Current Status of Cemented Carbide Tool Materials

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Abstract

The rapid development of metal cutting technology has put forward more and more high technical requirements for cutting tools. The emergence of coating tools has realized the comprehensive modification of traditional tools, which can effectively improve machining efficiency and machining accuracy, extend tool life and reduce production. cost. Therefore, the preparation of high performance coated tools is particularly important. On the basis of an overview of the basic conditions of cemented carbide tools, the hard alloy coated tool base and superhard tool materials are introduced, and the development direction of coated tools is prospected.

Keywords

Cemented carbide tool base, superhard tool material.

1. Introduction

Cemented carbide is made of refractory metal hard compound and metal binder by powder metallurgy method. Its hardness (HRA) is 89~94, which is much higher than that of high-speed steel. At 540°C, the hardness (HRA) is 82~87, which is equivalent to the hardness of high-speed steel at room temperature (HRA83~86), and also has the advantages of good chemical stability and high heat resistance [1]. It is one of the widely used tool materials in the processing industry; It has high hardness and its hardness is higher than all other materials, and it also has excellent properties such as good thermal conductivity, good wear resistance and high chemical inertness, making it an ideal tool coating material; diamond-like (DLC) film. The coated tool has high hardness, low friction coefficient, strong friction and corrosion resistance, good anti-blocking performance, and can be used to make complex and special-shaped tools. It is an important development direction of future tools; ceramic tools have high hardness and Good wear resistance and other advantages, but there are shortcomings of brittleness and easy chipping. Cubic boron nitride (c-BN) has thermal stability and is chemically inert to iron group elements. It is widely used for cutting hardened steel and gray cast iron. Titanium alloy and Hard-to-machine materials such as high-temperature alloys are ideal ceramic material reinforcement phases.

Coating one or more layers of high-strength, wear-resistant metal or non-metallic compound films (such as TiC, TiN, A12O3, etc.) on the tool substrate can better solve the strength of the tool and The contradiction between hardness. It combines the tool base with a hard coating to maximize tool performance. The coating on the surface of the tool acts as a chemical barrier and thermal barrier, reducing the crater wear of the carbide tool, significantly improving machining efficiency, improving machining accuracy, extending tool life and reducing machining costs.

2. Cemented Carbide Overview

Commonly used hard coating materials mainly include some metal nitrides, carbides, oxides, borides and diamonds. The common features of these materials are high hardness, melting point and elastic modulus, and high wear resistance. The structure is compact, the chemical properties are stable, and the high temperature performance is superior, which can prevent and reduce the oxidation of the surface material, and resist the decay of the chemical substances such as acid and alkali.

Coated knives have a variety of classification methods [2], (1) according to different coating methods, can be divided into chemical vapor deposition coating tools and physical vapor deposition coating tools. (2) According to the different coating base materials, it can be divided into cemented carbide coated tools, high-speed steel coated tools and coated tools on ceramics and superhard materials (diamond and cubic boron nitride). (3)According to the different coating structure, the coating tool is divided into: single layer coating, multi-layer coating, gradient coating, soft and hard composite coating, nano coating, super hard film coating and so on. (4) According to the nature of the coating material, it can be divided into two categories: "hard" coated tool and "soft" coated tool. The "hard" coated tool has high hardness and wear resistance. The coating materials are TiC, TiN, TiCN, Al2O3, TiAlN, and the like, and combinations thereof. The "soft" coated tool has a low coefficient of friction with the workpiece material, which can reduce the station junction, reduce friction, reduce cutting force and cutting temperature, mainly including MoS2, WS2, TaS2, etc.; The ingredients are classified and described.

2.1. Tungsten Carbide (WC) Based Hard Alloy

At present, most of the cemented carbides are based on WC and are classified into WC+CO (YG class, corresponding to ISO standard K class), WC+TiC+Co (YT class, corresponding to ISO standard P class), WC+TaC. (NbC) + Co (YA type) and WC + TiC + TaC (NbC) + Co (YW type, corresponding to the M standard of the ISO standard) 4 types, a small part of the cemented carbide with TiC as the matrix.

(1) YG type (WC+CO) cemented carbide (K type)

YG-based hard alloys commonly used are: medium particles, YG3 (3%), YG6 (6%), YG8 (8%); fine particles, YG3X, YG6X. YG is suitable for processing short-cut black metal, non-ferrous metals and non-metallic materials, and can also process heat-resistant steel such as titanium alloy at low speed.

(2) YT type (WC+TiC+Co) cemented carbide (P type)

YT-based hard alloys are commonly used in YT30 (TiC: 30%), YT15 (15%), YT14 (14%), and YT5 (5%). Compared with WC, their hardness and heat resistance are good, but toughness and the thermal conductivity is poor. Therefore, as the TiC content increases and the Co content decreases, the hardness, heat resistance and wear resistance of the YT-based cemented carbide increase, while the strength, impact toughness and thermal conductivity decrease. The YT class is suitable for processing long swarf ferrous metals. The more TiC is contained, the better the heat resistance, the lower the strength, and the fine processing, and the less TiC is used for roughing.

(3) YW type (WC + TiC + TaC (NbC) + Co) cemented carbide (M type)

YW type cemented carbide is a TaC (NbC) hard phase added to YT, which has increased flexural strength, impact toughness and fatigue strength, improved high temperature performance and oxidation resistance, and can process long chips or short chips. And non-ferrous metals, known as general alloys.

The above three categories are collectively referred to as WC set cemented carbide.

(4) YN type cemented carbide

Commonly used grades of YN hard alloys are YN05, YN10 and so on. Such cemented carbides are alloys in which TiC is the main hard phase and Ni or Mo is the binder phase. It has higher wear resistance, heat resistance and high hardness than WC-based cemented carbide, but has poor flexural strength and impact toughness, and is generally used for finishing, semi-finishing steel and cast iron.

The main components are tungsten carbide, titanium carbide, tantalum carbide and cobalt, and the grade is YW (collectively referred to as M in the world). This type of cemented carbide is based on the addition of tantalum carbide to the YT type. The hardness, strength and wear resistance of the cemented carbide are improved. Such cemented carbides are known as versatile because they can be used not only for processing cast iron but also for processing steel. Or general purpose carbide.

2.2. Carbon (Nitrogen) Titanium-Based Hard Alloy

TiC (N)-based cemented carbide is an alloy with Ni-Mo as the binder, TiC as the main component, little or no WC, and a small amount of other carbides added, which has high hardness and low density. It has good heat resistance, stable chemical properties and good oxidation resistance. Compared with WC-based cemented carbide, carbon (nitrogen) titanium-based cemented carbide has many advantages. TiC (N) has a small coefficient of friction to metal, the highest hardness in carbide, anti-diffusion wear and anti-adhesion during cutting. It has strong abrasion resistance, good wear resistance and less hardness reduction at high temperatures.

The properties of TiC (N)-based cemented carbides are between cemented carbide and ceramics and are known as cermets. TiC (N)-based cemented carbides are close to ceramic materials with high hardness and heat resistance, and have high flexural strength and fracture orientation than ceramics. Therefore, they can be used as high-speed cutting tool materials [3]. However, TiC (N)-based hard alloys also have disadvantages such as poor anti-abrasive wear resistance and poor resistance to plastic deformation than base alloys, and are not suitable for processing heat-resistant alloys and wear-resistant materials such as fiberglass and cast iron.

Japan's Kyocera Corporation has studied and used TiCN-NbC and TiC-TiN-based cermets, and its performance has been further improved; Kyocera Corporation of Japan has also developed ultra-fine grain cermets with an average grain size of 0.6 μm and flexural strength. At 2.5GPa, the company has further developed TiAlN-coated cermets using PVD coating technology, which is superior to uncoated ceramics [4-5].

2.3. Ultra-Fine Grained Carbide

Ultra-fine grained cemented carbide is a kind of hard alloy with high strength and high hardness. It consists of ultra-fine grained tungsten carbide, ie 0.5μm WC, metallic cobalt Co, vanadium carbide VC and chromium carbide Cr3C2. Cutting speeds are too low to use traditional hard alloys, as well as traditional hard alloy wear due to vibration or insufficient wear resistance of high speed steel tools.

The ultrafine grained cemented carbide has a particle size of generally 0.2~1.0 μm, and most of it is 0.5μm or less, which is a fraction of a part to a few tens of the ordinary cemented carbide WC particle size, and its hardness is generally 90-93 HRA. The flexural strength is 2~3.5GPa, which is higher than the general WC-Co cemented carbide with the same cobalt content. It has less interaction with the processing material, especially suitable for heat-resistant alloy steel, high-strength alloy steel and other difficulties. Processing materials [6-8]. Generally, a grain size of 1.0-1.3μm is called a micro-grain cemented carbide; a grain size of 0.6~0.9 μm is called a submicron-grain cemented carbide; and a grain size of 0.4~0.5μm is called Ultrafine microcrystalline cemented carbide; a nano-series microcrystalline cemented carbide with a grain size of 0.1~0.3 μm (100~300 nm).

2.4. Surface Coated Cemented Carbide

Coated cemented carbide is coated with a layer of high-hard, wear-resistant and refractory metal compounds (such as TiC, Tic (N), Al2O3) on the YG alloy substrate to make the surface layer high hardness and wear resistance. Strong chemical stability, high flexural strength, good toughness and high thermal conductivity. Coated cemented carbide can be used for semi-finishing, finishing, roughing (small load) steel and cast iron, but TiC and TiN alloys are difficult to process titanium alloy and austenitic stainless steel, and the cost is high, which affects the use. Range.

3. Superhard Tool Material

3.1. Ceramics

Ceramic tool materials mainly include Al2O3 and Si3N4 based ceramics. The hardness is 92~95HRA. The heat resistance is good. The Al2O3 tool can be cut at 1200°C or above. The Si3N4 can be cut at 1300~1400°C. The chemical stability is good. The coefficient is low and the cutting speed is 2~5 times that of cemented carbide. Al2O3 based tools are suitable for semi-finishing and finishing of hard and hard materials such as hardened steel and hard cast iron. The Si3N4 based tool is suitable for processing materials such as cast iron and nickel-based alloys, and the representative grade is sialon (Si3N4-Al2O3-Y2O3). However, ceramic tool materials have low flexural strength and poor toughness.

(1) Pure alumina ceramics

It is mainly used for Al2O3 plus trace additives (such as MgO), which is formed by cold pressing and is an inexpensive non-metallic tool material. Its flexural strength is 400-500 N/mm2 and its hardness is 91~92 HRA. Since the bending strength is too low, it is difficult to promote the application.

Al2O3 ceramics [9] is one of the most commonly used structural ceramic materials. Al2O3 ceramics have good chemical and thermal stability, do not react with various substances such as carbides and nitrides, and are bonded to metals. Poor sex. It has strong oxidation resistance during cutting and is suitable for continuous high speed cutting. However, Al2O3 ceramics have low flexural strength and fracture toughness, poor thermal shock resistance and high brittleness, so they are prone to chipping during cutting. At present, pure Al2O3 ceramic tools are few, mostly combined with other compounds, such as (Ti, W) C to improve the composite bending strength and fracture toughness comprehensive mechanical properties.

(2) Composite alumina ceramics

A ceramic in which a high hardness, refractory carbide is added to an Al2O3 matrix and some other metal such as TiC is added for hot pressing. Its flexural strength is above 800N/mm2 and its hardness reaches 93~94HRA.

The ceramic has a very high hardness, and the hardness can reach 80HRA at 1200 ° C; the chemical stability is good, and the affinity with the metal to be processed is small. However, ceramics have poor flexural strength and impact toughness and are very sensitive to impact. They are currently used for semi-finishing and finishing of various metal materials, and are especially suitable for the processing of hardened steel and chilled cast iron.

SiC and ZrO2 whiskers are added to the Al2O3 matrix to form whisker ceramics, which greatly improves the toughness.

(3) Composite silicon nitride ceramics

A composite silicon nitride ceramic can be produced by adding a compound such as SiC and a metal Co to a Si3N4 substrate by hot pressing. Its mechanical properties are similar to those of composite alumina ceramics, and it is especially suitable for cutting chilled cast iron and hardened steel.

Si3N4 ceramics[10] have higher flexural strength and fracture toughness than Al2O3 ceramics, and Si3N4 ceramics have higher thermal shock resistance. It is superior to Al2O3 ceramics in machining, and is suitable for processing cast iron and high hardness materials. However, Si3N4 ceramics have a high affinity with iron, so when a steel is processed, a low melting point compound is formed, which causes the tool material to be destroyed. Therefore, the Si3N4 ceramic tool material also adds some toughening and strengthening phase to improve the mechanical properties of the composite. For example, the addition of Al2O3 to form a sialon tool has good comprehensive properties such as high temperature creep resistance and chemical stability.

3.2. Diamond

Diamond is divided into natural and artificial, its hardness is up to 10000HV, which is the hardest material in nature. Natural diamonds are of good quality but expensive. Synthetic diamond is converted from graphite under the conditions of high temperature and high pressure by means of the catalytic action of certain alloys. Diamond can cut difficult materials such as ceramics, high-silicon aluminum alloys, hard alloys, etc. It can also cut non-ferrous metals and their alloys, but it cannot cut iron-based materials because carbon and iron have strong affinity, carbon. Spread to the workpiece to accelerate tool wear. However, when the temperature is greater than 700 ° C, the diamond is converted into a graphite structure and loses strength.

Diamond is a crystal of a single carbon atom, and its crystal structure is an equiaxed face-centered cubic system (the highest atom density of the crystal system). The bond between carbon atoms in diamond is sp3 hybrid covalent bond, which has strong binding force, stability and directionality. The performance of synthetic diamond depends on the relative ratio of the sp3 hybrid covalent bond to the amorphous amorphous carbon sp2 hybrid covalent bond. If the content of sp3 is too low, the mixture of the two is diamond-like (Dia-mond-Like Carbon, DLC for short). Unique crystal structure gives diamond the highest hardness, rigidity, thermal conductivity and excellent resistance to wear, corrosion and chemical stability qualitative and so on are higher than cemented carbide [11].

3.3. Cubic Boron Nitride

Boron nitride has various structures, and common crystal structures such as cubic boron nitride (c-BN) and cubic boron nitride (h-BN), in which cubic boron nitride has ultra-high hardness, its hardness is second only to Diamond, with excellent wear resistance, thermochemical stability and oxidation resistance, Guang'an has been concerned and researched by researchers [12].

In addition, the bonding bond and lattice constant between c-BN atoms are similar to those of diamond, so that c-BN is similar in nature to diamond. Diamond may be converted to graphite at high temperatures, and carbon may be used as a tool cutting material. The material to be processed undergoes a pro-carbon metal reaction, which in turn leads to a reduction in tool life. However, c-BN is less susceptible to chemical reaction with iron group elements and alloy materials, and c-BN has higher oxidation resistance, so c-BN has better chemical properties than diamond [13]. When c-BN is used as a tool material, it is less likely to be bonded than hard alloy [14].

The hexagonal boron nitride crystal is converted into cubic boron nitride (CBN) by high temperature and high pressure treatment, including integral polycrystalline CBN and composite polycrystalline CBN. The microhardness of cubic boron nitride is 8000~9000 HV, second only to diamond. However, cubic boron nitride has better thermal stability and chemical inertness than diamond, and can withstand temperatures of 1300~1500 °C, and can also be processed at 1200 °C. Cubic boron nitride can be used to cut hardened steel, chilled cast iron, superalloy, etc., and the cutting speed is 3 times higher than that of hard alloy.

3.4. Coating Tool

Coated cemented carbide is coated with a 5~30nm high-hard, wear-resistant, refractory metal compound (such as TiC, TiC (N), Al2O3) on the surface of the cemented carbide (or ceramic). High hardness, good wear resistance, strong chemical stability, high bending strength, good toughness and high thermal conductivity. At present, composite coating tools, diamond coated tools, CBN tools, etc. should be developed.

4. Conclusion

The types of cemented carbide coatings range from single compound coatings to multi-component complex coatings, with layers ranging from several layers to more than a dozen layers. The coating process is not only constantly updated, but also enables a flexible combination of multiple processes to achieve a high performance tool coating. At present, there has been a new development in coating materials, which can not only produce multi-layer (up to 13 layers) coated alloys, but also successfully obtain ultra-hard coatings such as diamond and cubic boron nitride. A new type of coating substrate is also being introduced, and a cemented carbide coating matrix with a gradient structure further improves the performance of the cemented carbide coating tool. Multi-layer coatings, multi-component composite coatings, multi-component composite nano-coatings, diamond coatings, and CBN coatings will be the future direction of coated tools.

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