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Research and Selection of Cutting Tool Materials in CNC Machines

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Abstract

The paper studies and discusses the material of cutting tools and the select principle of the cutting tools by sorting, consulting and collecting the information to deal with the problem that the much cutting force, high cutting temperature and serious tool deflection in the machining process of CNC machine. It provides a series of important theory and principle for selecting and studying the cutting tools of CNC machine.

Keywords

CNC Machine; Cutting Tool Material; Select Principle; Machinability.

1. Introduction

Numerical control processing can effectively solve the problem of complex, precise, small batch and variable parts processing in mechanical products, and greatly shorten the manufacturing period of products.[1-3] At present, CNC machining technology is an important indicator to measure the level of a country's machinery manufacturing industry, and it also reflects the manufacturing level of a machinery manufacturing enterprise. Among them, the three core parts of CNC technology are mainly machine tool structure, CNC system, and peripheral technology. The tool is the most important part of peripheral technology.

As a key component of CNC machine tools, modern cutting tool material selection has gradually transitioned from carbon tool steel and high-speed steel to cemented carbide tools, cubic boron nitride and other super wear-resistant and high-performance tools.[4]

Only with advanced processing equipment and high-performance CNC tools can they give full play to their due effectiveness. The reasonable choice of cutting tool material, cutting tool structure and cutting parameters directly affects the productivity and tool life in the cutting process, the amount of processing cost, processing accuracy and the quality of the machined surface.[5-8]

2. The Basic Performances of the Cutting Tool Materials of CNC Machine Tools

The choice of cutting tool material has a great influence on life of cutting tool , processing efficiency, processing quality and processing cost. When cutting subjects, cutting tools have to withstand high pressure, high temperature, friction, impact and vibration. Therefore, the material of cutting tools should have the following basic properties:

2.1. High Hardness and Better Wear Resistance

The hardness of the cutting tool material must be higher than that of the workpiece material, and it is generally required to be above HRC60. The higher the hardness of the cutting tool material, the better the wear resistance, and the two have a certain proportional relationship to a certain extent.

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2.2. Sufficient Toughness and Strength

The cutting tool material should have high strength and toughness to withstand cutting force, impact and vibration, thereby preventing brittle fracture and chipping of the cutting tool, effectively reducing tool deformation and maintaining the original machining accuracy.

2.3. Good Heat Resistance

It should withstand high cutting temperatures and maintain the original hardness, wear resistance, strength and toughness at high temperatures. It should have good oxidation resistance and effectively reduces the thermal deformation of the cutting tool and the impact on the workpiece.

2.4. Good Processing Property and High Cost Performance

Cutting tool materials should have good forging performance, heat treatment performance, welding performance and cutting performance, etc., and a high cost-performance ratio should be pursued.

3. Comparison of Different Cutting Tool Materials

3.1. High Speed Steel

High-speed steel was invented by American metallurgical engineer White and mechanical engineering Taylor in 1898, and has a history of more than 100 years. Although the alloying and manufacturing process of high-speed steel is constantly improving, the basic composition of the material has not changed much. High-speed steel is a high-alloy tool steel with more elements such as tungsten, molybdenum, chromium, and vanadium added to the tool steel. High-speed steel has high hardness, high wear resistance and high heat resistance. After heat treatment, it has high thermal hardness. When the cutting temperature is 500-600°C, the hardness of the high-speed steel does not decrease significantly, and the cutting operation can still be continued. The cutting speed of the cutting tool made of high-speed steel is 1-3 times that of ordinary tool steel, and can reach more than 60m/min, so it is named high-speed steel, and it improves the durability of the cutting tool by more than 10-40 times.

High-speed steel is a complex steel grade, with carbon content generally between 0.7% and 1.65%. It contains more alloying elements, and the total amount can reach 10%-25%. According to the purpose, it can be divided into general high-speed steel and high-performance high-speed steel.

3.2. Cemented Carbide

Cemented carbide is a powder metallurgical product made of high-hardness, refractory metal carbides in the micron order, sintered with cobalt, molybdenum, nickel, etc. Among them, the content of high-temperature carbides exceeds that of high-speed steel, the allowable cutting temperature is as high as 800-1000°C, the hardness at room temperature is HRC89-93, the hardness at 760°C is HRC77-85, and the cutting speed can reach 100-300m/min, far exceeding that of high-speed steel. The life of cemented carbide is several to several tens of times that of high-speed steel, but its strength and toughness are only 1/30-1/8 of high-speed steel, and its ability to withstand vibration and impact is relatively poor.

3.3. Ceramic Cutting Tool Material

The high hardness and high temperature resistance of ceramic materials make it a necessary material for a new generation of cutting tools. It is a non-metallic material that is made of alumina or silicon nitride as the main component, plus trace additives, and sintered after cold pressing. It has high hardness and high temperature hardness, the hardness reaches HRC58 at 120°C, and it can process high-hardness and difficult-to-machine materials with hardness up to

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HRC65; Ceramic materials have stable chemical properties, low oxidation resistance and low friction factor. The cutting tool durability which is made of the Ceramic materials is several to several tens of times higher than that of cutting tool made of the cemented carbide, and the cutting efficiency is increased by 3-10 times. It is widely used in high-speed precision cutting. However, ceramic tools mainly face the main problems of material brittleness and low toughness.

3.4. Diamond Cutting Tool Materials

Diamond is one of many allotropes of carbon. As a tool material, diamond has superior thermal conductivity and fast heat dissipation during cutting. But the cutting heat should not be higher than 700°C, otherwise graphitization will occur, and the tool will wear quickly. On the other hand, diamond has an affinity with iron, and will undergo chemical wear with ferrous metals (iron-carbon alloys) during processing at high temperatures. Therefore, diamond cannot be used to process ferrous metals, but can only be used on non-ferrous metals and non-metallic materials.

3.5. Coating Cutting Tool Materials

Coating technology mainly refers to CVD and PVD coating technology. In the past, it was mainly used for high-speed steel tools. In recent years, it has also been successfully used for cemented carbide tools. The main advantage of coated cutting tools is that the performance of the tools can be comprehensively improved, and its comprehensive performance can be greatly improved. Coated tools have the characteristics of high hardness, wear resistance and high temperature resistance, so it allows coating tools to have higher cutting speed, higher cutting efficiency and longer life, and coating tools can effectively improve the surface quality of parts processing.

4. Selection of CNC Machine Tools

4.1. Types and Characteristics of Commonly Used Cutting Tools for CNC Machining

CNC machining tools must adapt to the characteristics of high-speed, high-efficiency, and high degree of automation of CNC machine tools. Generally, they should include general-purpose tools, general-purpose connection tool shank and a small number of special-purpose tool shank. The tool shank needs to be connected and installed on the power head of the machine tool, so it has gradually been standardized and serialized.

4.2. Classification of CNC Tools

According to the tool structure, it can be divided into three types: integral type, inlaid type, and special type (such as composite tools and shock-absorbing tools). The inlaid type adopts welding or machine clamp connection, and the machine clamp type can be divided into two types: non-indexed and indexed.

According to the material of the tool, it can be divided into high-speed steel tools, cemented carbide tools, diamond tools and other material tools.

From the cutting process, it can be divided into turning tools, drilling tools, boring tools, milling tools, etc.

4.3. Selection of CNC Tools

The tool selection is carried out under the human-computer interaction state of CNC programming. The tool and tool shank should be selected correctly according to the processing capacity of the machine tool, the performance of the workpiece material, the processing procedure, the cutting amount and other related factors.

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4.3.1. Select the Tool According to the Surface Size of the Workpiece

When selecting a tool, the size of the tool must be adapted to the surface size of the workpiece. In production, end mills are often used to machine the peripheral contours of flat parts; for plane milling, carbide blade milling cutters should be selected; for bosses and grooves, high-speed steel end mills should be selected; for rough machining of rough surfaces or holes , You can choose corn milling cutters with carbide inserts; when processing some three-dimensional profiles and more complex shapes, you can choose ball-end milling cutters, ring milling cutters, tapered milling cutters and disc milling cutters.

4.3.2. Select the Tool According to the Surface Shape of the Workpiece

When processing free-form surfaces, since the end cutting speed of the ball-end tool is zero, in order to ensure the machining accuracy, the cutting line spacing generally adopts the top-end close pitch, so the ball end is often used for surface finishing. The flat-end tool is superior to the ball-end tool in terms of surface processing quality and cutting efficiency. Therefore, as long as it is guaranteed not to cut, whether it is roughing or finishing of curved surfaces, flat-end knives should be preferred. Therefore, as long as it is guaranteed not to overcut, whether it is roughing or finishing of curved surfaces, flat-end knives should be preferred. In addition, the durability and accuracy of the tool have a great relationship with the price of the tool. It must be noted that in general, although the selected tool increases the cost of the tool, the resulting increase in processing quality and processing efficiency, then The overall processing cost can be greatly reduced.

4.3.3. Tool Shank Selection

On the machining center, various tools are installed in the tool magazine, and the tool selection and tool change actions are carried out at any time according to the program regulations. Therefore, standard tool shank must be used so that standard tools used in drilling, boring, expanding, milling and other processes can be quickly and accurately installed on the machine tool spindle or tool magazine. The programmer should understand the structural size, adjustment method and adjustment range of the tool shank used on the machine tool in order to determine the radial and axial dimensions of the tool during programming.

4.3.4. Arrange the Order of the Tools Reasonably

In the machining process of economical CNC machine tools, since the sharpening, measurement and replacement of tools are mostly performed manually, it takes a long time to assist. Therefore, the order of the tools must be arranged reasonably. Generally follow the following principles:

a) Minimize the number of tools;

b) After a tool is clamped, it should be able to complete all its processing steps;

c) Rough and finishing tools should be used separately;

d) Drill after milling;

e) Perform surface finishing first, then two-dimensional contour finishing;

f) The automatic tool change function of CNC machine tools should be used as much as possible to improve production efficiency.

5. Conclusion

Through the research on the material requirements, types and performance of CNC machine tools, we have a certain degree of understanding of CNC machine tools. According to different processing parts and processing requirements, it is necessary for technicians to select CNC machine tools that meet the processing requirements and have good economic benefits according to the selection principles of different types of CNC machine tools.

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