20 to 100 m/min, depending on the workpiece material. For example, steel is usually 50 to 80 m/min, while aluminum alloys can reach 80 to 100 m/min. In terms of hardness, the hardness of reamers is generally between HV 1800 and 2100. YT10 can reach HV 2000 to 2100 due to titanium carbide, which is enough to cope with high-hardness workpieces. The fracture toughness is 12 to 16 MPa· $m^{1/2}$. The YG6 grade has balanced toughness due to its moderate cobalt content (6%), which is particularly suitable for continuous finishing. The wear resistance is less than 0.02 cubic millimeters per Newton meter, and after coating, it is further reduced to 0.015 cubic millimeters per Newton meter, which greatly extends the service life. Heat resistance up to 1000°C (thanks to CVD coating), making it stable in high temperature environments . Processing accuracy is controlled within 0.002 mm, meeting the strict requirements of high-precision hole processing .

4. Processing requirements and applications

The processing requirements and application scenarios of carbide reamers reflect their unique value in precision manufacturing. Cutting parameters vary depending on the material. For example, the cutting speed of steel is 50 to 80 meters per minute, the feed rate is 0.02 to 0.1 mm per revolution, and the cutting depth is 0.1 to 0.5 mm; aluminum alloys require a cutting speed of 80 to 100 meters per minute, a feed rate of 0.05 to 0.15 mm per revolution, and a cutting depth of 0.2 to 0.8 mm. The choice of cooling method is also critical . Dry cutting is suitable for aluminum alloys and can reduce the use of coolant; wet cutting using emulsion or oil-based coolant is more suitable for steel and cast iron, which can effectively reduce thermal damage; for deep hole reaming, low-pressure cooling (5-10 bar) significantly improves chip removal efficiency through external spraying. In practical applications, the automotive industry often uses reamers to fine-tune the guide holes of connecting rods and cylinder blocks, which requires high precision and surface quality; mold manufacturing relies on it to trim the locating holes of stamping dies, focusing on the consistency of hole diameters; the aviation industry, such as the cooling hole processing of turbine blades, also relies on its excellent performance.

5. Challenges and Solutions

There are some challenges when using carbide reamers, but these problems can be properly solved through scientific coping strategies. During the reaming process , poor chip removal is a common problem in deep hole processing, which can be alleviated by optimizing the spiral blade design and adding self-lubricating coatings (such as MoS_2); heat accumulation is prone to occur during continuous finishing, and an efficient cooling system and heat-resistant coating can effectively control the temperature; reamer runout may cause hole diameter deviation, and the use of a high-rigidity tool body and edge polishing can improve stability; for sticky materials, surface adhesion is the main problem, and regular cleaning or the use of low-friction coatings can significantly extend the service life. These solutions together ensure the reliability of the reamer in complex working

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conditions.

6. Optimization and development trends

The optimization and development direction of cemented carbide reamers reflect the industry's pursuit of efficiency and intelligence. In terms of structural optimization, the integrated external spray cooling channel can effectively reduce the temperature of the reamer, the adjustable cutter head design is convenient for adapting to different apertures, and the dynamic balancing technology improves the stability of low-speed finishing. In terms of material innovation, nano-cemented carbide improves hardness and toughness with its fine grains (less than 0.5 microns), and the gradient material design allows the reamer to have both high hardness and high toughness. The trend of intelligence allows sensors to be embedded in the reamer to monitor wear and temperature in real time, and dynamically adjust the reaming parameters in combination with artificial intelligence algorithms . In terms of manufacturing technology, 3D printing technologies such as selective laser melting (SLM) can create complex reamer structures, such as optimizing cooling channels, while laser deposition technology provides the possibility of repairing worn reamers. The environmental protection trend has promoted the development of dry cutting coatings (such as graphene composite coatings), reducing dependence on coolants, while the use of recyclable materials also reduces environmental impact.

7. Lifespan and maintenance

The life of carbide reamers varies depending on the processing conditions and workpiece materials, and is generally between 20 and 40 hours, such as about 25 hours for steel processing and up to 35 hours for aluminum alloy processing. Maintenance work includes regular sharpening , using diamond grinding wheels to ensure that the angle error is less than 0.5°, coating repair through CVD technology to restore performance, and laser pre-adjustment to ensure that the error is less than 0.002 mm. These measures can effectively extend the service life of the reamer. After the reamer is scrapped, the tungsten and cobalt materials in it can be recycled and reused by smelting and returning to the furnace, reflecting the concept of sustainable development.

8. Detailed classification

Carbide reamers can be divided into several categories according to processing requirements and application scenarios, each type has its own unique design and purpose:

Straight blade reamer

Suitable for finishing of standard holes, with diameters ranging from 5 to 50 mm and blade numbers ranging from 4 to 8. Rake angle 0° to 3°, back angle 5° to 8°, YG6 grade, TiN coating (thickness 2-5 microns) for wear resistance. Cutting speed 50 to 80 m/min, accuracy below 0.002 mm, widely used for general hole processing.

Spiral blade reamer

Use a helix angle of 15° to 30° to improve chip evacuation, a diameter range of 10 to 40 mm, and 6 to 10 edges . The rake angle is 2° to 5°, the back angle is 6° to 10°, and the YT10 grade is selected. The TiAlN coating (thickness 5-15 microns) enhances heat resistance. The cutting speed is 40 to 100 meters per minute, and the accuracy is less than 0.002 mm, which is common in deep holes and

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sticky materials.

Adjustable reamer

The fine adjustment of the hole diameter is achieved through the fine adjustment mechanism, and the drilling diameter range is 20 to 100 mm. The rake angle is 0° to 5°, the back angle is 5° to 10°, and the YW1 grade is selected. The multi-layer coating (such as TiN+Al_2O_3) provides comprehensive performance. The cutting speed is 30 to 80 meters per minute, and the accuracy is less than 0.002 mm. It is widely used in multi-process and strict tolerance processing.

9. Selection and matching

Choosing the right carbide reamer requires a comprehensive consideration of the workpiece material and the type of processing. For example, YT10 spiral blade reamer is suitable for finishing steel, YG6 straight blade reamer is suitable for aluminum alloy processing, and YW1 adjustable reamer with multi-layer coating is more suitable for complex hole processing . The performance of the machine tool is also critical, the spindle power needs to exceed 3 kilowatts and the speed should reach 500 to 2000 rpm to fully utilize the potential of the reamer.

1 0 . Classification summary table

Reamer Type	Number of blades	Diameter(mm)	Rake angle (°)	Relief angle (°)	Applicable grades	Coating Type	Cutting speed (m/min)	Depth of cut (mm)	Accuracy (mm)	Typical Applications
Straight blade reamer	4-8	5-50	0-3	5-8	YG6	TiN (2-5 µm)	50-80	0.1-0.5	<0.002	Universal hole, steel
Spiral blade reamer	6-10	10-40	2-5	6-10	YT10	TiAlN (5-15 µm)	40-100	0.2-0.8	<0.002	Deep holes, viscous materials
Adjustable reamer	-	20-100	0-5	5-10	YW1	TiN + Al_2O_3	30-80	0.1-0.5	<0.002	Complex holes, multiple processes

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appendix

What is a Carbide Straight Edge Reamer?

1. Overview

1.1 Definition and Function

Carbide straight blade reamer is a high-performance cutting tool designed for high-precision hole processing and surface finish optimization. It is widely used in mechanical processing, mold manufacturing, aerospace, automotive industry, medical device production and precision instrument manufacturing. Its core feature is the straight blade (no helix angle) multi-edge design, combined with the excellent performance of the overall cemented carbide material, it can achieve the finishing of pre-drilled holes, dimensional correction and surface smoothness improvement. Carbide straight blade reamer is based on cemented carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, suitable for reaming high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy, cast iron and aluminum alloy. The straight -edge design reduces cutting force fluctuations (force dispersion rate <15%) and chip entanglement through a straight cutting edge. It is widely suitable for CNC machine tools (CNC), drilling machines, machining centers or special reaming equipment, and can efficiently complete hole fine reaming, dimensional finishing and roundness correction. The processing accuracy can reach IT5-IT6 level and the surface roughness can reach Ra 0.05-0.4 microns. Compared with spiral -edge reamers, carbide straight-edge reamers have higher precision stability and cutting consistency (roundness error <0.003 mm) in the processing of straight-wall holes or short-depth holes (L/D<5:1), which is particularly suitable for scenes requiring extremely high surface quality and dimensional tolerance. It has high design flexibility and can customize the number of blades , blade geometry and shank type according to the hole diameter, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software and online monitoring systems to optimize cutting parameters through real-time data feedback.

1.2 Development Background

With the rise of Industry 4.0 and smart manufacturing technology, the demand for high-precision hole processing tools has increased significantly. Carbide straight- edge reamers have gradually replaced traditional high-speed steel reamers in high-end manufacturing due to their excellent processing performance and adaptability, especially in the fields of aerospace and medical devices. In 2025, with the application and promotion of new alloy materials (such as high-entropy alloys), higher requirements are placed on the heat resistance and wear resistance of straight -edge reamers, which promotes further innovation in tool materials and coating technology.

2. Technical characteristics

2.1 Structural characteristics

carbide straight blade reamers aims to achieve high-precision reaming, excellent surface quality and

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vibration resistance . They usually adopt straight shank or tapered shank structure, with straight blade multi-edge layout, combined with axial cutting ability to adapt to precision hole processing. The diameter range is from 3 mm to 50 mm. Micro straight blade reamers (D<6 mm) are used for micro hole precision reaming, medium-sized (D=6-20 mm) are suitable for general hole processing, and large (D>20 mm) are used for heavy reaming. The tolerance grade is h7 (0/-0.01 mm). The shank types include straight shank (DIN 6535 HA/HB) or tapered shank (BT40, CAT50). The shank diameter matches the cutting diameter, the tolerance grade is h6 (0/-0.006 mm), and the shank length (50-300 mm) is customized according to the processing depth and machine tool clamping requirements. The tapered shank enhances high torque transmission (torque range 20-150 Nm). The total length is 100 mm to 500 mm, suitable for small CNC (100-200 mm) or heavy machining center (300-500 mm), and the extra-long type (600 mm) is used for deep hole reaming (depth up to 10D). The effective cutting length is 20 mm to 400 mm. Shallow reaming (20-80 mm) is suitable for surface finishing, and deep reaming (200-400 mm) is suitable for deep holes or multi-stage reaming. The ratio of cutting length to diameter is usually controlled at 3:1-10:1. The number of cutting edges is 2-8 cutting edges, depending on the diameter and machining accuracy. Small diameters (D<10 mm) are 2-4 edges, and medium and large diameters (D>10 mm) are 4-8 edges. Increasing the number of edges can improve cutting efficiency but requires high-rigidity machine tool support. The error of the spacing between edges is <0.01 mm. The blade angle is a straight blade design (helix angle 0°), the blade tip angle is usually 90°-120° (customizable), and the blade guide section length accounts for 10%-20% of the total length to ensure smooth hole walls. The straight blade adopts a multi- edge straight cutting design and is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure smooth cutting edges (Ra ≤ 0.02 microns) and geometric accuracy. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 12000 RPM) to reduce vibration during high-speed reaming (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.3-1.5 mm, pressure 5-15 bar) or external chip grooves (width 0.5-1 mm), which significantly improve chip removal (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <500°C), suitable for deep hole reaming or sticky material processing. Some models have introduced a replaceable cutter head design, where the cutter head and cutter bar are connected by high-precision threads (tolerance 6H/6g), which facilitates quick replacement and blade regrinding.

2.2 Materials

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include YG6X (cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 80-120 hours), YT15 (containing titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloy, life can reach 90-130 hours), K20 (cobalt content 8%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially for aluminum alloys and non-ferrous metals, strong anti-adhesion, life can reach 100-150 hours). Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (400-700°C). Some models

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add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance and microstructure.

3. Manufacturing process

3.1 Raw material preparation

High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the grade (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) are added to enhance the performance, and the particle size is controlled at 0.5-2 microns. A planetary ball mill (speed 50-100 RPM, time 24-48 hours) is used for wet mixing, and ethanol is added as a dispersant to ensure powder uniformity (segregation <1%). The particle size distribution is detected by a laser particle size analyzer, and the chemical composition is analyzed by an X-ray fluorescence spectrometer (XRF), and the deviation is controlled within ±0.05%.

3.2 Pressing

The hydraulic press applies 150-200 MPa pressure to form the blade blank, with a density of 14.5-15.2 g/cm³ . Cold isostatic pressing (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of high-strength steel (hardness HRC 50-55) with an accuracy of ±0.02 mm. Laser cutting and EDM are used to ensure the forming accuracy of the straight blade. The blank density is measured by the Archimedean method (error <0.1 g/cm³) , and the internal porosity is checked by microscope (<0.5%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2200).

3.4 Post-processing

External turning is performed using CBN tools, with runout accuracy <0.01 mm and surface roughness Ra ≤ 0.2 microns. Ultra- precision five-axis CNC grinding machines are used to process straight blades (accuracy ±0.002 mm), with edge profile error <0.005 mm and surface Ra ≤ 0.02 microns. Diamond abrasives with grain size W0.5-W1.0 are used for mirror polishing, with edge Ra ≤ 0.01 microns, and electrolytic polishing (current density 0.1 A/cm²) is used to remove microscopic burrs. The blade tip is chamfered (0.1-0.2 mm, angle 5°-10°) to enhance the ability to resist edge collapse, and the blade geometry is calibrated by laser interferometer.

3.5 Coating treatment

by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h). Coating types include TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), reducing the friction coefficient (<0.3) and increasing the service life by 30%-50%. SEM checks the uniformity of the coating, and the nanoindenter tests the hardness and

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adhesion (>70 N), with a thickness deviation of <0.5 microns.

3.6 Testing packaging

Coordinate measuring machines (CMM) are used to check diameter and blade accuracy (<0.01 mm), and dynamic balancing machines are used to correct imbalance (<5 g·mm /kg). Anti-rust oil coating or vacuum packaging is used to prevent oxidation. Laser engraving of diameter, length, number of blades , brand and batch number ensures traceability.

4. Technical parameters

Hardness: substrate HV 1800-2200, coated HV 3400. Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 30-120 m/min for steel, 20-80 m/min for titanium alloy, 80-200 m/min for aluminum alloy.

Feed rate (fz): 0.01-0.10 mm/rev. Depth of cut (ap): 0.01-2 mm (fine reaming).

Tolerance: diameter ±0.005 mm, hole accuracy <0.003 mm. Surface roughness: Ra 0.05-0.4 microns.

5. Application scenarios

5.1 Mould manufacturing

Precision reaming of mold guide pin holes, positioning holes and cooling holes, common diameters are 6-20 mm and depths are 20-80 mm. A mold factory uses a 10 mm diameter straight blade reamer to precision ream the guide pin holes of stamping molds, with a cutting speed of 80 m/min, a feed rate of 0.03 mm/rev, a hole diameter tolerance of ±0.002 mm after processing, Ra 0.1 micron, a tool life of 100 hours, an annual output of 1,500 sets of molds, and an efficiency improvement of 30%. High finish and coaxiality are required, and the internal cooling system (10 bar) supports deep hole processing.

5.2 Automobile Industry

Precision reaming of engine cylinder bores, connecting rod bores and gearbox shaft bores, with common diameters of 15-40 mm and depths of 30-120 mm. An automotive parts company uses a 20 mm diameter straight- edged reamer to precision ream cylinder bores, with a cutting speed of 70 m/min and a feed rate of 0.02 mm/rev. The roundness of the processed holes is <0.002 mm, Ra is 0.05 microns, and the tool life is 120 hours. The annual output is 800,000 cylinders, and the process time is reduced by 20%. The electric vehicle transmission system has higher requirements for the roundness and finish of the holes, and the high precision of the straight- edged reamer has become an advantage.

5.3 Aerospace

Precision reaming of titanium alloy or high-strength steel fuselage connection holes and landing gear strut holes, common diameter 10-30 mm, depth 50-150 mm. An airline uses a 15 mm diameter straight blade reamer to process titanium alloy connection holes, cutting speed 50 m/min, feed rate 0.02 mm/rev, after processing, the hole diameter tolerance is ±0.001 mm, Ra 0.05 microns, tool life 130 hours, in line with AS9100 standards. Heat resistance and extremely high precision are required, and the internal cooling pressure must be above 15 bar.

5.4 Medical Devices

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Precision reaming of orthopedic implant inner holes or surgical instrument positioning holes, common diameters are 4-12 mm and depths are 10-50 mm. A medical company uses a 6 mm diameter straight blade reamer to process titanium alloy hip joint inner holes, with a cutting speed of 40 m/min, a feed rate of 0.01 mm/rev, a hole diameter tolerance of ±0.001 mm after processing, Ra 0.03 microns, and a tool life of 90 hours, which meets FDA biocompatibility standards . Extremely high precision and surface quality are required, and TiAlN coating is often used to reduce metal contamination.

5.5 Precision Instruments

Precision reaming of optical instrument shaft holes, precision bearing seat holes and sensor mounting holes, with common diameters of 5-15 mm and depths of 20-80 mm. A precision instrument manufacturer uses a straight- edged reamer with a diameter of 8 mm to process the shaft holes of optical lenses, with a cutting speed of 60 m/min, a feed rate of 0.02 mm/rev, a hole diameter tolerance of ±0.001 mm after processing, Ra 0.04 microns, a tool life of 110 hours, and an annual output of 600,000 instruments, in line with ISO 2768 standards. As semiconductors and optical equipment have increased their requirements for micro-hole precision, the high stability and smoothness of straight- edged reamer have become key.

5.6 Energy equipment manufacturing

Precision reaming of turbine shaft holes and pump body inner holes, common diameters are 20-50 mm and depths are 100-300 mm. An energy equipment manufacturer uses a 30 mm diameter straight- edge reamer to process hydraulic pump body holes, with a cutting speed of 70 m/min and a feed rate of 0.03 mm/rev. The hole diameter error after processing is <0.002 mm, Ra 0.06 microns, and a tool life of 140 hours. The annual output is 2,000 pump bodies, and the efficiency is increased by 25%. High precision and durability are required, and the internal cooling system needs high pressure support (15 bar).

6. Precautions for use

6.1 Machine tool requirements

Three-axis or five-axis CNC, runout <0.003 mm, spindle power ≥3 kW, it is recommended to use a high-rigidity spindle (guideway rigidity >3000 N/ μm).

6.2 Cooling and lubrication

High-pressure cutting fluid (10 bar, 15-20 L/min) or internal cooling system (pressure 5-15 bar), viscous materials (such as stainless steel) require enhanced cooling (flow rate increased to 25 L/min).

6.3 Cutting parameters

Vc 70 m/min, fz 0.02-0.05 mm/rev, depth of cut segmented (3D per segment), feed rate halved during fine reaming to optimize surface quality.

6.4 Installation and calibration

Coaxiality <0.001 mm, clamping force 20-40 Nm (straight shank) or 40-60 Nm (taper shank), clean the residual chips in the chuck before installation.

6.5 Wear and maintenance

Replace it when the blade wear VB reaches 0.2 mm, the hole diameter is out of tolerance (>0.005 mm), or there are surface scratches. It is recommended to check it every 15 hours and record the

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wear data to optimize the usage cycle.

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appendix:

What is a Carbide Spiral Edge Reamer?

1. Overview

1.1 Definition and Function

Carbide spiral blade reamer is a high-performance cutting tool designed for high-precision hole processing and efficient chip removal. It is widely used in mechanical processing, mold manufacturing, aerospace, automotive industry, energy equipment production and precision instrument manufacturing. Its core feature is the use of spiral blade (with helix angle) multi-edge design, combined with the excellent performance of overall cemented carbide materials, it can achieve the finishing of pre-drilled holes, size correction and surface finish optimization, and has good chip removal ability. Carbide spiral blade reamer is based on cemented carbide, with high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, suitable for reaming high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy, cast iron and aluminum alloy. The spiral blade design improves chip removal efficiency (efficiency increased by 30%-40%) and vibration reduction effect (vibration reduced by 20%-30%) by tilting the cutting edge and the helix angle (usually 10°-40°). It is widely suitable for CNC machine tools (CNC), drilling machines, machining centers or special reaming equipment, and can efficiently complete the fine reaming, deep hole processing and roundness correction of holes. The processing accuracy can reach IT5-IT7 level, and the surface roughness can reach Ra 0.05-0.5 microns.

Carbide spiral blade reamers have higher efficiency and stability (hole wall finish consistency increased by 15%) in deep hole (L/D>5:1) or viscous material processing, and are particularly suitable for scenarios that require continuous cutting and long life. Its design is highly flexible, and the helix angle, number of blades and shank type can be customized according to the hole diameter, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software and sensor systems to optimize cutting parameters through real-time data feedback.

1.2 Development Background

With the increasing demand for deep hole processing and complex material processing in modern manufacturing, carbide spiral blade reamers have gradually become the mainstream of the industry due to their efficient chip removal and vibration resistance, especially in the fields of aerospace and energy equipment. In 2025, with the widespread application of high-performance alloys (such as titanium-based alloys) and composite materials, higher requirements are placed on the heat resistance, cutting efficiency and surface quality of spiral blade reamers, which promotes the continuous innovation of tool geometry design and coating technology.

2. Technical characteristics

2.1 Structural characteristics

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carbide spiral blade reamers is aimed at achieving efficient reaming, excellent chip evacuation and vibration resistance . They usually adopt straight shank or tapered shank structure, with spiral blade multi-edge layout, combining axial and radial cutting capabilities to adapt to deep hole and complex hole processing. The diameter range is from 5 mm to 80 mm. Micro spiral blade reamers (D<10 mm) are used for micro hole precision reaming, medium-sized (D=10-30 mm) are suitable for general hole processing, and large (D>30 mm) are used for heavy or deep hole reaming. The tolerance grade is h7 (0/-0.01 mm). The shank types include straight shank (DIN 6535 HA/HB) or tapered shank (BT40, CAT50, HSK-A63). The shank diameter matches the cutting diameter, the tolerance grade is h6 (0/-0.006 mm), and the shank length (100-400 mm) is customized according to the processing depth and machine tool clamping requirements. The tapered shank supports high torque transmission (torque range 30-200 Nm). The total length is 150 mm to 800 mm, suitable for medium-sized CNC (150-300 mm) or heavy-duty machining centers (400-800 mm), and the extra-long type (1000 mm) is used for ultra-deep hole reaming (depth up to 20D). The effective cutting length is 30 mm to 600 mm. Shallow reaming (30-100 mm) is suitable for surface finishing, and deep reaming (300-600 mm) is suitable for deep holes or multi-stage reaming. The ratio of cutting length to diameter is usually controlled at 5:1-20:1. The number of cutting edges is 2-10 cutting edges, depending on the diameter and processing requirements. Small diameters (D<15 mm) are 2-4 edges, and medium and large diameters (D>15 mm) are 4-10 edges. Increasing the number of edges can improve cutting efficiency but requires high-rigidity machine tool support. The error of the spacing between edges is <0.01 mm. The helix angle is 10°-40°, the standard value is 15°-30°, the helix design optimizes chip removal and vibration reduction, 25°-30° is commonly used for fine processing to improve surface quality, and 30°-40° can be selected for deep hole processing to enhance chip removal. The length of the blade guide section accounts for 10%-20% of the total length to ensure smooth hole walls. The spiral blade is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure smooth edges (Ra ≤ 0.02 microns) and geometric accuracy. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration during high-speed reaming (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-2 mm, pressure 5-20 bar) or external chip grooves (width 1-2 mm), which significantly improve chip removal (efficiency increased by 35%-40%) and thermal management (cutting zone temperature <600°C), suitable for deep hole reaming or sticky material processing. Some models introduce modular tool head design, the tool head and tool rod are connected by high-precision threads or bayonet (tolerance 6H/6g), support quick replacement and blade re-grinding, and the modular length can reach 800 mm.

2.2 Materials

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include YG6X (cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 90-130 hours), YT15 (containing titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloy, life can reach 100-140 hours), K30 (cobalt content 8%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially for aluminum alloys and non-ferrous metals, strong anti-adhesion, life can reach 110-160 hours). Material selection needs to consider the

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workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (500-800°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance, oxidation resistance and microstructural uniformity.

3. Manufacturing process

3.1 Raw material preparation

High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the grade (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) are added to enhance the performance, and the particle size is controlled at 0.5-2 microns. A planetary ball mill (speed 50-100 RPM, time 24-48 hours) is used for wet mixing, and ethanol is added as a dispersant to ensure powder uniformity (segregation <1%). The particle size distribution is detected by a laser particle size analyzer, and the chemical composition is analyzed by an X-ray fluorescence spectrometer (XRF), and the deviation is controlled within ±0.05%.

3.2 Pressing

The hydraulic press applies 150-200 MPa pressure to form the blade blank, with a density of 14.5-15.2 g/cm³ , and cold isostatic pressing technology (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of high-strength steel (hardness HRC 50-55) with an accuracy of ±0.02 mm. Laser cutting and EDM are used to ensure the forming accuracy of the spiral blade. The blank density is measured by the Archimedean method (error <0.1 g/cm³) , and the internal porosity is checked by microscope (<0.5%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2200).

3.4 Post-processing

External turning is performed using CBN tools with runout accuracy <0.01 mm and surface roughness Ra ≤ 0.2 microns. The spiral blade is machined on an ultra -precision five-axis CNC grinder (accuracy ±0.002 mm), with edge profile error <0.005 mm and surface Ra ≤ 0.02 microns. Mirror polishing with diamond abrasives of grain size W0.5-W1.0, edge Ra ≤ 0.01 microns, and electrolytic polishing (current density 0.1 A/cm²) removes microscopic burrs. The blade tip is chamfered (0.1-0.2 mm, angle 5°-10°) to enhance the ability to resist edge collapse, and the blade geometry is calibrated by laser interferometer.

3.5 Coating treatment

by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h). Coating types include TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction

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coefficient <0.1), reducing the friction coefficient (<0.3) and increasing the service life by 30%-50%. SEM checks the uniformity of the coating, and the nanoindenter tests the hardness and adhesion (>70 N), with a thickness deviation of <0.5 microns.

3.6 Testing and packaging

Coordinate measuring machines (CMM) are used to check diameter and blade accuracy (<0.01 mm), and dynamic balancing machines are used to correct imbalance (<5 g·mm /kg). Anti-rust oil coating or vacuum packaging is used to prevent oxidation. Laser engraving of diameter, length, number of blades , brand and batch number ensures traceability.

4. Technical parameters

Hardness: substrate HV 1800-2200, coated HV 3400. Heat resistance: 600°C-1000°C.

Cutting speed (Vc): steel 40-150 m/min, titanium alloy 25-100 m/min, aluminum alloy 100-250 m/min.

Feed rate (fz): 0.01-0.15 mm/rev. Depth of cut (ap): 0.01-3 mm (fine reaming).

Tolerance: diameter ±0.005 mm, hole accuracy <0.003 mm.

Surface roughness: Ra 0.05-0.5 microns.

5. Application scenarios

5.1 Mould manufacturing

Precision reaming of mold guide holes , cooling holes and inner holes, common diameters are 10-30 mm and depths are 50-150 mm. A mold factory uses a 20 mm diameter spiral blade reamer to precision ream stamping mold cooling holes, with a cutting speed of 100 m/min, a feed rate of 0.05 mm/rev, a hole diameter tolerance of ±0.002 mm after processing, Ra 0.1 micron, a tool life of 110 hours, an annual output of 1,200 sets of molds, and an efficiency improvement of 35%. Efficient chip removal and deep hole processing capabilities are required, and internal cooling system (15 bar) support.

5.2 Automobile Industry

Precision reaming of engine cylinder bores, crankshaft bores and gearbox housing bores, with common diameters of 20-50 mm and depths of 80-200 mm. An automotive parts company uses a 30 mm diameter spiral blade reamer to precision ream cylinder bores, with a cutting speed of 90 m/min, a feed rate of 0.04 mm/rev, and a hole roundness of <0.003 mm after processing, Ra 0.05 microns, a tool life of 130 hours, and an annual production of 700,000 cylinders, reducing process time by 25%. The demand for deep hole processing in electric vehicle motor housings has increased, and the high efficiency of spiral blade reamers has become an advantage.

5.3 Aerospace

Precision reaming of titanium alloy or high-strength steel fuselage connection holes and landing gear strut holes, common diameter 15-40 mm, depth 100-300 mm. An airline uses a 25 mm diameter spiral blade reamer to process titanium alloy connection holes, cutting speed 60 m/min, feed rate 0.03 mm/rev, after processing, the hole diameter tolerance is ±0.002 mm, Ra 0.05 microns, tool life 140 hours, in line with AS9100 standards. Heat resistance and deep hole processing capabilities are required, and the internal cooling pressure must reach 20 bar.

5.4 Energy equipment manufacturing

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Precision reaming of turbine shaft holes, large pump body holes and valve body holes, with common diameters of 30-70 mm and depths of 200-500 mm. An energy equipment manufacturer uses a 40 mm diameter spiral blade reamer to process hydraulic pump body holes, with a cutting speed of 80 m/min and a feed rate of 0.06 mm/rev . The hole diameter error after processing is <0.003 mm, Ra 0.1 micron, and a tool life of 150 hours. The annual output is 2,500 pump bodies, and the efficiency is increased by 30%. As wind power and nuclear power equipment have higher requirements for deep hole accuracy, the chip removal design of spiral blade reamer is particularly important.

5.5 Precision Instruments

Precision reaming of optical instrument shaft holes and sensor mounting holes, common diameters are 5-20 mm and depths are 30-100 mm. A precision instrument manufacturer uses a 10 mm diameter spiral blade reamer to process optical lens shaft holes, with a cutting speed of 70 m/min, a feed rate of 0.02 mm/rev, a processed hole diameter tolerance of ±0.001 mm, Ra 0.04 microns, a tool life of 120 hours, and an annual output of 500,000 instruments, in line with ISO 2768 standards. With the increasing demand for deep processing of micro-holes, the high stability of spiral blade reamer has become the key.

5.6 Shipbuilding

Precision reaming of marine engine cylinder bores and propeller shaft holes, common diameters are 50-100 mm and depths are 300-800 mm. A shipyard uses a 80 mm diameter spiral blade reamer to process propeller shaft holes, with a cutting speed of 70 m/min, a feed rate of 0.08 mm/rev, a hole diameter tolerance of ±0.003 mm after processing, Ra 0.1 micron, a tool life of 160 hours, an annual output of 200 propellers, and an efficiency increase of 40%. High rigidity and deep hole processing capabilities are required , and the internal cooling system requires high pressure support (20 bar).

6. Precautions for use

6.1 Machine tool requirements

Five-axis CNC or heavy-duty drilling machine, runout <0.003 mm, spindle power ≥5 kW, it is recommended to use a high-rigidity spindle (guideway rigidity >4000 N/ µm).

6.2 Cooling and lubrication

High-pressure cutting fluid (10-20 bar, 20-30 L/min) or internal cooling system (pressure 5-20 bar), viscous materials (such as stainless steel) require enhanced cooling (flow rate increased to 35 L/min).

6.3 Cutting parameters

Vc 90 m/min, fz 0.03-0.08 mm/rev, depth of cut segmented (5D per segment), feed rate halved for deep hole machining to optimize chip evacuation.

6.4 Installation and calibration

Coaxiality <0.001 mm, clamping force 30-60 Nm (taper shank) or 40-80 Nm (modular), calibrate the coaxiality of the tool shank and spindle before installation.

6.5 Wear and maintenance

Replace it when the blade wear VB reaches 0.2 mm, the hole diameter is out of tolerance (>0.005 mm), or there are surface scratches. It is recommended to check it every 20 hours and record the wear data to optimize the service life.

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appendix:

What is a Carbide Adjustable Reamer?

1. Overview

1.1 Definition and Function

The carbide adjustable reamer is a high-performance cutting tool designed for high-precision hole processing and flexible size adjustment. It is widely used in mechanical processing, mold manufacturing, aerospace, automotive industry, medical device production, precision instrument manufacturing and other fields. Its core feature is the combination design of adjustable cutter head and carbide cutting edge . It can accurately adjust the cutting diameter through the precision adjustment mechanism to meet various hole diameter requirements and achieve high-precision processing. The carbide adjustable reamer is based on carbide and has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance. It is suitable for reaming high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy, cast iron and aluminum alloy. The adjustable design achieves diameter adjustment (adjustment range 0.01-5 mm, accuracy ±0.002 mm) through threads, eccentricity or hydraulic mechanisms. It is widely applicable to CNC machine tools (CNC), drilling machines, machining centers or special reaming equipment, and can efficiently complete hole precision reaming, size correction and surface finish optimization. The machining accuracy can reach IT4-IT6 level, and the surface roughness can reach Ra 0.05-0.4 microns. Carbide adjustable reamer has higher flexibility (adaptability increased by 50%-70%) and economy (reduced tool replacement frequency) in small-batch production, multi-specification hole processing or aperture fine-tuning scenarios, and is particularly suitable for complex workpiece processing that requires high precision and dynamic adjustment. Its design is highly flexible, and the blade geometry, adjustment mechanism and shank type can be customized according to the aperture range, depth and workpiece material. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAM software and sensor systems to optimize cutting parameters through real-time data feedback.

1.2 Development Background

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With the increasing demand for customized production and multi-variety small batch processing, carbide adjustable reamers are gradually favored in the field of precision manufacturing due to their flexibility and high precision. In 2025, as high-end manufacturing industries (such as aerospace and medical devices) have higher requirements for hole processing tolerances and surface quality, the fine-tuning technology and durability of adjustable reamers have become the focus of industry development, promoting the continuous optimization of tool design and material technology.

2. Technical characteristics

2.1 Structural characteristics

The structural design of carbide adjustable reamers aims to achieve high-precision reaming, adjustability and excellent surface quality. They usually adopt straight shank or tapered shank structure, with single-edge or multi-edge layout of the blade, and equipped with precision adjustment mechanism to meet different hole diameter requirements. The diameter range is from 3 mm to 60 mm. Micro adjustable reamers (D<10 mm) are used for micro-hole precision reaming, medium-sized (D=10-30 mm) are suitable for general hole processing, and large (D>30 mm) are used for heavy or large diameter reaming. The adjustment range is 0.01-5 mm and the accuracy is ±0.002 mm. The shank types include straight shank (DIN 6535 HA/HB) or tapered shank (BT40, CAT50). The shank diameter matches the maximum cutting diameter, the tolerance grade is h6 (0/-0.006 mm), and the shank length (100-350 mm) is customized according to the processing depth and machine tool clamping requirements. The tapered shank supports high torque transmission (torque range 20-150 Nm). The total length is 150 mm to 600 mm, suitable for medium-sized CNC (150-300 mm) or heavy-duty machining centers (400-600 mm), and the extra-long type (800 mm) is used for deep hole reaming (depth up to 15D). The effective cutting length is 20 mm to 500 mm. Shallow reaming (20-80 mm) is suitable for surface finishing, and deep reaming (300-500 mm) is suitable for deep holes or multi-stage reaming. The ratio of cutting length to diameter is usually controlled at 3:1-15:1. The number of cutting edges is 1-6, depending on the diameter and processing requirements. Small diameters (D<15 mm) are 1-3 edges, and medium and large diameters (D>15 mm) are 3-6 edges. Increasing the number of edges can improve cutting efficiency but requires high-rigidity machine tool support. The error of the spacing between edges is <0.01 mm. The blade design can be straight or micro-helix (5°-15°), and the length of the guide section accounts for 10%-20% of the total length to ensure smooth hole walls. The adjustment mechanism includes precision thread (pitch 0.5-1 mm), eccentric adjustment (eccentricity 0.01-3 mm) or hydraulic fine adjustment (pressure 0.1-1 bar), and is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.002 mm) to ensure smooth cutting edge (Ra ≤ 0.02 microns) and geometric accuracy. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 12000 RPM) to reduce vibration during high-speed reaming (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.3-1.5 mm, pressure 5-15 bar) or external chip grooves (width 0.5-1.5 mm) to improve chip removal (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <500°C), suitable for deep hole reaming or sticky material processing. Some models introduce modular tool head design, and the tool head and tool bar are connected by high-precision threads (tolerance 6H/6g), which supports fast replacement and blade re-grinding.

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2.2 Materials

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include YG6X (cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for hardened steel and cast iron, excellent wear resistance, cutting life can reach 80-120 hours), YT15 (containing titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloy, life can reach 90-130 hours), K25 (cobalt content 7%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially for aluminum alloys and non-ferrous metals, strong anti-adhesion, life can reach 100-150 hours). Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (400-700°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance and microstructure.

3. Manufacturing process

3.1 Raw material preparation

High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the grade (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) are added to enhance the performance, and the particle size is controlled at 0.5-2 microns. A planetary ball mill (speed 50-100 RPM, time 24-48 hours) is used for wet mixing, and ethanol is added as a dispersant to ensure powder uniformity (segregation <1%). The particle size distribution is detected by a laser particle size analyzer, and the chemical composition is analyzed by an X-ray fluorescence spectrometer (XRF), and the deviation is controlled within ±0.05%.

3.2 Pressing

The hydraulic press applies 150-200 MPa pressure to form the blade blank, with a density of 14.5-15.2 g/cm³ , and cold isostatic pressing technology (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of high-strength steel (hardness HRC 50-55) with an accuracy of ±0.02 mm. Laser cutting and electrospark machining are used to ensure the forming accuracy of the blade and adjustment mechanism. The density of the blank is measured by the Archimedean method (error <0.1 g/cm³) , and the internal porosity is checked by microscope (<0.5%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2200).

3.4 Post-processing

External turning with CBN tools, runout accuracy <0.01 mm, surface roughness Ra ≤ 0.2 microns. Ultra- precision five-axis CNC grinder for cutting edge and adjustment mechanism (accuracy

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±0.002 mm), cutting edge profile error <0.005 mm, surface Ra ≤ 0.02 microns. Mirror polishing with diamond abrasives of grain size W0.5-W1.0, cutting edge Ra ≤ 0.01 microns, electrolytic polishing (current density 0.1 A/cm²) to remove microscopic burrs. Chamfering of cutting edge (0.1-0.2 mm, angle 5°-10°) enhances anti-chipping ability, adjustment mechanism thread accuracy 6H/6g, geometry calibrated by laser interferometer.

3.5 Coating treatment

by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h). Coating types include TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), reducing the friction coefficient (<0.3) and increasing the service life by 30%-50%. SEM checks the uniformity of the coating, and the nanoindenter tests the hardness and adhesion (>70 N), with a thickness deviation of <0.5 microns.

3.6 Final testing and packaging

Coordinate measuring machines (CMM) detect diameter, blade accuracy and adjustment range (<0.01 mm), and dynamic balancing machines correct imbalance (<5 g·mm /kg). Anti-rust oil coating or vacuum packaging to prevent oxidation. Laser engraving of diameter range, length, brand and batch number to ensure traceability.

4. Technical parameters

Hardness: substrate HV 1800-2200, coated HV 3400. Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 30-120 m/min for steel, 20-80 m/min for titanium alloy, 80-200 m/min for aluminum alloy.

Feed rate (fz): 0.01-0.10 mm/rev. Depth of cut (ap): 0.01-2 mm (fine reaming).

Tolerance: Diameter adjustment accuracy ±0.002 mm, hole diameter accuracy <0.003 mm. Surface roughness: Ra 0.05-0.4 microns.

5. Application scenarios

5.1 Mould manufacturing

Precision reaming of mold guide sleeve holes , positioning holes and cooling holes, common diameters are 8-25 mm and depths are 30-100 mm. A mold factory uses a 15-20 mm diameter adjustable reamer to precision ream the guide sleeve holes of stamping molds , with a cutting speed of 80 m/min, a feed rate of 0.03 mm/rev, an adjustment accuracy of ±0.002 mm, a hole diameter tolerance of ±0.001 mm after processing, Ra 0.05 microns, a tool life of 100 hours, an annual output of 1,000 sets of molds, and a 60% reduction in tool replacement. High finish and adaptability to multiple specifications are required, and internal cooling system (10 bar) support.

5.2 Automobile Industry

Precision reaming of engine cylinder bores, connecting rod bores and gearbox shaft bores, with common diameters of 15-40 mm and depths of 50-150 mm. An automotive parts company uses a 20-30 mm diameter adjustable reamer to precision ream cylinder bores, with a cutting speed of 70 m/min, a feed rate of 0.02 mm/rev, an adjustment accuracy of ±0.002 mm, a hole roundness of <0.002 mm after processing, Ra 0.04 microns, a tool life of 120 hours, an annual output of 600,000 cylinders, and a 20% reduction in process time. As the demand for multi-specification hole

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processing increases in electric vehicle transmission systems, the flexibility of adjustable reamer becomes an advantage.

5.3 Aerospace

Precision reaming of titanium alloy or high-strength steel fuselage connection holes and landing gear strut holes, common diameter 10-30 mm, depth 80-200 mm. An airline uses a 15-25 mm diameter adjustable reamer to process titanium alloy connection holes, cutting speed 50 m/min, feed rate 0.02 mm/rev, adjustment accuracy ±0.002 mm, hole diameter tolerance after processing ±0.001 mm, Ra 0.03 microns, tool life 130 hours, in line with AS9100 standards. Heat resistance and high precision are required, and the internal cooling pressure must reach 15 bar.

5.4 Medical Devices

Precision reaming of orthopedic implant inner holes or surgical instrument positioning holes, common diameters are 4-12 mm and depths are 10-50 mm. A medical company uses a 6-10 mm diameter adjustable reamer to process titanium alloy hip joint inner holes, with a cutting speed of 40 m/min, a feed rate of 0.01 mm/rev, an adjustment accuracy of ±0.002 mm, a hole diameter tolerance of ±0.001 mm after processing, Ra 0.02 microns, and a tool life of 90 hours, which meets FDA biocompatibility standards. Extremely high precision and surface quality are required, and DLC coating is often used to reduce friction.

5.5 Precision Instruments

Precision reaming of optical instrument shaft holes and sensor mounting holes, common diameters are 5-15 mm and depths are 20-80 mm. A precision instrument manufacturer uses an adjustable reamer with a diameter of 8-12 mm to process optical lens shaft holes, with a cutting speed of 60 m/min, a feed rate of 0.02 mm/rev, an adjustment accuracy of ±0.002 mm, a hole diameter tolerance of ±0.001 mm after processing, Ra 0.03 microns, a tool life of 110 hours, and an annual output of 500,000 instruments, in line with ISO 2768 standards. With the increasing demand for micro-hole multi-specification processing, the high adaptability of adjustable reamer becomes the key.

5.6 Energy equipment manufacturing

Precision reaming of turbine shaft holes and pump body inner holes, common diameters are 20-50 mm and depths are 100-300 mm. An energy equipment manufacturer uses a 30-40 mm diameter adjustable reamer to process hydraulic pump body holes, with a cutting speed of 70 m/min, a feed rate of 0.03 mm/rev, an adjustment accuracy of ±0.002 mm, a hole diameter error of <0.002 mm after processing, Ra 0.05 microns, a tool life of 140 hours, an annual output of 2,000 pump bodies, and an efficiency increase of 25%. High precision and deep hole processing capabilities are required , and the internal cooling system requires high pressure support (15 bar).

6. Precautions for use

6.1 Machine tool requirements

Three-axis or five-axis CNC, runout <0.003 mm, spindle power ≥3 kW, it is recommended to use a high-rigidity spindle (guideway rigidity >3000 N/ µm).

6.2 Cooling and lubrication

High-pressure cutting fluid (10 bar, 15-20 L/min) or internal cooling system (pressure 5-15 bar), viscous materials (such as stainless steel) require enhanced cooling (flow rate increased to 25 L/min).

6.3 Cutting parameters

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Vc 70 m/min, fz 0.02-0.05 mm/rev, depth of cut segmented (3D per segment), recalibration of cutting parameters after adjustment to optimize surface quality.

6.4 Installation and calibration

Coaxiality <0.001 mm, clamping force 20-40 Nm (straight shank) or 30-60 Nm (taper shank), calibrate the tool arbor and adjust the coaxiality of the mechanism before installation.

6.5 Wear and maintenance

Replace when the blade wear VB reaches 0.2 mm, the hole diameter is out of tolerance (>0.005 mm) or there are surface scratches. Maintenance is required when the adjustment mechanism is worn (clearance >0.01 mm). It is recommended to check it every 15 hours and record the wear data to optimize the usage cycle.

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appendix:

What are Carbide Broaches ?

Carbide broaches are high-precision tools used for efficient cutting and forming in machining. With their excellent hardness and wear resistance, they provide reliable support for the processing of complex contours on the surface or inside of workpieces. These broaches gradually cut the workpiece in a linear motion on a broaching machine or special equipment to achieve the processing of precision shapes such as tooth shapes, keyways, gears or polygonal holes. They are widely used in manufacturing scenarios that require high efficiency and high quality. Carbide broaches are based on tungsten carbide (WC), with cobalt (Co) added as a binder, and sintered by precision powder metallurgy. Common material grades include YG10 (high toughness, suitable for intermittent cutting), YT20 (strong heat resistance, suitable for steel processing) and YW3 (excellent comprehensive performance, suitable for complex contours). Its design forms are diverse, with both integral carbide structures and modular configurations with segmented or replaceable teeth. The tool body is usually made of high-strength steel or carbide to ensure stability during high-load broaching.

1. Geometry design and optimization

of carbide broaches is the key to their efficient cutting. Designers fine-tune parameters to meet different processing requirements. The cutting edge of the broach is usually stepped, with the rake angle set between 0° and 5°. This small angle design helps reduce cutting force and ensure smooth cutting; the back angle is generally between 5° and 10° to ensure that the broach does not wear excessively when in contact with the workpiece; the chamfer of the cutting edge (0.1-0.2 mm) enhances the ability to resist chipping by dispersing stress , especially in intermittent broaching. Cylindrical broaches are suitable for finishing of circular holes, with a diameter range of 10 to 100 mm and a length of up to 500 mm; keyway broaches are designed for keyway or spline processing, with a width of 5 to 50 mm and a length adjusted according to the depth of the workpiece; gear broaches are used for gear profile forming, with the number of teeth ranging from 10 to 50, suitable for mass production. Geometry optimization combines computer-aided design (CAD) and finite element analysis to ensure that the broach remains stable during low-speed, high-load broaching (up to 50 m/min), and the chip flute width (2-4 mm) is adjusted according to the cutting depth to ensure smooth chip evacuation.

2. Coating and surface treatment

Coating technology has given carbide broaches additional performance advantages, enabling them to adapt to more complex machining environments. PVD (physical vapor deposition) coatings such as TiN (golden yellow, 2-5 microns thick) provide good wear protection and are particularly suitable for machining non-ferrous metals; CVD (chemical vapor deposition) coatings such as TiAlN (purple black, 10-20 microns thick) are ideal for steel and cast iron broaching with their heat resistance up to 1000°C. In terms of surface treatment, the polishing process controls the surface roughness to Ra <0.2 microns to reduce chip adhesion; laser micro-texturing technology carves micro-lubrication grooves on the surface of the broach to reduce the friction coefficient; some high-end broaches use nano-coatings (such as nano- TiAlN , with grains less than 50 nanometers), which significantly improves performance in ultra-precision machining. Coating adhesion is verified by scratch testing

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(critical load >80 N) to ensure that the coating will not peel off during high-load broaching.

3. Technical characteristics and performance

of carbide broaches makes them a powerful assistant for efficient forming processing and has won high recognition in the industry. The cutting speed ranges from 5 to 50 meters per minute, depending on the workpiece material. For example, steel is usually 10 to 30 meters per minute, while cast iron can reach 20 to 50 meters per minute. In terms of hardness, the hardness of broaches is generally between HV 1800 and 2100. YT20 can reach HV 2000 to 2100 due to titanium carbide, which is enough to cope with high-hardness workpieces. The fracture toughness is 14 to 18 $MPa \cdot m^{1/2}$. The YG10 grade is more tough due to its high cobalt content (10%), which is particularly suitable for intermittent broaching. The wear resistance is less than 0.03 cubic millimeters per Newton meter, and it is further reduced to 0.02 cubic millimeters per Newton meter after coating, which greatly extends the service life. The heat resistance can reach up to 1000°C (thanks to the CVD coating), making it stable in high temperature environments. The processing accuracy is controlled within 0.01 mm, meeting the requirements of high-precision molding processing.

4. Processing requirements and applications

of carbide broaches reflect their unique value in efficient manufacturing. Cutting parameters vary depending on the material. For example, the cutting speed of steel is 10 to 30 meters per minute, the feed rate is 0.02 to 0.1 mm per stroke, and the cutting depth is 0.5 to 2 mm; cast iron requires a cutting speed of 20 to 50 meters per minute, a feed rate of 0.05 to 0.15 mm per stroke, and a cutting depth of 1 to 3 mm. The choice of cooling method is also critical . Dry broaching is suitable for cast iron and can reduce the use of coolant; wet broaching using emulsion or oil-based coolant is more suitable for steel and titanium alloys, which can effectively reduce thermal damage; for complex contour broaching, low-pressure cooling (5-10 bar) significantly improves chip removal efficiency through external spraying. In practical applications, the automotive industry often uses broaches to process gear shafts and spline holes, which require high efficiency and surface quality; mold manufacturing relies on it to form the tooth shape of stamping dies, focusing on contour accuracy; the mechanical industry, such as batch processing of polygonal holes, also relies on its excellent performance.

5. Challenges and Solutions

using carbide broaches , but these problems can be properly solved through scientific coping strategies. During the broaching process , poor chip removal is a common problem in complex contour processing, which can be alleviated by optimizing the chip groove design and adding self-lubricating coatings (such as MoS_2); heat accumulation is prone to occur in high-load broaching, and an efficient cooling system and heat-resistant coating can effectively control the temperature; broach wear may cause contour errors, and the selection of high-wear-resistant grades and edge strengthening treatment can improve stability; for sticky materials, surface adhesion is the main problem, and regular cleaning or the use of low-friction coatings can significantly extend the service life. Together, these solutions ensure the reliability of broaches in complex working conditions.

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6. Optimization and development trends

of cemented carbide broaches reflects the industry's pursuit of efficiency and intelligence. In terms of structural optimization, the integrated external spray cooling channel can effectively reduce the temperature of the broach , the segmented design facilitates the replacement of worn parts, and the dynamic balancing technology improves the stability of low-speed and high- load broaching. In terms of material innovation, nano-cemented carbide improves hardness and toughness with its fine grains (less than 0.5 microns), and the gradient material design allows the broach to have both high hardness and high toughness. The trend of intelligence allows sensors to be embedded in the broach to monitor wear and temperature in real time, and dynamically adjust the broaching parameters in combination with artificial intelligence algorithms. In terms of manufacturing technology, 3D printing technologies such as selective laser melting (SLM) can create complex broach structures , such as optimizing cooling channels, while laser deposition technology provides the possibility of repairing worn broaches . The environmental protection trend has promoted the development of dry broaching coatings (such as graphene composite coatings), reducing dependence on coolants, while the use of recyclable materials also reduces environmental impact.

7. Lifespan and maintenance

of carbide broaches varies depending on the processing conditions and workpiece materials, and is generally between 20 and 50 hours, such as about 30 hours for steel processing and up to 40 hours for cast iron processing. Maintenance work includes regular sharpening , using diamond grinding wheels to ensure that the angle error is less than 0.5°, coating repair through CVD technology to restore performance, and laser pre-adjustment to ensure that the error is less than 0.01 mm. These measures can effectively extend the service life of the broach . After the broach is scrapped , the tungsten and cobalt materials in it can be recycled and reused by smelting and returning to the furnace, reflecting the concept of sustainable development.

8. Detailed classification

Carbide broaches can be divided into several categories according to processing requirements and application scenarios, each type has its own unique design and purpose:

Cylindrical broach

Suitable for finishing and forming of circular holes, with diameters ranging from 10 to 100 mm and lengths up to 500 mm. Rake angle 0° to 3°, back angle 5° to 8°, YG10 grade, TiN coating (thickness 2-5 microns) for wear resistance. Cutting speed 10 to 30 m/min, accuracy below 0.01 mm, widely used in bearing hole and cylindrical parts processing.

Keyway broach

Designed for keyway or spline processing, width 5 to 50 mm, length adjusted according to workpiece depth. Rake angle 0° to 5°, back angle 5° to 10°, YT20 grade, TiAlN coating (thickness 10-20 microns) to enhance heat resistance. Cutting speed 5 to 20 meters per minute, accuracy less than 0.01 mm, commonly used in gear shaft and transmission shaft processing.

Gear broach

Used for gear profile forming, with the number of teeth ranging from 10 to 50 and the length up to 600 mm. The rake angle is 0° to 5°, the back angle is 5° to 10°, and the YW3 grade is selected. The

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multi-layer coating (such as $TiN+Al_2O_3$) provides comprehensive performance. The cutting speed is 5 to 15 meters per minute, and the accuracy is less than 0.01 mm. It is widely used in mass production of gears.

9. Selection and matching

Choosing the right carbide broach requires a comprehensive consideration of the workpiece material and the type of processing. For example, for steel broaching, choose the YT20 keyway broach, for cast iron forming, choose the YG10 cylindrical broach, and for gear processing, the YW3 gear broach with multi-layer coating is more suitable. The performance of the machine tool is also critical . The broaching machine needs to have a pulling force of more than 10 tons and a speed of 5 to 50 meters per minute to fully utilize the potential of the broach .

1 0 . Classification summary table

Broach type	Number of teeth/width (mm)	Diameter/Length(mm)	Front Angle (°)	Rear Angle (°)	Applicable Brand	Coating Type	Cutting speed (m/min)	Depth of cut (mm)	Accuracy (mm)	Typical Applications
cylinder Broach	-	10-100 / 500	0-3	5-8	YG10	TiN (2-5 µm)	10-30	0.5-2	<0.01	Bearing holes, cylindrical parts
keyway Broach	5-50	- / Adjustment	0-5	5-10	YT20	TiAlN (10-20 µm)	5-20	0.5-2	<0.01	gear shaft, transmission shaft
gear Broach	10-50	- / 600	0-5	5-10	YW3	TiN + Al_2O_3	5-15	0.5-2	<0.01	Gear batch, forming

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appendix:

What are carbide forming tools ?

Carbide forming tools are precision tools used to shape complex contours and special shapes in machining. With their excellent hardness and wear resistance, they provide efficient solutions for customized shaping of the surface or interior of workpieces. These tools can complete the processing of non-circular, curved surfaces or specific contours in one go through cutting or plastic deformation movements on lathes, milling machines or special equipment. They are widely used in manufacturing scenarios that require high precision and unique shapes. Carbide forming tools are based on tungsten carbide (WC), with cobalt (Co) added as a binder, and sintered through a precision powder metallurgy process. Common material grades include YG6 (moderate hardness, suitable for general forming), YT25 (strong heat resistance, suitable for steel processing) and YW4 (excellent comprehensive performance, suitable for complex contours). Its design forms are diverse, with both integral carbide structures and adjustable or modular configurations. The tool body is usually made of high-strength steel or carbide to ensure stability in diversified processing.

1. Geometry design and optimization

The geometric design of carbide forming tools is the key to achieving complex forming. Designers fine-tune parameters to meet different processing requirements. The front angle of the tool is usually set between 5° and 15°. This angle design is adjusted according to the workpiece material and shape to balance the cutting force and surface quality; the back angle is generally between 6° and 12° to ensure that the tool remains stable when in contact with the workpiece to avoid excessive wear; the chamfer of the cutting edge (0.1-0.3 mm) enhances the ability to resist chipping by dispersing stress , especially in intermittent cutting. Forming turning tools are suitable for non-circular forming of external circles or end faces, with a diameter range of 10 to 100 mm, and the blade is customized according to the contour of the workpiece; forming milling cutters are used for complex curved surface processing, with a diameter of 20 to 150 mm and 2 to 8 blades ; die-casting tools combine cutting and plastic deformation, with a diameter of 50 to 200 mm, suitable for mass production. Geometry optimization combines computer-aided design (CAD) and finite element analysis to ensure that the tool remains stable at moderate speeds (up to 5000 rpm or 200 m/min), and the chip flute width (2-5 mm) is adjusted according to the cutting depth to ensure smooth chip evacuation.

2. Coating and surface treatment

Coating technology has injected additional performance advantages into carbide forming tools, enabling them to adapt to more complex processing environments. PVD (physical vapor deposition) coatings such as TiN (golden yellow, 2-5 microns thick) provide good wear protection and are particularly suitable for processing aluminum alloys and copper materials; CVD (chemical vapor deposition) coatings such as TiAlN (purple black, 10-25 microns thick) are ideal for forming steel and titanium alloys with their heat resistance up to 1100°C. In terms of surface treatment, the polishing process controls the surface roughness to Ra <0.2 microns to reduce chip adhesion; laser micro-texturing technology engraves micro-lubrication grooves on the tool surface to reduce the friction coefficient; some high-end forming tools use nano-coatings (such as nano- TiAlN , with grains less than 50 nanometers), which significantly improves performance in ultra-precision

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processing. The coating adhesion is verified by scratch tests (critical load >80 N) to ensure that the coating will not peel off during long-term use.

3. Technical characteristics and performance

The technical performance of cemented carbide forming tools makes them a powerful assistant for complex forming processing and has won high recognition in the industry. The cutting speed ranges from 50 to 300 meters per minute, depending on the workpiece material. For example, steel is usually 100 to 200 meters per minute, while aluminum alloys can reach 200 to 300 meters per minute. In terms of hardness, the hardness of the tool is generally between HV 1800 and 2200. YT25 can reach HV 2100 to 2200 due to titanium carbide, which is enough to cope with high-hardness workpieces. The fracture toughness is 12 to 18 $MPa \cdot m^{1/2}$. The YG6 grade has balanced toughness due to its moderate cobalt content (6%), which is particularly suitable for continuous forming. The wear resistance is less than 0.03 cubic millimeters per Newton meter, and after coating, it is further reduced to 0.02 cubic millimeters per Newton meter, which greatly extends the service life. Heat resistance up to 1100°C (thanks to CVD coating), making it stable in high temperature environments. Processing accuracy is controlled within 0.01 mm, meeting the strict requirements of complex contour processing.

4. Processing requirements and applications

The processing requirements and application scenarios of cemented carbide forming tools reflect their unique value in customized manufacturing. Cutting parameters vary depending on the material. For example, the cutting speed of steel is 100 to 200 meters per minute, the feed rate is 0.05 to 0.2 mm per revolution, and the cutting depth is 0.5 to 3 mm; aluminum alloys require a cutting speed of 200 to 300 meters per minute, a feed rate of 0.1 to 0.3 mm per revolution, and a cutting depth of 1 to 5 mm. The choice of cooling method is also critical . Dry cutting is suitable for aluminum alloys and can reduce the use of coolant; wet cutting using emulsion or oil-based coolant is more suitable for steel and titanium alloys, which can effectively reduce thermal damage; for complex surface processing, low-pressure cooling (5-15 bar) significantly improves chip removal efficiency through external spraying. In practical applications, the automotive industry often uses forming tools to process camshafts and curved parts, which require high precision and surface quality; mold manufacturing relies on it to form complex mold cavities, focusing on contour consistency; the aviation industry, such as non-circular forming of blade roots, also relies on its outstanding performance.

5. Challenges and Solutions

There are some challenges when using carbide forming tools, but these problems can be properly solved through scientific coping strategies. During the forming process, poor chip removal is a common problem in complex contour processing, which can be alleviated by optimizing the chip groove design and adding self-lubricating coatings (such as MoS_2); heat accumulation is prone to occur in continuous forming, and an efficient cooling system and heat-resistant coating can effectively control the temperature; tool runout may cause contour errors, and the use of a high-rigidity tool body and edge strengthening treatment can improve stability; for hard materials, accelerated wear is the main problem, and regular sharpening or the use of diamond coatings can

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significantly extend the service life. These solutions together ensure the reliability of forming tools under complex working conditions.

6. Optimization and development trends

The optimization and development direction of cemented carbide forming tools reflect the industry's pursuit of efficiency and intelligence. In terms of structural optimization, the integrated external spray cooling channel can effectively reduce the tool temperature, the adjustable tool head design is convenient to adapt to different contours, and the dynamic balancing technology improves the stability of medium-speed processing. In terms of material innovation, nano-cemented carbide improves hardness and toughness with its fine grains (less than 0.5 microns), and the gradient material design allows the forming tool to have both high hardness and high toughness. The trend of intelligence allows the tool to be embedded with sensors to monitor wear and temperature in real time, and dynamically adjust the forming parameters in combination with artificial intelligence algorithms. In terms of manufacturing technology, 3D printing technologies such as selective laser melting (SLM) can create complex tool structures, such as optimizing cooling channels, while laser deposition technology provides the possibility of repairing worn tools. The environmental protection trend has promoted the development of dry cutting coatings (such as graphene composite coatings), reducing dependence on coolants, while the use of recyclable materials also reduces environmental impact.

7. Lifespan and maintenance

The life of carbide forming tools varies depending on the processing conditions and workpiece materials, and is generally between 15 and 40 hours, such as about 20 hours for steel processing and up to 30 hours for aluminum alloy processing. Maintenance work includes regular sharpening , using diamond grinding wheels to ensure that the angle error is less than 0.5°, coating repair through CVD technology to restore performance, and laser pre-adjustment to ensure that the error is less than 0.01 mm. These measures can effectively extend the service life of forming tools. After the tool is scrapped, the tungsten and cobalt materials in it can be recycled and reused by smelting and returning to the furnace, reflecting the concept of sustainable development.

8. Industry standards and certification

The production and use of cemented carbide forming tools must comply with international and domestic standards, such as ISO 3002-1 in the ISO standard and the Chinese national standard GB/T series, to ensure quality and safety.

9. Detailed classification

Carbide forming tools can be divided into several categories according to processing requirements and application scenarios, each type has its own unique design and purpose:

Forming turning tool : Suitable for non-circular forming of outer circle or end face, with diameter range of 10 to 100 mm, and the blade is customized according to the contour of the workpiece. The rake angle is 5° to 10°, the back angle is 6° to 10°, and the YG6 grade is selected . The TiN coating (thickness 2-5 microns) provides wear resistance. The cutting speed is 100 to 200 meters per minute,

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and the accuracy is less than 0.01 mm. It is widely used in camshaft and curved surface parts processing.

Form milling cutter : used for complex surface processing, diameter 20 to 150 mm, number of blades 2 to 8. Rake angle 5° to 15°, back angle 6° to 12°, YT25 grade, TiAlN coating (thickness 10-25 microns) to enhance heat resistance. Cutting speed 100 to 300 meters per minute, accuracy less than 0.01 mm, commonly used in mold cavity and aviation parts processing.

Die forming tool : Combine cutting and plastic deformation, diameter 50 to 200 mm, blade designed according to the shape of the workpiece. Rake angle 5° to 10°, back angle 6° to 10°, YW4 grade, multi-layer coating (such as TiN+Al_2O_3) provides comprehensive performance. Cutting speed 50 to 150 m/min, accuracy below 0.01 mm, widely used in large-scale non-circular forming.

10. Selection and matching

Choosing the right carbide forming tool requires comprehensive consideration of the workpiece material and processing type. For example, for steel forming, choose the YT25 forming milling cutter, for aluminum alloy processing, choose the YG6 forming turning tool, and for complex curved surface processing, it is more suitable to use the YW4 die-casting tool with multi-layer coating. The performance of the machine tool is also critical. The spindle power must exceed 5 kilowatts, the speed must reach 1000 to 5000 revolutions per minute, or the cutting speed must reach 50 to 300 meters per minute to give full play to the potential of the forming tool.

11. Classification summary table

Tool Type	Number of blades	diameter (mm)	Rake angle (°)	Relief angle (°)	Applicable Brand	coating type	Cutting speed (m/min)	Depth of cut (mm)	Accuracy (mm)	Typical Applications
Forming turning tool	-	10-100	5-10	6-10	YG6	TiN (2-5 μm)	100-200	0.5-3	<0.01	Camshaft, curved parts
Form milling cutter	2-8	20-150	5-15	6-12	YT25	TiAlN (10-25 μm)	100-300	1-5	<0.01	Mold cavity, aviation parts
Molding tool	-	50-200	5-10	6-10	YW4	TiN + Al_2O_3	50-150	0.5-3	<0.01	Large batch, non-round forming

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appendix:

What is a carbide forming turning tool?

1. Overview

1.1 Definition and Function

Carbide forming turning tools are high-performance cutting tools designed for complex contour processing and precision turning. They are widely used in mechanical processing, mold manufacturing, automotive industry, aerospace, energy equipment production, and precision instrument manufacturing. Its core feature is that the forming blade made of carbide material can complete the finishing of specific contours (such as threads, grooves, bosses, chamfers, etc.) in one go without multiple adjustments to the workpiece or tool. Carbide forming turning tools use carbide as the base material, have high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and are suitable for turning high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloys, cast iron, and aluminum alloys. The forming blade is formed into a specific geometric shape through precision grinding. It is widely suitable for CNC lathes, ordinary lathes or machining centers. It can efficiently complete the turning of external circles, end faces, steps, threads and complex curved surfaces. The processing accuracy can reach IT6-IT8 level, and the surface roughness can reach Ra 0.2-0.8 microns. Compared with ordinary turning tools, carbide forming turning tools have higher efficiency (production efficiency increased by 30%-50%) and consistency (contour error <0.01 mm) in mass production of complex parts. It is particularly suitable for scenarios that require high-precision and repeatable processing. It has high design flexibility and can customize the blade shape and angle according to the workpiece contour. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAD/CAM software to optimize the cutting path through digital models.

1.2 Development Background

With the growing demand for lightweight automobiles, high-performance aerospace parts and precision molds, carbide forming turning tools are becoming increasingly important in modern manufacturing due to their efficient forming capabilities and durability. In 2025, with the increasing application of new materials (such as high entropy alloys) and complex geometric shapes, higher requirements are placed on the edge accuracy, heat resistance and life of forming turning tools, which promotes the continuous innovation of tool design, material ratio and coating technology.

2. Technical characteristics

2.1 Structural characteristics

The structural design of carbide forming turning tools aims to achieve efficient forming, stable cutting and excellent surface quality. They usually adopt square shank, round shank or machine clamping structure, and the blade is a customized forming blade layout, combined with a rigid tool body to adapt to high-load turning. The total length of the tool ranges from 100 mm to 400 mm,

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suitable for small CNC (100-200 mm) or heavy lathes (300-400 mm), and the extra-long type (500 mm) is used for deep grooves or special contour processing. Shank types include square shanks (section 10x10 mm to 25x25 mm, tolerance h6) or round shanks (diameter 10-32 mm, tolerance h6), and the shank length (80-300 mm) is customized according to the machine tool clamping and processing depth requirements. Machine clamping tools support high torque transmission (torque range 20-200 Nm). The effective cutting length is 20 mm to 150 mm. Shallow turning (20-50 mm) is suitable for surface finishing, and deep turning (100-150 mm) is suitable for groove or step processing. The blade geometry is customized according to the workpiece contour, such as thread type (pitch 0.5-10 mm), groove type (width 1-20 mm) or curved surface type (radius of curvature 5-50 mm). The blade angle is usually 5°-15° for the front angle and 5°-10° for the back angle (customizable). The length of the guide section accounts for 10%-15% of the total length to ensure contour accuracy. The profiled blade is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure a smooth edge (Ra ≤ 0.02 microns) and a geometric error of <0.005 mm. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, tested at a speed of 10,000 RPM) to reduce vibration during high-speed turning (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-1.5 mm, pressure 5-15 bar) or external chip grooves (width 1-2 mm) to improve chip removal (efficiency increased by 20%-30%) and thermal management (cutting zone temperature <600°C), suitable for high-load or sticky material processing. The machine-clamped tool adopts a replaceable blade design, and the blade and the tool bar are connected by high-precision threads or bayonet (tolerance 6H/6g), which supports quick replacement and blade re-sharpening.

2.2 Materials

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include YG8 (cobalt content 8%, hardness HV 1800-1900, bending strength 2000-2200 MPa, suitable for rough turning and cast iron, excellent wear resistance, cutting life can reach 100-140 hours), YT14 (containing titanium carbide, hardness HV 1900-2000, heat resistance 850°C, suitable for stainless steel and titanium alloys, life can reach 110-150 hours), K20 (cobalt content 6%-8%, hardness HV 1700-1900, bending strength 1900-2100 MPa, specially for aluminum alloys and non-ferrous metals, strong anti-adhesion, life can reach 120-160 hours). Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (500-900°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-0.3%) to optimize heat resistance and oxidation resistance.

3. Manufacturing process

3.1 Raw material preparation

High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the grade (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) are added to enhance the performance, and

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the particle size is controlled at 0.5-2 microns. A planetary ball mill (speed 50-100 RPM, time 24-48 hours) is used for wet mixing, and ethanol is added as a dispersant to ensure powder uniformity (segregation <1%). The particle size distribution is detected by a laser particle size analyzer, and the chemical composition is analyzed by an X-ray fluorescence spectrometer (XRF), and the deviation is controlled within ±0.05%.

3.2 Pressing

The hydraulic press applies 150-200 MPa pressure to form the blade blank, with a density of 14.5-15.2 g/cm³ . Cold isostatic pressing (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of high-strength steel (hardness HRC 50-55) with an accuracy of ±0.02 mm. Laser cutting and EDM are used to ensure the forming accuracy of the blade. The blank density is measured by the Archimedean method (error <0.1 g/cm³) , and the internal porosity is checked by microscope (<0.5%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2200).

3.4 Post-processing

External turning is performed using CBN tools, with runout accuracy <0.01 mm and surface roughness Ra ≤ 0.2 microns. The blade is machined using an ultra -precision five-axis CNC grinder (accuracy ±0.002 mm), with edge profile error <0.005 mm and surface Ra ≤ 0.02 microns. Mirror polishing with diamond abrasives of grain size W0.5-W1.0, edge Ra ≤ 0.01 microns, and electrolytic polishing (current density 0.1 A/ cm²) to remove microscopic burrs. The blade tip is chamfered (0.1-0.2 mm, angle 5°-10°) to enhance the ability to resist edge collapse, and the profile is calibrated by a laser interferometer.

3.5 Coating treatment

by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h). Coating types include TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), reducing the friction coefficient (<0.3) and increasing the service life by 30%-50%. SEM checks the uniformity of the coating, and the nanoindenter tests the hardness and adhesion (>70 N), with a thickness deviation of <0.5 microns.

3.6 Testing packaging

The CMM detects the blade profile accuracy and geometric error (<0.01 mm), and the dynamic balancing machine corrects the imbalance (<5 g·mm /kg). Anti-rust oil coating or vacuum packaging

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to prevent oxidation. Laser engraving of tool type, length, brand and batch number ensures traceability.

4. Technical parameters

Hardness: substrate HV 1800-2200, after coating 3400 HV.

Heat resistance: 600°C-1000°C.

Cutting speed (Vc): 50-200 m/min for steel, 30-120 m/min for titanium alloy, 100-300 m/min for aluminum alloy.

Feed rate (fz): 0.05-0.20 mm/rev.

Cutting depth (ap): 0.1-5 mm.

Tolerance: Contour accuracy <0.01 mm, surface roughness <0.005 mm.

Surface roughness: Ra 0.2-0.8 microns.

5. Application scenarios

5.1 Mould manufacturing

Turning die punch, die and guide pin profiles, common diameter 10-50 mm, depth 20-100 mm. A mold factory uses a forming turning tool to turn stamping die bosses , cutting speed 120 m/min, feed rate 0.10 mm/rev, contour error after processing <0.008 mm, Ra 0.3 micron, tool life 120 hours, annual production of 800 sets of molds, efficiency increased by 40%. High precision and complex contour forming are required , supported by internal cooling system (10 bar).

5.2 Automobile Industry

Turning crankshaft cams, piston ring grooves and gear profiles, common diameters are 20-80 mm and depths are 30-150 mm. An automotive parts company uses profile turning tools to turn crankshaft cams, with a cutting speed of 100 m/min, a feed rate of 0.08 mm/rev, a profile error of <0.01 mm after processing, Ra 0.4 microns, a tool life of 140 hours, an annual output of 500,000 crankshafts, and a 30% reduction in process time. In the mass production of complex parts, the efficiency of profile turning tools has become an advantage.

5.3 Aerospace

Turning the root of turbine blades and the contour of fuselage connectors, common diameters are 15-60 mm and depths are 50-200 mm. An airline uses a forming turning tool to turn the root of titanium alloy blades, with a cutting speed of 60 m/min, a feed rate of 0.05 mm/rev, a contour error of <0.005 mm after processing, Ra 0.2 microns, and a tool life of 150 hours, in line with AS9100 standards. Heat resistance and high precision are required, and the internal cooling pressure must reach 15 bar.

5.4 Energy equipment manufacturing

Turning turbine shaft grooves and valve body complex contours, common diameter 30-100 mm, depth 100-300 mm. An energy equipment manufacturer uses a profile turning tool to turn turbine shaft grooves, cutting speed 80 m/min, feed rate 0.10 mm/rev, contour error after processing <0.01

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mm, Ra 0.5 micron, tool life 160 hours, annual production of 2,000 turbine shafts, efficiency improvement of 35%. High rigidity and deep groove processing capabilities are required, and the internal cooling system needs high pressure support (15 bar).

5.5 Precision Instruments

Turning the contour of optical lens barrels and precision bearing seats, common diameters are 5-30 mm and depths are 20-80 mm. A precision instrument manufacturer uses a profile turning tool to turn the lens barrel contour, with a cutting speed of 70 m/min, a feed rate of 0.03 mm/rev, a contour error of <0.003 mm after processing, Ra 0.2 microns, a tool life of 110 hours, and an annual output of 400,000 lens barrels, in line with ISO 2768 standards. In micro-complex contour processing, the high precision of the profile turning tool becomes the key.

5.6 Electronics Manufacturing

Turning connector housing and heat sink profile, common diameter 10-40 mm, depth 10-50 mm. An electronics company uses a profile turning tool to turn aluminum alloy heat sinks, cutting speed 150 m/min, feed rate 0.15 mm/rev, contour error after processing <0.008 mm, Ra 0.3 micron, tool life 130 hours, annual production of 1 million heat sinks, efficiency increased by 45%. High efficiency and surface quality are required, and internal cooling system (10 bar) support.

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appendix:

What is a carbide profile milling cutter?

1. Overview

1.1 Definition and Function

Carbide forming milling cutter is a high-performance cutting tool designed for complex three-dimensional contour milling and precision machining. It is widely used in mechanical processing, mold manufacturing, aerospace, automotive industry, energy equipment production and precision instrument manufacturing. Its core feature is that the forming blade made of cemented carbide material can complete the milling of specific shapes (such as tooth shape, groove, curved surface, chamfer, etc.) in one go without multiple adjustments to the workpiece or tool. Carbide forming milling cutter uses cemented carbide as the base, has high hardness (HV 1800-2200), excellent wear resistance and high temperature resistance, and is suitable for milling high-strength materials such as hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), nickel-based alloy, cast iron and aluminum alloy. The forming blade is formed into a customized geometric shape through precision grinding. It is widely compatible with CNC milling machines (CNC), machining centers or special milling equipment. It can efficiently complete the milling of planes, sides, contours and complex surfaces. The machining accuracy can reach IT6-IT8 level and the surface roughness can reach Ra 0.2-0.8 microns. Compared with ordinary milling cutters, carbide forming milling cutters have higher efficiency (production efficiency increased by 40%-60%) and consistency (contour error <0.01 mm) in mass production of complex parts, and are particularly suitable for scenarios that require high-precision and repeatable processing. It has high design flexibility and can customize the blade shape, number of teeth and helix angle according to the workpiece contour. With the advancement of intelligent manufacturing technology, the tool can be integrated with CAD/CAM software to optimize the cutting path through digital models.

1.2 Development Background

With the growing demand for complex aerospace components, lightweight automotive parts and precision molds, carbide forming milling cutters occupy an important position in modern manufacturing due to their efficient forming capabilities and durability. In 2025, with the increasing application of high-performance materials (such as carbon fiber composites) and complex geometric shapes, higher requirements are placed on the blade accuracy, heat resistance and life of forming milling cutters, which promotes continuous innovation in tool design, material ratio and coating technology.

2. Technical characteristics

2.1 Structural characteristics

The structural design of carbide profile milling cutters aims to achieve efficient milling, stable cutting and excellent surface quality. They usually adopt straight shank, taper shank or machine clamping structure, and the blade is a customized profile blade layout, combined with multi- tooth

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design to adapt to high-load milling. The total diameter of the tool ranges from 6 mm to 50 mm. Micro profile milling cutters (D<10 mm) are used for fine milling, medium-sized (D=10-25 mm) are suitable for general processing, and large (D>25 mm) are used for heavy or large-area milling. The tolerance grade is h6 (0/-0.006 mm). The shank types include straight shank (DIN 6535 HA/HB) or taper shank (BT40, CAT50). The shank diameter matches the cutting diameter, the tolerance grade is h6, and the shank length (50-250 mm) is customized according to the machine tool clamping and processing depth requirements. The taper shank supports high torque transmission (torque range 30-300 Nm). The total length is 100 mm to 400 mm, suitable for small CNC (100-200 mm) or heavy machining centers (300-400 mm). The effective cutting length is 15 mm to 150 mm. Shallow milling (15-50 mm) is suitable for surface finishing, and deep milling (100-150 mm) is suitable for groove or complex contour processing. The number of teeth is 2-8 cutting edges , depending on the diameter and processing requirements. Small diameters (D<15 mm) are 2-4 teeth, and medium and large diameters (D>15 mm) are 4-8 teeth. Increasing the number of teeth can improve cutting efficiency but requires high-rigidity machine tool support. The tooth spacing error is <0.01 mm. The helix angle is 10°-45°, and the standard value is 15°-30°. The spiral design optimizes chip removal and vibration reduction. 25°-30° is commonly used for finishing to improve surface quality, and 30°-45° can be selected for roughing to enhance chip removal. The geometry of the forming blade is customized according to the contour of the workpiece, such as tooth shape (module 0.5-5 mm), groove type (width 1-20 mm) or curved surface type (radius of curvature 5-50 mm). The blade angle is usually 5°-15° for the front angle and 5°-10° for the back angle (customizable). The length of the guide section accounts for 10%-15% of the total length to ensure the contour accuracy. The blade is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure a smooth edge (Ra ≤ 0.02 microns) and a geometric error of <0.005 mm. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, test speed 15000 RPM) to reduce vibration in high-speed milling (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-2 mm, pressure 5-20 bar) or external chip grooves (width 1-2.5 mm) to improve chip removal (efficiency increased by 30%-40%) and thermal management (cutting zone temperature <600°C), suitable for deep grooves or sticky materials. The machine-clamped tool adopts a replaceable blade design, and the blade and the tool bar are connected by high-precision threads or bayonet (tolerance 6H/6g), which supports quick replacement and blade re-grinding.

2.2 Materials

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co), and the fine particle structure ensures wear resistance and impact resistance. Common grades include YG10 (cobalt content 10%, hardness HV 1800-1900, bending strength 2100-2300 MPa, suitable for rough milling and cast iron, excellent wear resistance, cutting life can reach 100-140 hours), YT15 (containing titanium carbide, hardness HV 1900-2000, heat resistance 850°C, suitable for stainless steel and titanium alloys, life can reach 110-150 hours), K30 (cobalt content 8%-10%, hardness HV 1700-1900, bending strength 2000-2200 MPa, specially for aluminum alloys and non-ferrous metals, strong anti-adhesion, life can reach 120-160 hours). Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (500-900°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or rare earth elements (such as Ce, 0.1%-

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0.3%) to optimize heat resistance and oxidation resistance.

3. Manufacturing process

3.1 Raw material preparation

High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the cobalt content is adjusted according to the grade (6%-12%), titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) are added to enhance the performance, and the particle size is controlled at 0.5-2 microns. A planetary ball mill (speed 50-100 RPM, time 24-48 hours) is used for wet mixing, and ethanol is added as a dispersant to ensure powder uniformity (segregation <1%). The particle size distribution is detected by a laser particle size analyzer, and the chemical composition is analyzed by an X-ray fluorescence spectrometer (XRF), and the deviation is controlled within ±0.05%.

3.2 Pressing

The hydraulic press applies 150-200 MPa pressure to form the blade blank, with a density of 14.5-15.2 g/cm³ . Cold isostatic pressing (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of high-strength steel (hardness HRC 50-55) with an accuracy of ±0.02 mm. Laser cutting and EDM are used to ensure the forming accuracy of the blade. The blank density is measured by the Archimedean method (error <0.1 g/cm³) , and the internal porosity is checked by microscope (<0.5%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 1-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2200).

3.4 Post-processing

External turning is performed using CBN tools, with runout accuracy <0.01 mm and surface roughness Ra ≤ 0.2 microns. The blade is machined using an ultra -precision five-axis CNC grinder (accuracy ±0.002 mm), with edge profile error <0.005 mm and surface Ra ≤ 0.02 microns. Mirror polishing with diamond abrasives of grain size W0.5-W1.0, edge Ra ≤ 0.01 microns, and electrolytic polishing (current density 0.1 A/ cm²) to remove microscopic burrs. The blade tip is chamfered (0.1-0.2 mm, angle 5°-10°) to enhance the ability to resist edge collapse, and the profile is calibrated by a laser interferometer.

3.5 Coating treatment

by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h). Coating types include TiAlN (thickness 3-8 microns, hardness 2800-3200 HV), AlCrN (thickness 3-7 microns, hardness 3000-3400 HV) or DLC (thickness 1-3 microns, hardness 3000-3500 HV, friction coefficient <0.1), reducing the friction coefficient (<0.3) and increasing the service life by 30%-50%. SEM checks the uniformity of the coating, and the nanoindenter tests the hardness and adhesion (>70 N), with a thickness deviation of <0.5 microns.

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3.6 Final testing and packaging

The three-dimensional coordinate measuring machine (CMM) detects the blade profile accuracy and geometric error (<0.01 mm), and the dynamic balancing test machine corrects the imbalance (<5 g·mm /kg). Anti-rust oil coating or vacuum packaging to prevent oxidation. Laser engraving of tool type, diameter, number of teeth, brand and batch number to ensure traceability.

4. Technical parameters

Hardness: substrate HV 1800-2200, 3000-3500 HV after coating.

Heat resistance: 600°C-1100°C. Cutting speed (Vc): 60-300 m/min for steel, 40-180 m/min for titanium alloys, 200-400 m/min for aluminum alloys.

Feed (fz): 0.05-0.30 mm/tooth. Depth of cut (ap): 0.1-12 mm. Tolerance: profile accuracy ±0.01 mm, surface roughness ±0.005 mm. Surface roughness: Ra 0.2-1.0 microns.

5. Application scenarios

5.1 Mould manufacturing

Milling mold cavities, tooth grooves and complex curved surfaces, common diameters are 10-40 mm and depths are 20-100 mm. A mold factory uses a 20 mm diameter forming milling cutter to mill stamping model cavities, with a cutting speed of 150 m/min, a feed rate of 0.15 mm/tooth, a contour error of <0.008 mm after processing, Ra 0.3 microns, a tool life of 130 hours, an annual output of 600 sets of molds, and an efficiency increase of 50%. High-precision and complex contour forming is required , and internal cooling system (15 bar) is supported.

5.2 Automobile Industry

Milling of engine cylinder head grooves, gear profiles and lightweight parts surfaces, common diameters are 15-50 mm and depths are 30-150 mm. An automotive parts company uses a 25 mm diameter profile milling cutter to mill cylinder head grooves, with a cutting speed of 120 m/min, a feed rate of 0.10 mm/tooth, a profile error of <0.01 mm after processing, Ra 0.4 microns, a tool life of 150 hours, an annual output of 400,000 cylinder heads, and a 35% reduction in process time. In the mass production of complex parts, the high efficiency of profile milling cutters has become an advantage.

5.3 Aerospace

Milling turbine blades, fuselage connections and composite material profiles, common diameters are 10-30 mm and depths are 50-200 mm. An airline uses a 15 mm diameter profile milling cutter to mill titanium alloy blades, with a cutting speed of 80 m/min, a feed rate of 0.08 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.2 microns, and a tool life of 160 hours, in line with AS9100 standards. Heat resistance and high precision are required, and the internal cooling pressure must reach 20 bar.

5.4 Energy equipment manufacturing

Milling turbine blade slots and valve body complex curved surfaces, common diameter 20-60 mm, depth 100-300 mm. An energy equipment manufacturer uses a 30 mm diameter profile milling cutter to mill turbine blade slots, cutting speed 100 m/min, feed rate 0.12 mm/tooth, contour error after processing <0.01 mm, Ra 0.5 microns, tool life 170 hours, annual production of 1,500 blades,

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efficiency improvement of 40%. High rigidity and deep groove processing capabilities are required, and the internal cooling system needs high pressure support (20 bar).

5.5 Precision Instruments

Milling of optical lens molds and micro gear contours, common diameters are 5-20 mm and depths are 10-50 mm. A precision instrument manufacturer uses a 10 mm diameter forming milling cutter to mill lens molds, with a cutting speed of 90 m/min, a feed rate of 0.05 mm/tooth, a contour error of <0.003 mm after processing, Ra 0.2 microns, a tool life of 120 hours, and an annual output of 300,000 molds, in line with ISO 2768 standards. In micro complex contour processing, the high precision of the forming milling cutter becomes the key.

5.6 Electronics Manufacturing

Milling circuit board connectors and heat sinks with complex contours, common diameters are 10-30 mm and depths are 10-40 mm. An electronics company uses a 15 mm diameter forming milling cutter to mill aluminum alloy heat sinks, with a cutting speed of 200 m/min, a feed rate of 0.20 mm/tooth, a contour error of <0.008 mm after processing, Ra 0.3 microns, a tool life of 140 hours, an annual output of 800,000 heat sinks, and an efficiency increase of 50%. High efficiency and surface quality are required, and internal cooling system (15 bar) support.

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appendix:

What are Nano Carbide Cutting Tools?

1. Overview

1.1 Definition and Function

Nano-carbide cutting tools are high-performance cutting tools made of nano-grained carbide materials. They are widely used in mechanical processing, aerospace, automotive industry, energy equipment manufacturing and precision instruments. Its core feature is that it uses nano-grain structure (grain size is less than 100 nanometers) to significantly improve hardness, wear resistance and impact resistance. It can efficiently cut high-strength and difficult-to-process materials such as hardened steel (HRC 50-65), high-temperature alloys (Inconel 718), titanium alloys (HRC 35-40), composite materials and superhard materials. Nano-carbide cutting tools are based on tungsten carbide (WC) and add nano- scale binding phases (such as cobalt Co or nickel Ni). They have ultra-high hardness (HV 2000-2500) and excellent high temperature resistance (heat resistance of more than 1000°C), and are suitable for a variety of processing processes such as turning, milling, and drilling . Compared with traditional micron-grade carbide cutting tools, nano-carbide cutting tools excel in cutting speed (increased by 20%-40%), tool life (extended by 50%-100%) and surface quality (Ra 0.05-0.3 microns), and are particularly suitable for high-precision and high-speed processing scenarios. Its design flexibility is high, and the blade geometry, coating and shank type can be customized according to processing requirements . With the advancement of intelligent manufacturing technology, the tool can be integrated with a real-time monitoring system to optimize cutting parameters.

1.2 Development Background

With the rapid development of Industry 4.0 and high-end manufacturing, the demand for efficient cutting of difficult-to-process materials has surged, and nano-carbide cutting tools have become a hot topic in the industry due to their excellent mechanical properties and processing capabilities. In 2025, with the increasing demand for ultra-high precision and long-life tools in the aerospace, medical equipment and new energy fields, the application of nanotechnology in the field of cemented carbide will be further deepened, promoting innovations in material ratios, sintering processes and surface treatments.

2. Technical characteristics

2.1 Structural characteristics

The structural design of nano-carbide cutting tools aims to achieve high-efficiency cutting, excellent durability and stability. They usually adopt straight shank, taper shank or machine clamping structure, with multi-edge or single-edge layout of the cutting edge, combined with high- rigidity tool body to adapt to high-speed machining. The total diameter of the tool ranges from 3 mm to 60 mm. Micro tools (D<10 mm) are used for micro-machining, medium-sized (D=10-30 mm) are suitable for general cutting, and large (D>30 mm) are used for heavy-duty machining. The tolerance grade is h6 (0/-0.006 mm). The shank types include straight shank (DIN 6535 HA/HB) or taper

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shank (BT40, CAT50). The shank diameter matches the cutting diameter, the tolerance grade is h6, and the shank length (50-300 mm) is customized according to the machine tool clamping and processing depth requirements. The taper shank supports high torque transmission (torque range 20-250 Nm). The total length is 100 mm to 500 mm, suitable for small CNC (100-200 mm) or heavy machining centers (400-500 mm). The effective cutting length is 15 mm to 200 mm, shallow cutting (15-50 mm) is suitable for finishing, and deep cutting (150-200 mm) is suitable for deep holes or slots. The number of cutting edges is 2-10, depending on the diameter and processing type, 2-4 for small diameters (D<15 mm), 4-10 for medium and large diameters (D>15 mm), and the error of the cutting edge spacing is <0.01 mm. The helix angle is 10°-40° (customizable), the standard value is 15°-30°, which optimizes chip removal and vibration reduction, and 25°-30° is commonly used for finishing. The blade is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure a smooth edge (Ra ≤ 0.02 microns) and a geometric error of <0.005 mm. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, tested at 18,000 RPM) to reduce vibrations during high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.3-2 mm, pressure 5-25 bar) or external chip grooves (width 0.5-2.5 mm) to improve chip removal efficiency (40%-50%) and thermal management (cutting zone temperature <650°C), making them suitable for difficult-to-process materials. The machine-clamped tool adopts a replaceable blade design, and the blade and tool shank are connected by high-precision threads (tolerance 6H/6g), which supports quick replacement and blade regrinding.

2.2 Materials

The material is mainly a composite material of nano-scale tungsten carbide (WC) and nano -scale binding phase (such as Co 6%-12%, Ni 0.5%-2%), with a grain size controlled at 20-80 nanometers to ensure ultra-high hardness and toughness. Common grades include Nano-WC-Co10 (cobalt content 10%, hardness HV 2200-2400, bending strength 2300-2600 MPa, suitable for high-hardness steel and high-temperature alloys, life span can reach 150-200 hours), Nano-WC-TiC-Co8 (containing titanium carbide, hardness HV 2300-2500, heat resistance 1050°C, suitable for titanium alloys and composite materials, life span can reach 160-220 hours), Nano-WC-Ni6 (nickel-based binding phase, hardness HV 2100-2300, strong corrosion resistance, specially designed for non-ferrous metals, life span can reach 140-180 hours). Material selection needs to consider the workpiece hardness (steel HRC 50-65, titanium alloy HRC 35-40), thermal conductivity (steel 40-50 W/ m·K , titanium alloy 15-20 W/ m·K) and cutting temperature (600-1000°C). Some models add nano-grade tantalum carbide (TaC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) to optimize wear resistance and thermal crack resistance.

3. Manufacturing process

3.1 Raw material preparation

Ultra-high purity nano-tungsten carbide (WC) powder is mixed with nano-cobalt (Co) or nickel (Ni) powder in proportion (accuracy ±0.05%), the particle size is controlled at 20-80 nanometers, and nano-titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance performance. A high-energy ball mill (speed 200-300 RPM, time 36-72 hours) is used for wet

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mixing, and isopropanol is added as a dispersant to ensure powder uniformity (segregation <0.5%). The particle size distribution is detected by a laser particle size analyzer, and the crystal phase structure is analyzed by X-ray diffraction (XRD) , and the deviation is controlled within ±0.02%.

3.2 Pressing

The hydraulic press applies 200-300 MPa pressure to form the blade blank, with a density of 15.0-15.5 g/cm³ , and cold isostatic pressing technology (CIP, pressure 200-250 MPa, duration 15-20 minutes) is used to improve uniformity. The mold is made of super-hard steel (hardness HRC 58-62), with an accuracy of ±0.01 mm, and laser cutting and electrospark machining are used to ensure the accuracy of blade forming. The density of the blank is measured by the Archimedean method (error <0.05 g/cm³) , and the internal porosity is checked by microscope (<0.3%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-3} Pa) or in an argon atmosphere, the temperature is 1450°C-1650°C for 12-16 hours, and the temperature is increased in stages (60°C per hour, 300°C-700°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 150-200 MPa) technology is used to eliminate micro defects, control the grain size to 20-80 nanometers, and uniformly distribute the microhardness (standard deviation <40 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and nanoindentation instrument tests the hardness (HV 2000-2500).

3.4 Post-processing

External turning is performed using CBN tools with runout accuracy <0.01 mm and surface roughness Ra ≤ 0.1 micron. The blade is machined on an ultra -precision five-axis CNC grinder (accuracy ±0.001 mm), with edge profile error <0.003 mm and surface Ra ≤ 0.01 micron. Mirror polishing with diamond abrasives of grain size W0.1-W0.5, edge Ra ≤ 0.005 micron, electrolytic polishing (current density 0.05-0.1 A/cm²) to remove microscopic burrs. The blade tip is chamfered (0.05-0.15 mm, angle 5°-10°) to enhance the ability to resist edge collapse, and the blade geometry is calibrated by laser interferometer.

3.5 Coating treatment

PVD or CVD process (pressure 10^{-3} Pa, temperature 450-550°C, deposition rate 0.1-0.3 μm /h). Coating types include nano- TiAlN (thickness 2-6 microns, hardness 3000-3500 HV), nano- AlCrN (thickness 2-5 microns, hardness 3200-3600 HV) or nano-DLC (thickness 1-2 microns, hardness 3200-3700 HV, friction coefficient <0.1), reducing the friction coefficient (<0.2) and increasing the service life by 50%-70%. High-resolution SEM is used to check the uniformity of the coating, and nano-indentation instrument is used to test the hardness and adhesion (>80 N), with a thickness deviation of <0.2 microns.

3.6 Testing and packaging

The three-dimensional coordinate measuring machine (CMM) detects the blade profile accuracy and geometric error (<0.005 mm), and the dynamic balancing test machine corrects the imbalance

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(<3 g·mm /kg). Anti-rust oil coating or vacuum packaging to prevent oxidation. Laser engraving of tool type, diameter, number of teeth, brand and batch number to ensure traceability.

4. Technical parameters

Hardness: substrate HV 2000-2500, coated 3000-3700 HV.

Heat resistance: 800°C-1100°C. Cutting speed (Vc): steel 80-350 m/min, titanium alloy 50-200 m/min, aluminum alloy 250-450 m/min.

Feed (fz): 0.03-0.35 mm/tooth. Depth of cut (ap): 0.1-15 mm. Tolerance: profile accuracy ±0.005 mm, surface roughness ±0.003 mm. Surface roughness: Ra 0.05-0.3 microns.

5. Application scenarios

5.1 Aerospace

Processing turbine blades, fuselage frames and titanium alloy parts, common diameters are 10-30 mm and depths are 50-200 mm. An airline uses a 15 mm diameter nano-carbide cutting tool to process Inconel 718 blades, with a cutting speed of 120 m/min and a feed rate of 0.08 mm/tooth. The contour error after processing is <0.003 mm, Ra 0.1 micron, and the tool life is 180 hours, which meets the AS9100 standard. It needs to be resistant to high temperatures and high precision, with an internal cooling pressure of 25 bar.

5.2 Automobile Industry

Processing crankshafts, gears and lightweight aluminum alloy parts, common diameters are 20-50 mm and depths are 30-150 mm. An automotive parts company uses a 25 mm diameter nano-carbide cutting tool to process high-strength steel crankshafts, with a cutting speed of 200 m/min, a feed rate of 0.15 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.2 microns, a tool life of 170 hours, an annual output of 500,000 pieces, and an efficiency improvement of 45%. In the processing of high-hardness materials, the tool life advantage is significant.

5.3 Energy equipment manufacturing

Processing turbine shaft grooves and high-pressure valve bodies, common diameters are 30-70 mm and depths are 100-300 mm. An energy equipment manufacturer uses a 40 mm diameter nano-carbide cutting tool to process high-temperature alloy turbine shafts, with a cutting speed of 150 m/min, a feed rate of 0.12 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.15 microns, a tool life of 200 hours, an annual output of 1,200 pieces, and an efficiency improvement of 40%. High wear resistance and deep groove processing capabilities are required, and the internal cooling system requires 20 bar.

5.4 Medical Devices

Processing orthopedic implants and micro-devices, common diameter 5-15 mm, depth 10-50 mm. A medical company uses 8 mm diameter nano-carbide cutting tools to process titanium alloy hip joints, cutting speed 80 m/min, feed 0.05 mm/tooth, contour error after processing <0.002 mm, Ra 0.05 microns, tool life 150 hours, in line with FDA standards. Extremely high precision and

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biocompatibility are required, and DLC coating is commonly used.

5.5 Precision Instruments

Processing optical lens molds and micro gears, common diameters are 5-20 mm and depths are 10-40 mm. A precision instrument manufacturer uses a 10 mm diameter nano-carbide cutting tool to process lens molds, with a cutting speed of 120 m/min, a feed rate of 0.06 mm/tooth, a contour error of <0.002 mm after processing, Ra 0.1 micron, a tool life of 160 hours, and an annual output of 250,000 pieces, in line with ISO 2768 standards. In micro high-precision processing, tool stability becomes the key.

5.6 Electronics Manufacturing

Processing circuit board connectors and heat sinks, common diameters are 10-30 mm, depths are 10-30 mm. An electronics company uses a 15 mm diameter nano-carbide cutting tool to process aluminum alloy heat sinks, with a cutting speed of 300 m/min, a feed rate of 0.20 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.15 microns, a tool life of 180 hours, an annual output of 600,000 pieces, and an efficiency increase of 50%. High efficiency and surface quality are required, and internal cooling system (15 bar) support.

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appendix:

What are carbide composite tools?

1. Overview

1.1 Definition and Function

Cemented carbide composite cutting tools are high-performance cutting tools made by combining cemented carbide with a variety of reinforcing materials (such as ceramics, cubic boron nitride CBN, diamond or carbide composite phases). They are widely used in mechanical processing, aerospace, automotive industry, energy equipment manufacturing and precision instruments. Its core feature is that through composite material design, it combines the high hardness of cemented carbide (HV 1800-2400) and the ultra-high wear resistance or high temperature resistance of reinforcing materials. It can efficiently cut extremely difficult-to-process materials such as hardened steel (HRC 55-70), high-temperature alloys (Inconel 718), titanium alloys (HRC 35-45), composite materials and glass fiber reinforced plastics. Cemented carbide composite cutting tools are based on tungsten carbide (WC) and combined with nano- or micron- level reinforcement phases. They have excellent impact resistance (bending strength 2000-2800 MPa) and heat resistance (above 1000°C), and are suitable for a variety of processing processes such as turning, milling, drilling and grinding. Compared with single carbide tools, composite tools have significant advantages in cutting speed (increased by 30%-50%), tool life (extended by 70%-120%) and surface quality (Ra 0.05-0.25 microns), and are particularly suitable for high-precision, high-efficiency and extreme environment processing scenarios. Its design is highly flexible, and the blade geometry, composite ratio and coating type can be customized according to processing requirements. With the advancement of intelligent manufacturing technology, the tool can be integrated with the sensor system to optimize cutting parameters in real time.

1.2 Development Background

With the increasing demand for superhard materials and composite materials processing in high-end manufacturing, cemented carbide composite tools have become the focus of the industry due to their excellent comprehensive performance. In 2025, with the pursuit of long-life and high-precision tools in the aerospace, energy and medical fields, the application of composite technology in tool manufacturing will be further expanded, promoting the innovative development of material ratio, interface bonding and surface treatment.

2. Technical characteristics

2.1 Structural characteristics

The structural design of cemented carbide composite tools aims to achieve efficient cutting, excellent durability and stability. They usually adopt straight shank, taper shank or machine clamping structure, with multi- edge or single-edge layout of the cutting edge, combined with high -rigidity composite tool body to adapt to extreme processing conditions. The total diameter of the tool ranges from 4 mm to 70 mm. Micro tools (D<12 mm) are used for micro-machining, medium-sized (D=12-35 mm) are suitable for general cutting, and large (D>35 mm) are used for heavy-duty

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machining. The tolerance grade is h6 (0/-0.006 mm). The shank types include straight shank (DIN 6535 HA/HB) or taper shank (BT40, CAT50, HSK-A63). The shank diameter matches the cutting diameter, the tolerance grade is h6, and the shank length (60-350 mm) is customized according to the machine tool clamping and processing depth requirements. The taper shank supports high torque transmission (torque range 30-350 Nm). The total length is 120 mm to 600 mm, suitable for medium-sized CNC (120-300 mm) or heavy-duty machining centers (400-600 mm). The effective cutting length is 20 mm to 250 mm, shallow cutting (20-60 mm) is suitable for finishing, and deep cutting (200-250 mm) is suitable for deep holes or grooves. The number of cutting edges is 2-12, depending on the diameter and processing type, 2-5 for small diameters (D<18 mm), 5-12 for medium and large diameters (D>18 mm), and the edge spacing error is <0.01 mm. The helix angle is 10°-50° (customizable), the standard value is 15°-35°, which optimizes chip discharge and vibration reduction. 25°-30° is commonly used for finishing, and 35°-50° can be selected for heavy-duty processing. The blade geometry is customized according to the workpiece requirements, such as tooth shape (module 0.5-6 mm), groove type (width 1-25 mm) or curved surface type (radius of curvature 5-60 mm). The blade angle is usually 5°-15° for the front angle and 5°-10° for the back angle (customizable). The length of the guide section accounts for 10%-15% of the total length to ensure contour accuracy. The blade is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.001 mm) to ensure a smooth edge (Ra ≤ 0.01 micron) and a geometric error of <0.003 mm. The cutter body is dynamically balanced (unbalance <3 g·mm /kg, tested at 20,000 RPM) to reduce vibration during high-speed cutting (amplitude <0.003 mm). High-end models are equipped with internal cooling channels (diameter 0.5-2.5 mm, pressure 5-30 bar) or external chip grooves (width 0.5-3 mm), which improve chip removal efficiency (40%-60%) and thermal management (cutting zone temperature <700°C), suitable for extreme processing conditions. The machine-clamped tool adopts a replaceable blade design, and the blade and the tool bar are connected by high-precision threads or bayonet (tolerance 6H/6g), which supports quick replacement and blade re-sharpening.

2.2 Materials

The material is based on nano/micron-sized tungsten carbide (WC), with a composite reinforcement phase (such as CBN 10%-30%, diamond 5%-15%, TiC 5%-10% or Al_2O_3 5 % -10 %), and a bonding phase of cobalt (Co 6%-12%) or nickel (Ni 1%-3%), and the grain size is controlled at 50-150 nanometers. Common composite types include WC-Co-CBN (hardness HV 2200-2600, bending strength 2300-2700 MPa, suitable for high hardness steel, life span up to 180-250 hours), WC- TiC -Co (hardness HV 2300-2700, heat resistance 1100°C, suitable for titanium alloys, life span up to 190-260 hours), WC-Diamond-Co (hardness HV 2500-3000, extremely high wear resistance, specially designed for composite materials, life span up to 200-300 hours). Material selection needs to consider the workpiece hardness (steel HRC 55-70, titanium alloy HRC 35-45), thermal conductivity (steel 40-50 W/ m·K , titanium alloy 15-20 W/ m·K) and cutting temperature (600-1200°C). Some models add nano-grade tantalum carbide (TaC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) to optimize heat crack resistance and interface bonding strength.

3. Manufacturing process

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3.1 Raw material preparation

Ultra-high purity nano/micron tungsten carbide (WC) powder is mixed with reinforcing phase powder (such as CBN, diamond) in proportion (accuracy ±0.05%), the bonding phase is nano-scale cobalt or nickel, and the particle size is controlled at 50-150 nanometers. A high-energy ball mill (speed 200-350 RPM, time 48-72 hours) is used for wet mixing, and isopropanol is added as a dispersant to ensure powder uniformity (segregation <0.5%). The particle size distribution is detected by a laser particle size analyzer, and the crystal phase and interface bonding are analyzed by X-ray diffraction (XRD), and the deviation is controlled within ±0.02%.

3.2 Pressing

The hydraulic press applies 250-350 MPa pressure to form the blade blank, with a density of 15.2-15.8 g/cm³ , and cold isostatic pressing technology (CIP, pressure 250-300 MPa, lasting 15-20 minutes) is used to improve uniformity. The mold is made of super-hard steel (hardness HRC 60-65), with an accuracy of ±0.01 mm, and laser cutting and electrospark machining are used to ensure the forming accuracy of the blade and composite interface. The density of the blank is measured by the Archimedean method (error <0.03 g/cm³) , and the internal porosity is checked by microscope (<0.2%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-3} Pa) or in an argon atmosphere, the temperature is 1500°C-1700°C for 12-18 hours, and the temperature is increased in stages (60°C per hour, 300°C-700°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 200-250 MPa) technology is used to eliminate micro defects, control the grain size to 50-150 nanometers, and uniformly distribute the microhardness (standard deviation <30 HV). Scanning electron microscopy (SEM) analyzes the microstructure and interface bonding, and nanoindentation instrument tests the hardness (HV 2200-3000).

3.4 Post-processing

External turning is performed using CBN tools, with runout accuracy <0.01 mm and surface roughness Ra ≤ 0.1 micron. The blade is machined on an ultra- precision five-axis CNC grinder (accuracy ±0.001 mm), with edge profile error <0.003 mm and surface Ra ≤ 0.01 micron. Mirror polishing with diamond abrasives of grain size W0.1-W0.5, edge Ra ≤ 0.005 micron, and electrolytic polishing (current density 0.05-0.1 A/cm²) removes microscopic burrs. The tip chamfer (0.05-0.15 mm, angle 5°-10°) enhances the ability to resist edge collapse, the composite interface is ultrasonically tested to ensure bonding strength, and the geometry is calibrated by laser interferometer.

3.5 Coating treatment

PVD or CVD process (pressure 10^{-3} Pa, temperature 500-600°C, deposition rate 0.1-0.3 μm /h). Coating types include nano- TiAlN (thickness 2-6 microns, hardness 3200-3600 HV), nano- AlCrN (thickness 2-5 microns, hardness 3400-3800 HV) or nano-DLC (thickness 1-2 microns, hardness

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3400-3900 HV, friction coefficient <0.1), reducing the friction coefficient (<0.2) and increasing the service life by 60%-80%. High-resolution SEM is used to check the uniformity of the coating, and nano-indentation instrument is used to test the hardness and adhesion (>90 N), with a thickness deviation of <0.2 microns.

3.6 Testing packaging

The CMM detects the blade profile accuracy and geometric error (<0.005 mm), and the dynamic balancing machine corrects the imbalance (<3 g·mm /kg). Anti-rust oil coating or vacuum packaging to prevent oxidation. Laser engraving of tool type, diameter, number of teeth, composite type and batch number ensures traceability.

4. Technical parameters

Hardness: substrate HV 2200-3000, coated 3200-3900 HV.
Heat resistance: 800°C-1200°C. Cutting speed (Vc): steel 100-400 m/min, titanium alloy 60-250 m/min, aluminum alloy 300-500 m/min.
Feed (fz): 0.04-0.40 mm/tooth. Depth of cut (ap): 0.1-20 mm. Tolerance: profile accuracy ±0.005 mm, surface roughness ±0.003 mm. Surface roughness: Ra 0.05-0.25 microns.

5. Application scenarios

5.1 Aerospace

Processing turbine blades, fuselage frames and high-temperature alloy parts, common diameters are 12-35 mm and depths are 60-250 mm. An airline uses a 20 mm diameter carbide composite tool to process Inconel 718 blades, with a cutting speed of 180 m/min and a feed rate of 0.10 mm/tooth. The contour error after processing is <0.003 mm, Ra 0.08 microns, and the tool life is 220 hours, which meets the AS9100 standard. High temperature resistance and high precision are required , and the internal cooling pressure reaches 30 bar.

5.2 Automobile Industry

Machining crankshafts, gears and super-hard steel parts, common diameters are 25-60 mm and depths are 40-200 mm. An automotive parts company uses a 30 mm diameter carbide composite tool to machine HRC 60 steel crankshafts, with a cutting speed of 250 m/min, a feed rate of 0.15 mm/tooth, a contour error of <0.005 mm after machining, Ra 0.15 microns, a tool life of 200 hours, an annual output of 400,000 pieces, and an efficiency improvement of 50%. In the machining of high-hardness materials, the tool life and efficiency advantages are significant.

5.3 Energy equipment manufacturing

Processing turbine shaft grooves and high-pressure valve bodies, common diameters are 35-70 mm and depths are 120-350 mm. An energy equipment manufacturer uses a 45 mm diameter cemented carbide composite tool to process a high-temperature alloy turbine shaft, with a cutting speed of 200 m/min, a feed rate of 0.12 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.10 microns, a tool life of 250 hours, an annual output of 1,000 pieces, and an efficiency improvement of 45%.

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High wear resistance and deep groove processing capabilities are required, and the internal cooling system requires 25 bar.

5.4 Medical Devices

Processing orthopedic implants and micro-devices, common diameters are 6-18 mm and depths are 15-60 mm. A medical company uses a 10 mm diameter carbide composite tool to process titanium alloy hip joints, with a cutting speed of 100 m/min, a feed rate of 0.06 mm/tooth, a contour error of <0.002 mm after processing, Ra 0.05 microns, and a tool life of 180 hours, which meets FDA standards. Extremely high precision and biocompatibility are required, and DLC coating is commonly used.

5.5 Precision Instruments

Processing optical lens molds and micro gears, common diameters are 6-25 mm and depths are 15-50 mm. A precision instrument manufacturer uses a 12 mm diameter carbide composite tool to process lens molds, with a cutting speed of 150 m/min, a feed rate of 0.08 mm/tooth, a contour error of <0.002 mm after processing, Ra 0.07 microns, a tool life of 200 hours, and an annual output of 200,000 pieces, in line with ISO 2768 standards. In micro high-precision processing, tool stability becomes the key.

5.6 Composite material processing

Processing carbon fiber reinforced plastic (CFRP) and glass fiber parts, common diameter 15-40 mm, depth 20-100 mm. An aviation composite material company uses 20 mm diameter carbide composite tool to process CFRP wing parts, cutting speed 300 m/min, feed 0.20 mm/tooth, contour error after processing <0.005 mm, Ra 0.10 micron, tool life 230 hours, annual output 5000 pieces, efficiency improvement 60%. High wear resistance and low cutting force, internal cooling system (20 bar) support.

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appendix:

What are carbide micro tools?

1. Overview

1.1 Definition and Function

Carbide micro-tools are precision cutting tools made of cemented carbide materials with extremely small sizes. They are mainly used for micro-machining, micro-hole drilling and complex micro-structure manufacturing. They are widely used in electronic manufacturing, medical devices, precision instruments, aerospace and micro-electromechanical systems (MEMS) and other fields. Its core feature is that the tool diameter is usually between 0.1 mm and 3 mm. Combined with high hardness (HV 1800-2200) and excellent wear resistance, it can efficiently cut micro-workpieces or high-precision materials such as stainless steel (HRC 20-40), titanium alloy (HRC 30-35), hard plastics and glass fiber reinforced materials. Carbide micro-tools are based on tungsten carbide (WC) and add cobalt (Co) as a binding phase. They have high precision (tolerance ±0.001 mm) and vibration resistance, and are suitable for a variety of micro-machining processes such as micro-turning, milling, drilling and engraving. Compared with traditional tools, carbide micro tools excel in micro-aperture processing (diameter 0.1-1 mm), surface quality (Ra 0.02-0.1 microns) and cutting stability, and are particularly suitable for scenarios that require ultra-high precision and microstructures. Its design is highly flexible, and the blade geometry, shank type and coating can be customized according to processing requirements. With the advancement of micro-nano processing technology, the tool can be integrated with high-precision CNC equipment and laser-assisted systems to optimize micro-processing parameters.

1.2 Development Background

With the rapid development of microelectronics, medical implants and precision instrument manufacturing, the demand for high precision and long life of micro tools has increased significantly. In 2025, with the widespread application of 5G technology, micro sensors and biomedical devices, the position of cemented carbide micro tools in the field of micro-nano processing will be further enhanced, promoting innovation in material refinement, manufacturing processes and surface treatment.

2. Technical characteristics

2.1 Structural characteristics

The structural design of cemented carbide micro-tools aims to achieve high-precision micro-machining, excellent stability and low vibration. They usually adopt an ultra-fine straight shank structure, with a single-edge or multi-edge layout of the blade, combined with a high- rigidity micro-tool body to meet the needs of micro-machining. The total diameter of the tool ranges from 0.1 mm to 3 mm. Micro-drills (D<0.5 mm) are used for micro-hole machining, micro-milling cutters (D=0.5-2 mm) are suitable for micro-grooving and contour machining, and micro-turning tools (D=1-3 mm) are used for micro-turning, with a tolerance grade of h5 (0/-0.004 mm). The shank type is an ultra-fine straight shank (diameter 0.3-4 mm, length 20-50 mm), with a tolerance grade of h6

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(0/-0.006 mm). The shank length is customized according to the clamping requirements of the micro-machine tool , with a total length of 30 mm to 80 mm, suitable for high-precision micro-CNC or special micro-machining equipment. The effective cutting length is 5 mm to 20 mm. Shallow cutting (5-10 mm) is suitable for micro surface finishing, and deep cutting (15-20 mm) is suitable for micro deep hole processing. The number of cutting edges is 1-4, depending on the diameter and processing type, D<0.5 mm is 1-2 edges, D>0.5 mm is 2-4 edges, and the edge spacing error is <0.005 mm. The helix angle is 5°-30° (customizable), micro drills are usually 10°-15° to reduce cutting forces, and micro milling cutters are usually 15°-30° to optimize chip evacuation. The blade geometry is customized according to the workpiece requirements, such as micro drill tip angle (angle 90°-140°), micro milling cutter curved edge (radius 0.01-0.1 mm) or micro turning tool straight edge. The blade is processed by ultra- precision five-axis CNC grinding machine (accuracy ±0.001 mm) to ensure smooth cutting edge (Ra ≤ 0.01 micron) and geometric error <0.002 mm. The cutter body is dynamically balanced (unbalance <2 g·mm /kg, tested at 25000 RPM) to reduce vibrations in micro high-speed cutting (amplitude <0.002 mm). High-end models are equipped with micro internal cooling channels (diameter 0.1-0.5 mm, pressure 5-10 bar) or external chip grooves (width 0.1-0.5 mm) to improve chip removal efficiency (30%-40%) and thermal management (cutting zone temperature <400°C), making them suitable for micro high-precision machining.

2.2 Materials

The material is mainly composed of ultra-fine tungsten carbide (WC) and cobalt (Co 6%-10%) composite materials, with grain size controlled at 0.2-0.8 microns to ensure high hardness and toughness. Common grades include YG6X (cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for micro-drilling and hard materials, life span up to 50-80 hours), YT05 (containing titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for stainless steel and titanium alloys, life span up to 60-90 hours), K10 (cobalt content 6%-8%, hardness HV 1700-1900, strong anti-adhesion, specially for aluminum alloys and plastics, life span up to 70-100 hours). Material selection needs to consider the workpiece hardness (steel HRC 20-40, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (300-600°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or tantalum carbide (TaC , 0.5%-1%) to optimize wear resistance and thermal crack resistance.

3. Manufacturing process

3.1 Raw material preparation

Ultra-high purity ultra-fine tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the particle size is controlled at 0.2-0.8 microns, and titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance performance. A planetary ball mill (speed 100-150 RPM, time 24-36 hours) is used for wet mixing, and ethanol is added as a dispersant to ensure powder uniformity (segregation <0.5%). The particle size distribution is detected by a laser particle size analyzer, and the chemical composition is analyzed by an X-ray fluorescence spectrometer (XRF), and the deviation is controlled within ±0.05%.

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3.2 Pressing

The hydraulic press applies 200-250 MPa pressure to form the blade blank, with a density of 14.8-15.2 g/cm³ , and cold isostatic pressing technology (CIP, pressure 200-250 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of high-strength steel (hardness HRC 58-62) with an accuracy of ±0.01 mm. Laser cutting and electrospark machining are used to ensure the accuracy of micro-blade forming. The density of the blank is measured by the Archimedean method (error <0.05 g/cm³) , and the internal porosity is checked by microscope (<0.3%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 150-200 MPa) technology is used to eliminate micro defects, control the grain size to 0.2-0.8 microns, and uniformly distribute the microhardness (standard deviation <40 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2000).

3.4 Post-processing

External turning is performed using CBN tools with runout accuracy <0.005 mm and surface roughness Ra ≤ 0.1 micron. The blade is machined on an ultra -precision five-axis CNC grinder (accuracy ±0.001 mm), with edge profile error <0.002 mm and surface Ra ≤ 0.01 micron. Mirror polishing with diamond abrasives of grain size W0.1-W0.5, edge Ra ≤ 0.005 micron, electrolytic polishing (current density 0.05-0.1 A/cm²) to remove microscopic burrs. The blade tip is chamfered (0.02-0.1 mm, angle 5°-10°) to enhance the ability to resist edge collapse, and the blade geometry is calibrated by laser interferometer.

3.5 Coating treatment

by PVD process (pressure 10^{-3} Pa, temperature 400-500°C, deposition rate 0.1-0.2 μm /h). Coating types include TiAlN (thickness 1-4 microns, hardness 2800-3200 HV), AlCrN (thickness 1-3 microns, hardness 3000- 3400 HV) or DLC (thickness 0.5-1 micron, hardness 3000-3500 HV, friction coefficient <0.1), reducing the friction coefficient (<0.3) and increasing the service life by 30%-50%. SEM checks the uniformity of the coating, and the nanoindenter tests the hardness and adhesion (>70 N), with a thickness deviation of <0.2 microns.

3.6 Testing packaging

The three-dimensional coordinate measuring machine (CMM) detects the blade profile accuracy and geometric error (<0.002 mm), and the dynamic balancing test machine corrects the imbalance (<2 g·mm /kg). Anti-rust oil coating or vacuum packaging to prevent oxidation. Laser engraving of tool type, diameter, number of blades , brand and batch number to ensure traceability.

4. Technical parameters

Hardness: substrate HV 1800-2000, coated 2800-3500 HV.

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Heat resistance: 500°C-800°C. Cutting speed (Vc): steel 30-150 m/min, titanium alloy 20-100 m/min, aluminum alloy 80-250 m/min.
Feed (fz): 0.005-0.05 mm/tooth. Depth of cut (ap): 0.01-2 mm. Tolerance: profile accuracy ±0.001 mm, surface roughness ±0.002 mm. Surface roughness: Ra 0.02-0.1 micron.

5. Application scenarios

5.1 Electronics Manufacturing

Processing micro-circuit board through holes and connectors, common diameter 0.1-1 mm, depth 0.5-5 mm. An electronics company uses 0.3 mm diameter carbide micro- tools to drill PCB through holes, cutting speed 100 m/min, feed rate 0.01 mm/tooth, hole diameter tolerance after processing ±0.001 mm, Ra 0.03 micron, tool life 60 hours, annual output 5 million pieces, efficiency improvement 40%. High precision and micro-hole consistency are required , and internal cooling system (5 bar) support.

5.2 Medical Devices

Processing micro-catheters and implant holes, common diameters are 0.2-1.5 mm and depths are 1-10 mm. A medical company uses a 0.5 mm diameter carbide micro-tool to process stainless steel catheter holes, with a cutting speed of 50 m/min, a feed rate of 0.008 mm/tooth, a hole diameter tolerance of ±0.0005 mm after processing, Ra 0.02 microns, and a tool life of 50 hours, which meets FDA standards. Extremely high precision and surface quality are required, and DLC coating is commonly used.

5.3 Precision Instruments

Processing micro gears and optical lens molds, common diameters are 0.5-2 mm and depths are 2-15 mm. A precision instrument manufacturer uses a 1 mm diameter carbide micro tool to mill the gear profile, with a cutting speed of 80 m/min, a feed rate of 0.01 mm/tooth, a profile error of <0.001 mm after processing, Ra 0.03 microns, a tool life of 70 hours, and an annual output of 300,000 pieces, in line with ISO 2768 standards. In the processing of micro complex structures, tool stability becomes the key.

5.4 Aerospace

Processing micro sensor housing and connection holes, common diameter 0.3-1.2 mm, depth 2-8 mm. An airline uses a 0.8 mm diameter carbide micro tool to drill titanium alloy sensor holes, cutting speed 60 m/min, feed 0.007 mm/tooth, after processing, the hole diameter tolerance is ±0.0008 mm, Ra 0.025 microns, tool life 65 hours, in line with AS9100 standards. Heat resistance and high precision are required , and the internal cooling pressure reaches 10 bar.

5.5 Micro-Electro-Mechanical Systems (MEMS)

Processing micro channels and structures, common diameter 0.1-0.8 mm, depth 0.5-5 mm. A MEMS company uses a 0.2 mm diameter carbide micro tool to carve silicon-based micro channels, cutting speed 40 m/min, feed 0.005 mm/tooth, channel width tolerance after processing ±0.0005 mm, Ra

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0.02 micron, tool life 45 hours, annual output 100,000 pieces, efficiency improvement 35%. Ultra-high precision and micro-machining capabilities are required, and internal cooling system (5 bar) support.

5.6 Watchmaking

Processing micro gears and case details, common diameter 0.5-2 mm, depth 1-10 mm. A watch manufacturer uses a 0.7 mm diameter carbide micro tool to mill gears, cutting speed 70 m/min, feed 0.008 mm/tooth, contour error after processing <0.001 mm, Ra 0.025 micron, tool life 60 hours, annual output 500,000 pieces, in line with high-end watch standards. High finish and micro complexity are required, supported by an internal cooling system (5 bar).

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appendix:

What are Carbide Coated Cutting Tools?

1. Overview

1.1 Definition and Function

Carbide coated cutting tools are high-efficiency cutting tools with high-performance coatings applied on carbide substrates. They are widely used in mechanical processing, aerospace, automotive industry, energy equipment manufacturing, mold manufacturing and other fields. Its core feature is that the hardness, wear resistance, oxidation resistance and thermal stability of the tool are significantly improved through coating technology (such as TiN , TiAlN , AlCrN), and it can efficiently cut a variety of materials, including hardened steel (HRC 40-60), stainless steel (HRC 20-40), titanium alloy (HRC 30-35), cast iron and aluminum alloy. Carbide coated cutting tools are based on tungsten carbide (WC) and cobalt (Co) is added as a binding phase. The coating thickness is usually 1-10 microns. It has ultra-high surface hardness (HV 3000-4000) and low friction coefficient (0.2-0.4), and is suitable for a variety of processing processes such as turning, milling, drilling and reaming . Compared with uncoated tools, coated tools have significant advantages in cutting speed (increased by 30%-60%), tool life (extended by 50%-150%) and surface quality (Ra 0.05-0.5 microns), and are particularly suitable for high-efficiency, high-speed and dry cutting scenarios. Its design flexibility is high, and the blade geometry, coating type and shank structure can be customized according to processing requirements. With the advancement of intelligent manufacturing technology, the tool can be integrated with a real-time monitoring system to optimize cutting parameters.

1.2 Development Background

With the manufacturing industry's higher requirements for production efficiency and tool life, carbide coated cutting tools have become a key technology in the field of modern machining. In 2025, with the widespread application of lightweight and high-performance materials (such as Inconel and titanium alloys) in aerospace and automobiles, the advancement of coating technology (such as nano-coatings and multi-layer coatings) has promoted the continuous improvement of tool performance and met the challenges of extreme machining conditions.

2. Technical characteristics

2.1 Structural characteristics

The structural design of carbide coated cutting tools aims to achieve efficient cutting, excellent durability and stability. They usually adopt straight shank, taper shank or machine clamping structure, with multi- edge or single-edge layout of the cutting edge, combined with high rigidity tool body to adapt to various processing needs. The total diameter of the tool ranges from 3 mm to 80 mm. Micro tools (D<10 mm) are used for fine processing, medium-sized (D=10-40 mm) are suitable for general cutting, and large (D>40 mm) are used for heavy processing. The tolerance grade is h6 (0/-0.006 mm). The shank types include straight shank (DIN 6535 HA/HB) or taper

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shank (BT40, CAT50, HSK-A63). The shank diameter matches the cutting diameter, the tolerance grade is h6, and the shank length (80-400 mm) is customized according to the machine tool clamping and processing depth requirements. The taper shank supports high torque transmission (torque range 30-400 Nm). The total length is 150 mm to 800 mm, suitable for medium-sized CNC (150-400 mm) or heavy-duty machining centers (500-800 mm). The effective cutting length is 20 mm to 600 mm. Shallow cutting (20-100 mm) is suitable for surface finishing, and deep cutting (400-600 mm) is suitable for deep hole or groove processing. The number of cutting edges is 2-12, depending on the diameter and processing type. Small diameters (D<15 mm) are 2-4 edges, and medium and large diameters (D>15 mm) are 4-12 edges. The edge spacing error is <0.01 mm. The helix angle is 10°-45° (customizable), and the standard value is 15°-30°, which optimizes chip discharge and vibration reduction. 25°-30° is commonly used for fine processing, and 35°-45° can be selected for heavy-duty processing. The cutting edge is machined by an ultra- precision five-axis CNC grinder (accuracy ±0.002 mm) to ensure a smooth cutting edge (Ra ≤ 0.02 microns) and a geometric error of <0.005 mm. The cutter body is dynamically balanced (unbalance <5 g·mm /kg, tested at 15,000 RPM) to reduce vibrations during high-speed cutting (amplitude <0.005 mm). High-end models are equipped with internal cooling channels (diameter 0.5-2.5 mm, pressure 5-30 bar) or external chip flutes (width 1-3 mm) to improve chip removal efficiency (30%-50%) and thermal management (cutting zone temperature <700°C), suitable for dry or high-load cutting. The machine-clamped tool adopts a replaceable blade design, and the blade and the tool bar are connected by high-precision threads or bayonet connections (tolerance 6H/6g), which supports quick replacement and blade re-grinding.

2.2 Materials

The material is mainly a composite material of tungsten carbide (WC) and cobalt (Co 6%-12%), with a grain size controlled at 0.5-2 microns to ensure high hardness and toughness. Common grades include YG8 (cobalt content 8%, hardness HV 1800-1900, bending strength 2000-2200 MPa, suitable for rough machining and cast iron, life span of up to 100-140 hours), YT15 (containing titanium carbide, hardness HV 1900-2000, heat resistance 850°C, suitable for stainless steel and titanium alloys, life span of up to 110-150 hours), K20 (cobalt content 6%-8%, hardness HV 1700-1900, strong anti-adhesion, specially for aluminum alloys, life span of up to 120-160 hours). Material selection needs to consider the workpiece hardness (steel HRC 40-60, aluminum alloy HB 50-100), thermal conductivity (steel 40-50 W/ m·K , aluminum alloy 200-250 W/ m·K) and cutting temperature (500-900°C). Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) or tantalum carbide (TaC , 0.5%-1%) to optimize wear resistance and thermal crack resistance. Coating materials include TiN (hardness 2000-2500 HV, heat resistance 500°C), TiAlN (hardness 3000-3500 HV, heat resistance 900°C), AlCrN (hardness 3200-3800 HV, heat resistance 1100°C) and DLC (hardness 3000-4000 HV, friction coefficient <0.1), and the coating thickness is adjusted according to the application.

3. Manufacturing process

3.1 Raw material preparation

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High-purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.1%), the particle size is controlled at 0.5-2 microns, and titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance performance. A planetary ball mill (speed 50-100 RPM, time 24-48 hours) is used for wet mixing, and ethanol is added as a dispersant to ensure powder uniformity (segregation <1%). The particle size distribution is detected by a laser particle size analyzer, and the chemical composition is analyzed by an X-ray fluorescence spectrometer (XRF), and the deviation is controlled within ±0.05%.

3.2 Pressing

The hydraulic press applies 150-200 MPa pressure to form the blade blank, with a density of 14.5-15.2 g/cm³ , and cold isostatic pressing technology (CIP, pressure 150-200 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of high-strength steel (hardness HRC 50-55) with an accuracy of ±0.02 mm. Laser cutting and electrospark machining are used to ensure the accuracy of blade forming. The density of the blank is measured by the Archimedean method (error <0.1 g/cm³) , and the internal porosity is checked by microscope (<0.5%).

3.3 High temperature sintering

In a vacuum furnace (pressure 10^{-2} Pa) or in a hydrogen atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 100-150 MPa) technology is used to eliminate micro defects, control the grain size to 0.5-2 microns, and uniformly distribute the microhardness (standard deviation <50 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2000).

3.4 Post-processing

External turning is performed using CBN tools with runout accuracy <0.01 mm and surface roughness Ra ≤ 0.2 microns. The blade is machined on an ultra -precision five-axis CNC grinder (accuracy ±0.002 mm), with edge profile error <0.005 mm and surface Ra ≤ 0.02 microns. Mirror polishing with diamond abrasives of grain size W0.5-W1.0, edge Ra ≤ 0.01 microns, and electrolytic polishing (current density 0.1 A/cm²) removes microscopic burrs. The blade tip is chamfered (0.1-0.2 mm, angle 5°-10°) to enhance the ability to resist edge collapse, and the blade geometry is calibrated by laser interferometer.

3.5 Coating treatment

PVD or CVD process (pressure 10^{-3} Pa, temperature 400-600°C, deposition rate 0.1-0.3 μm /h). Coating types include TiN (thickness 2-5 microns), TiAlN (thickness 3-8 microns), AlCrN (thickness 3-7 microns) or DLC (thickness 1-3 microns), which reduce the friction coefficient (<0.4) and increase the service life by 50%-150%. SEM checks the uniformity of the coating, and the nanoindenter tests the hardness and adhesion (>70 N), with a thickness deviation of <0.5 microns. The coating process optimizes the oxidation resistance and thermal stability of the tool. TiAlN and AlCrN are particularly suitable for dry cutting.

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3.6 Testing and packaging

The CMM detects the blade profile accuracy and geometric error (<0.01 mm), and the dynamic balancing machine corrects the imbalance (<5 g·mm /kg). Anti-rust oil coating or vacuum packaging to prevent oxidation. Laser engraving of tool type, diameter, number of blades , coating type and batch number ensures traceability.

4. Technical parameters

Hardness: substrate HV 1800-2000, coated 3000-4000 HV.

Heat resistance: 500°C-1100°C (depending on the type of coating). Cutting speed (Vc): steel 60-250 m/min, titanium alloy 40-180 m/min, aluminum alloy 100-350 m/min.

Feed (fz): 0.05-0.30 mm/tooth. Depth of cut (ap): 0.1-10 mm. Tolerance: profile accuracy ±0.005 mm, surface roughness ±0.003 mm. Surface roughness: Ra 0.05-0.5 microns.

5. Application scenarios

5.1 Aerospace

Processing titanium alloy fuselage parts and high-temperature alloy blades, common diameter 10-30 mm, depth 50-200 mm. An airline uses a 20 mm diameter TiAlN coated carbide tool to process titanium alloy connectors, cutting speed 120 m/min, feed 0.10 mm/tooth, contour error after processing <0.005 mm, Ra 0.1 micron, tool life 150 hours, in line with AS9100 standards. Heat resistance and high precision are required, and the internal cooling pressure reaches 20 bar.

5.2 Automobile Industry

Processing engine cylinders and gears, common diameters are 20-50 mm and depths are 30-150 mm. An automotive parts company uses a 25 mm diameter AlCrN coated carbide tool to process HRC 50 steel cylinders, with a cutting speed of 180 m/min, a feed rate of 0.15 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.15 microns, a tool life of 140 hours, an annual output of 600,000 pieces, and an efficiency improvement of 40%. In the processing of high-hardness materials, the coating life advantage is significant.

5.3 Energy equipment manufacturing

Processing turbine shafts and valve bodies, common diameters are 30-70 mm, depths are 100-300 mm. An energy equipment manufacturer uses a 40 mm diameter TiAlN coated carbide tool to process Inconel turbine shafts, with a cutting speed of 150 m/min, a feed rate of 0.12 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.12 microns, a tool life of 160 hours, an annual output of 1,000 pieces, and an efficiency improvement of 35%. High wear resistance and deep groove processing capabilities are required , and the internal cooling system requires 25 bar.

5.4 Mould Manufacturing

Processing mold cavities and guide sleeves , common diameters are 15-40 mm, depths are 20-100 mm. A mold factory uses a 20 mm diameter TiN coated carbide tool to mill mold cavities, with a cutting speed of 200 m/min, a feed rate of 0.15 mm/tooth, a contour error of <0.008 mm after processing, Ra 0.2 microns, a tool life of 130 hours, an annual output of 800 sets of molds, and an

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efficiency increase of 45%. High efficiency and complex contour forming are required, supported by an internal cooling system (15 bar).

5.5 Precision Instruments

Processing optical lens molds and micro parts, common diameters are 5-20 mm and depths are 10-50 mm. A precision instrument manufacturer uses a 10 mm diameter DLC coated carbide tool to process lens molds, with a cutting speed of 100 m/min, a feed rate of 0.08 mm/tooth, a contour error of <0.003 mm after processing, Ra 0.05 microns, a tool life of 120 hours, and an annual output of 400,000 pieces, in line with ISO 2768 standards. In micro high-precision processing, the coating has a significant vibration reduction effect.

5.6 Electronics Manufacturing

Processing aluminum alloy heat sinks and connectors, common diameters are 10-30 mm, depths are 10-40 mm. An electronics company uses a 15 mm diameter AlCrN coated carbide tool to process heat sinks, with a cutting speed of 250 m/min, a feed rate of 0.20 mm/tooth, a contour error of <0.005 mm after processing, Ra 0.15 microns, a tool life of 150 hours, an annual output of 800,000 pieces, and an efficiency increase of 50%. High efficiency and surface quality are required, and dry cutting is widely used.

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appendix:

What are carbide medical surgical knives?

1. Overview

1.1 Definition and Function

Cemented carbide medical surgical tools are high-precision cutting tools made of cemented carbide materials. They are designed for medical surgery, implant processing and biomaterial cutting and are widely used in orthopedics, neurosurgery, dentistry, minimally invasive surgery, ophthalmology and other fields. Its core feature is that it combines the high hardness (HV 1800-2200) and biocompatibility of cemented carbide, and can efficiently cut high-strength biomaterials such as bones (hardness HRC 20-40), titanium alloy implants (HRC 30-35), hard polymers and ophthalmic lens materials. Cemented carbide medical surgical tools are based on tungsten carbide (WC), with cobalt (Co) added as a binding phase, and special surface treatment is used to ensure non-toxicity and corrosion resistance. They are suitable for surgical-related processing such as cutting, drilling, milling, grinding and engraving. Compared with traditional stainless steel surgical knives, carbide medical knives excel in cutting accuracy (tolerance ±0.005 mm), durability (life extended by 50%-100%) and surface quality (Ra 0.02-0.1 microns), and are particularly suitable for medical scenarios that require high precision and long-term use. Its design is highly flexible, and the blade shape, handle type and coating can be customized according to surgical needs. With the advancement of medical technology, the tool can be integrated with the robot-assisted surgical system to improve surgical efficiency.

1.2 Development Background

With the aging population and the rapid development of medical technology, the demand for high-precision implants and minimally invasive surgical tools has surged. In 2025, with the popularization of 3D printed implants, personalized medicine and robotic surgery, cemented carbide medical surgical tools have become key tools for medical device manufacturing due to their excellent cutting performance and biosafety, promoting innovation in material optimization, surface treatment and aseptic processing technology.

2. Technical characteristics

2.1 Structural characteristics

The structural design of cemented carbide medical surgical tools aims to achieve high-precision cutting, sterility and human compatibility. They usually adopt ultra-fine straight handles or customized handle structures, with single-edged or multi-edged blades, combined with high-rigidity micro-knife bodies to meet surgical needs. The total diameter of the tool ranges from 0.5 mm to 10 mm. Micro-tools (D<2 mm) are used for neurosurgery and dentistry, medium-sized (D=2-6 mm) are suitable for orthopedics and implant processing, and large (D>6 mm) are used for heavy bone cutting. The tolerance grade is h5 (0/-0.004 mm). The handle type is an ultra-fine straight handle (diameter 1-12 mm, length 30-100 mm) or a medical handle that meets the ISO 13485 standard, with a tolerance grade of h6 (0/-0.006 mm). The handle length is customized according to

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the clamping requirements of the surgical instrument . The total length is 50 mm to 150 mm, suitable for surgical robots or manual instruments. The effective cutting length is 5 mm to 50 mm. Shallow cutting (5-20 mm) is suitable for soft tissue or micro-cutting, and deep cutting (30-50 mm) is suitable for bone or implant processing. The number of cutting edges is 1-6, depending on the diameter and type of surgery. D<2 mm is 1-2 edges, D>2 mm is 2-6 edges, and the edge spacing error is <0.005 mm. The blade angle is usually 15°-30° (customizable) to optimize cutting force and tissue damage control. The blade is processed by an ultra- precision five-axis CNC grinder (accuracy ±0.001 mm) to ensure smooth cutting edges (Ra ≤ 0.01 microns) and geometric errors <0.002 mm. The cutter body is dynamically balanced (unbalance <2 g·mm /kg, test speed 20000 RPM) to reduce vibration in micro-cutting (amplitude <0.002 mm). High-end models are equipped with micro internal irrigation channels (diameter 0.1-0.5 mm, pressure 2-5 bar) or external chip removal design to improve chip removal (efficiency 30%-40%) and thermal management (cutting zone temperature <200°C) to ensure a sterile surgical environment. The tool surface is electropolished and sterile coated to meet ISO 10993 biocompatibility standards.

2.2 Materials

The material is mainly composed of ultrafine tungsten carbide (WC) and cobalt (Co 6%-8%) composite materials, with a grain size controlled at 0.2-0.8 microns to ensure high hardness and biosafety. Common grades include YG6X (cobalt content 6%, hardness HV 1800-1900, bending strength 1800-2000 MPa, suitable for bones and titanium alloys, life span of up to 50-80 hours), YT05 (containing titanium carbide, hardness HV 1900-2000, heat resistance 800°C, suitable for hard polymers, life span of up to 60-90 hours), K10 (cobalt content 6%, hardness HV 1700-1900, strong corrosion resistance, specially designed for soft tissue cutting, life span of up to 70-100 hours). Material selection needs to consider the hardness of biomaterials (bone HRC 20-40, titanium alloy HRC 30-35), thermal conductivity (bone 0.3-0.5 W/ m·K , titanium alloy 15-20 W/ m·K) and cutting temperature (100-300°C). The cobalt content is strictly controlled to reduce toxicity in the body. Some models add trace amounts of niobium carbide (NbC , 0.5%-1%) to optimize wear resistance. The surface coating can be medical grade TiN (hardness 2500 HV) or ZrN (hardness 2300 HV) to ensure corrosion resistance and biocompatibility.

3. Types

Carbide medical surgical tools are divided into many categories according to the type of surgery and processing requirements. The following are the most comprehensive categories and their characteristics based on the information of the entire network and industry practice:

Micro drill bit

The diameter is 0.5-2 mm, the blade is a double spiral or single-point design , specially used for neurosurgery skull drilling, micro-implant processing and ophthalmic corneal perforation, the cutting angle is 10°-15°, suitable for high-precision microholes (tolerance ±0.0005 mm), such as skull fixation screw holes or ophthalmic surgical channels.

Bone saw blade

The length is 20-50 mm, the blade is a multi- tooth design (6-12 teeth), used for orthopedic osteotomy, plastic surgery and spinal correction, the blade angle is 20°-30°, suitable for hard bone

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(HRC 20-40) cutting, and is equipped with a flushing channel to reduce thermal damage.

Dental milling cutter

The diameter is 1-3 mm, the blade is ball-headed, cylindrical or conical, specially used for root carving, implant processing and crown finishing, the cutting angle is 15°-25°, and the surface Ra ≤ 0.02 microns ensures gingival tissue compatibility.

Minimally invasive cutting knife

The diameter is 0.5-1.5 mm, the blade is a single-edged or double-edged design, suitable for minimally invasive soft tissue cutting, microchannel processing and endoscopic surgery, the blade angle is 10°-20°, optimized for minimal invasiveness, and ZrN coating is commonly used.

Implant machining tools

The diameter is 3-8 mm, the blade has a customized geometry (such as a stepped or curved blade), and is specially used for finishing titanium alloy, stainless steel or PEEK implants. The cutting angle is 15°-30°, and the tolerance is ±0.002 mm to meet personalized medical needs.

Grinding tools

Diameter 4-10 mm, with multi-grain or spherical blade design, used for bone surface grinding, orthosis processing and joint replacement pretreatment, cutting speed 20-50 m/min, surface Ra ≤ 0.05 microns, equipped with high wear-resistant coating.

Ophthalmic scalpel

The diameter is 0.1-1 mm, the blade is an ultra-fine single-edged or micro-ring design, specially used for cataract cutting, corneal transplantation and vitreous surgery, the cutting angle is 5°-15°, and the blade Ra ≤ 0.005 microns, ensuring minimal tissue damage.

Vascular cutter

The diameter is 0.3-1.2 mm, the blade is an ultra-thin straight blade or hook-shaped design, suitable for cardiovascular surgery and vascular bypass transplantation, the cutting angle is 10°-20°, the surface is specially coated with anti-thrombotic coating, and the tolerance is ±0.001 mm.

Tissue carving knife

The diameter is 1-4 mm, the blade is a ball head or flat design, specially used for plastic surgery, soft tissue shaping and tumor resection, the cutting angle is 15°-25°, optimizing cutting force and tissue protection, and TiN coating is commonly used.

Bone Screw Drill Bit

The diameter is 1.5-3.5 mm, the blade is a spiral or stepped design, specially used for orthopedic fixation screw pre-drilling and fracture internal fixation, the cutting angle is 15°-20°, the depth is controlled at 10-30 mm, and it is highly durable.

Arthroscopic tools

The diameter is 0.8-2 mm, the blade is a micro ball head or spade-shaped design, suitable for knee and shoulder arthroscopy, the cutting angle is 10°-20°, equipped with a flushing channel, and the tolerance is ±0.0005 mm.

Spine Scalpel

The diameter is 2-6 mm, and the blade is a customized multi -blade or serrated design, specially used for spinal fusion and discectomy, with a cutting angle of 20°-30°, suitable for hard spinal materials, and a service life of up to 60-90 hours.

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4. Manufacturing process

4.1 Raw material preparation

Medical grade ultra-high purity tungsten carbide (WC) powder and cobalt (Co) powder are mixed in proportion (accuracy ±0.05%), the particle size is controlled at 0.2-0.8 microns, and titanium carbide (TiC , 0.5%-1%) or niobium carbide (NbC , 0.5%-1%) is added to enhance performance. A high-energy ball mill (speed 100-150 RPM, time 24-36 hours) is used for wet mixing, and medical-grade ethanol is added as a dispersant to ensure powder uniformity (segregation <0.5%). The particle size distribution is detected by a laser particle size analyzer, and the heavy metal content is analyzed by inductively coupled plasma mass spectrometry (ICP-MS). The deviation is controlled within ±0.01%, which meets FDA standards.

4.2 Pressing

The hydraulic press applies 200-250 MPa pressure to form the blade blank, with a density of 14.8-15.2 g/cm³ . Cold isostatic pressing technology (CIP, pressure 200-250 MPa, duration 10-15 minutes) is used to improve uniformity. The mold is made of medical stainless steel (hardness HRC 50-55) with an accuracy of ±0.01 mm. Laser cutting and electrospark machining are used to ensure the accuracy of blade forming. The density of the blank is measured by the Archimedean method (error <0.05 g/cm³) , and the internal porosity is checked by microscope (<0.3%).

4.3 High temperature sintering

In a vacuum furnace (pressure 10^{-3} Pa) or in an argon atmosphere, the temperature is 1400°C-1600°C for 10-12 hours, and the temperature is increased in stages (50°C per hour, 300°C-600°C in the preheating stage) to remove volatiles. Hot isostatic pressing (HIP, pressure 150-200 MPa) technology is used to eliminate micro defects, control the grain size to 0.2-0.8 microns, and uniformly distribute the microhardness (standard deviation <40 HV). Scanning electron microscopy (SEM) analyzes the microstructure, and Vickers hardness tester tests the hardness (HV 1800-2000).

4.4 Post-processing

External turning is performed using CBN tools with runout accuracy <0.005 mm and surface roughness Ra ≤ 0.1 micron. The blade is machined on an ultra -precision five-axis CNC grinder (accuracy ±0.001 mm), with edge profile error <0.002 mm and surface Ra ≤ 0.01 micron. Mirror polishing with diamond abrasives of grain size W0.1-W0.5, edge Ra ≤ 0.005 micron, electrolytic polishing (current density 0.05-0.1 A/cm²) to remove microscopic burrs. The blade tip is chamfered (0.02-0.1 mm, angle 10°-15°) to enhance the ability to resist edge collapse, and the blade geometry is calibrated by laser interferometer.

4.5 Coating treatment

The coating is achieved using a medical-grade PVD process (pressure 10^{-3} Pa, temperature 350-450°C, deposition rate 0.1-0.2 µm /h). Coating types include TiN (thickness 1-3 microns, hardness 2500 HV) or ZrN (thickness 1-2 microns, hardness 2300 HV), ensuring corrosion resistance and biocompatibility, reducing the friction coefficient (<0.3) and increasing the life by 30%-50%. SEM

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checks the uniformity of the coating, and nanoindentation tests hardness and adhesion (>70 N), with a thickness deviation of <0.2 microns. The coating is sterile and complies with ISO 10993 standards.

4.6 Testing and packaging

The tool profile accuracy and geometric error (<0.002 mm) are checked by a coordinate measuring machine (CMM), and the imbalance (<2 g·mm /kg) is corrected by a dynamic balancing machine. Sterility testing (SAL 10^{-6}) is performed , and gamma ray or ethylene oxide sterilization is used. Vacuum packaging prevents oxidation and contamination. Tool type, diameter, number of blades , batch number and sterility mark are laser engraved to ensure traceability.

5. Technical parameters

Hardness: substrate HV 1800-2000, coated 2300-2500 HV.

Heat resistance: 300°C-800°C. Cutting speed (Vc): bone 20-80 m/min, titanium alloy 30-120 m/min, polymer 50-150 m/min.

Feed (fz): 0.005-0.03 mm/tooth. Depth of cut (ap): 0.01-3 mm. Tolerance: profile accuracy ±0.005 mm, surface roughness ±0.002 mm. Surface roughness: Ra 0.02-0.1 micron.

6. Application Scenarios

6.1 Orthopedic surgery

Processing hip implants and bone plates, common diameter 2-6 mm, depth 10-30 mm. An orthopedic company uses a 4 mm diameter carbide medical tool to cut titanium alloy hip joints, cutting speed 60 m/min, feed 0.01 mm/tooth, contour error after processing <0.002 mm, Ra 0.03 microns, tool life 70 hours, in line with FDA standards. High precision and durability are required , and flushing channels (3 bar) are supported.

6.2 Neurosurgery

Processing skull drilling and micro implants, common diameter 0.5-2 mm, depth 5-15 mm. A neurosurgery hospital uses a 1 mm diameter carbide medical tool to drill the skull , cutting speed 40 m/min, feed 0.008 mm/tooth, hole diameter tolerance ±0.0005 mm after processing, Ra 0.02 microns, tool life 50 hours, meeting high precision requirements. Miniaturization and sterility are required, and TiN coating is commonly used .

6.3 Dental surgery

Processing tooth roots and implants, common diameters are 1-3 mm and depths are 5-20 mm. A dental clinic uses a 2 mm diameter carbide medical tool to cut tooth roots, with a cutting speed of 50 m/min, a feed rate of 0.01 mm/tooth, a contour error of <0.001 mm after processing, Ra 0.025 microns, and a tool life of 60 hours, meeting biocompatibility standards. High finish and corrosion resistance are required.

6.4 Minimally Invasive Surgery

Processing soft tissue and microchannels, common diameter 0.5-1.5 mm, depth 2-10 mm. A

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minimally invasive surgery center uses 0.8 mm diameter carbide medical tools to cut soft tissue, cutting speed 30 m/min, feed 0.005 mm/tooth, cut width tolerance ±0.0005 mm after processing, Ra 0.02 microns, tool life 45 hours, to ensure minimal trauma. High precision and sterile environment are required .

6.5 Implant Manufacturing

Processing customized titanium alloy implants, common diameter 3-8 mm, depth 15-40 mm. An implant manufacturer uses 5 mm diameter carbide medical tools to process skull implants, cutting speed 70 m/min, feed 0.012 mm/tooth, contour error after processing <0.002 mm, Ra 0.03 microns, tool life 80 hours, annual production of 100,000 pieces, in line with ISO 13485 standards. High durability and biosafety are required.

6.6 Orthopedic surgery

Processing bone orthoses, common diameter 4-10 mm, depth 20-50 mm. An orthopedic equipment company uses a 6 mm diameter carbide medical tool to cut bone brackets, cutting speed 60 m/min, feed 0.015 mm/tooth, contour error after processing <0.003 mm, Ra 0.04 micron, tool life 75 hours, annual production 50,000 pieces, support surgical robot operation. High stability and flushing design (5 bar) are required .

6.7 Ophthalmic Surgery

Processing ophthalmic lenses and corneas, common diameters are 0.1-1 mm and depths are 1-5 mm. An ophthalmology hospital uses a 0.5 mm diameter carbide medical tool to cut cataracts, with a cutting speed of 20 m/min, a feed rate of 0.003 mm/tooth, a cut tolerance of ±0.0003 mm after processing, Ra 0.01 micron, and a tool life of 40 hours, meeting high precision requirements. Ultra-miniaturization and sterility are required.

6.8 Cardiovascular Surgery

Processing vascular stents and bypasses, common diameters are 0.3-1.2 mm and depths are 2-8 mm. A cardiovascular center uses 0.8 mm diameter carbide medical tools to cut blood vessels, with a cutting speed of 30 m/min, a feed rate of 0.005 mm/tooth, a cut tolerance of ±0.0005 mm after processing, Ra 0.015 microns, and a tool life of 50 hours to ensure anti-thrombotic properties.

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