

Present Situation and Development Trend of Five-Axis CNC Machine Tool Technology

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Abstract: As an important indicator of a country's manufacturing technology level, CNC technology is developing rapidly in the direction of multi-axis, high-speed and high-precision. The advancement of high-performance five-axis numerical control technology is not only the requirement of the times, but also the requirement of the market. Therefore, the present situation and development trend of five-axis CNC machine tools are studied. Several structures and characteristics of five-axis CNC machine tools are analyzed. The research shows that the five-axis linkage CNC machine tool is one of the important basis for measuring the manufacturing level of CNC equipment in China. It is the only means to solve the complicated surface parts such as impeller, blade, marine propeller and large diesel engine crankshaft. Therefore, the development of new, independent and innovative five-axis linkage CNC machine tools is of great significance to improve the comprehensive level of China's manufacturing industry and international competitiveness. The machine tool is now in production, its operating conditions are good, processing accuracy and processing efficiency reach the level of similar imported machine tools.

1. Introduction

In the processing program of the NC automatic programming language, the part that transforms the tool path generated in the pre-processing into the motion track of the CNC machine or the special function of the CNC machine is called the post-processing program [1]. In the 1960s, some developed countries began to develop five-axis CNC machine tools. The five-axis CNC machine tool integrates computer control, high-performance servo drive and precision machining to efficiently and accurately complete the machining of complex surfaces [2]. In particular, it has unique advantages in processing impellers, blades, marine propellers and large diesel crankshafts. The post-processing is to process the information directly related to the machine tool and the controller. The general CAD/CAM software has obtained all the information of the tool path after calculation [3]. It can process continuous and smooth free-form surface which can not be machined by general three-axis NC machine tools or which is difficult to be clamped at one time. CNC machine tool is the industrial mother machine of assembly manufacturing industry, and it is the typical product of the world machine tool manufacturing industry entering the era of mechatronics with digital manufacturing technology as the core [4]. Western developed countries have always regarded the five-axis linkage CNC technology as an important strategic material to control exports. Developing countries have encountered great resistance in both R&D and import. Therefore, it is of far-reaching significance to study the five-axis linkage CNC technology to improve the comprehensive national strength of the country [5]. In this process, it is inevitable to calculate the rotation angle and coordinate transformation.

With the rapid development of science and technology, ordinary three-axis CNC machine tools cannot meet the higher requirements of processing parts [6]. In 2015, imports of high-end and large-scale CNC machine tools reached 7.2 billion US dollars, while in 2016 they increased to 8.4 billion US dollars. However, in order to meet the requirements of NC machine tools, post-processing is also needed to obtain NC codes for specific NC machine tools. However, due to the different systems used in NC machine tools, the post-processing must be done for specific machine tools [7]. It can improve the processing precision, quality and efficiency of space free-form surfaces. It can realize the one-time clamping of the workpiece, and the high-precision,

high-efficiency and composite processing in the centralized process, thus ensuring the positional accuracy between the various surfaces of the workpiece [8]. Due to the difficulty of the five-axis technology, the five-axis linkage numerical control technology is often used as an important indicator to measure the automation level of a country's production equipment [9]. At present, the proportion of imported high-end, large-scale, precision and high-speed CNC machine tools in China is over 80%, and more than 70% of China's automobile manufacturing equipment and more than 90% of automobile engine production lines rely on imports. And almost 100% of the CNC systems used in medium and high-end domestic CNC machine tools are also dependent on imports [10]. As a type of multi-axis CNC technology, five-axis linkage CNC technology has become an important indicator for evaluating the automation level of a country's production equipment.

2. Problems encountered in the research of five-axis CNC technology

The development of the five-axis linkage system requires a wide range of content, and the solid basic skills are the prerequisites for development work. In order to break the foreign technical blockade and realize the development goal of the "Eleventh Five-Year Plan", a company has developed the XTK138/5 five-axis linkage CNC machine tool with independent intellectual property rights and a number of patented technologies. Among them, the five-axis linkage machine with double turntable structure is only suitable for processing small parts, such as small overall turbines, impellers, small precision molds, etc. In the development process, five-axis linkage technology problems emerge one after another. This paper analyzes and summarizes the difficult problems encountered in the past two years. Choosing a general and stable five-axis mathematical model is the basis of building a five-axis CNC system. Reliable basic research can bring many conveniences for later development work. Series structure is more traditional, with long-term experience in design, manufacture and application, mature technology and large processing space. So far, it is still used by most high-speed machine tools. Before the development of five-axis CNC system, it is necessary to understand the three-axis or four-axis system. Without the support of three-axis or four-axis CNC system, developing five-axis system is like talking on paper. The compilation of G code is an indispensable part of five-axis linkage. High-quality code helps to improve the processing efficiency and quality. Reasonable simulation operation can improve the eligibility rate of code and avoid accidents such as cutter collision caused by improper code planning.

At present, there are two types of five-axis linkage machine tools: series, parallel and parallel. Series structure is widely used in traditional machine tools. It is characterized by the Cartesian Cartesian coordinate system, machine tool bed, pillar, slide board, table turntable and spindle box are connected in series through the corresponding rail support surface, and the motion of each axis can be carried out independently. The application of three-axis linear interpolation and arc interpolation is the most extensive, while the five-axis linear interpolation is no longer a straight line, but a composite curve operation, the importance of its interpolation method is self-evident. Under the same displacement loading condition, as the loading frequency increases, the damping lag angle and the damping loss factor increase. By comparison, the theoretical curve and the measured curve fit very well. Due to the structure itself: there is generally an electric spindle with a loose broach structure in the middle of the swing head, so the size of the double swing head itself is not easy to be small, generally about 400 to 500 mm. The machine speed is high, so the oil lubrication method is adopted. The oil and gas lubrication is one of the oil lubrication methods. This lubrication method uses compressed air to feed small oil droplets into the bearing gap, and the oil quantity can reach the optimal value. Lubricating oil can be recycled without pollution to the environment.

In recent years, the number of related researches on five-axis linkage machine tools has been increasing. This shows that the five-axis linkage machine tool technology is being paid attention to by many scholars. Figure 1 shows the trend of related research on five-axis linkage machine tools in recent years.

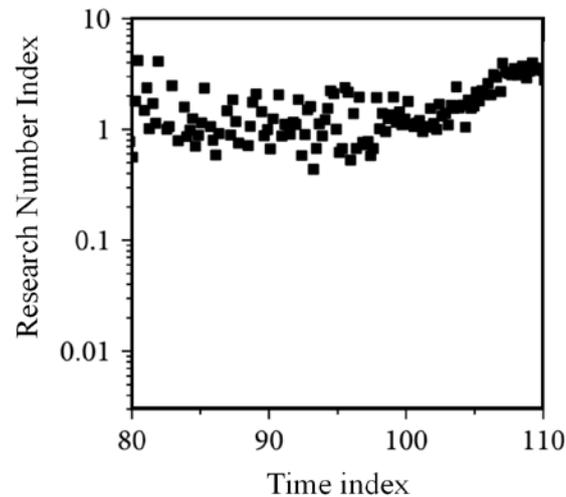


Fig 1 The number of related research increases and decreases in recent years

3. Five-axis linkage machine features

One is a single oscillating head plus a single degree of freedom rotary table, which realizes rotation in two directions through a single oscillating head and a rotary table, respectively. Since it is a series connection, there are disadvantages such as low structural rigidity, poor precision, and high overall quality. The determination of the inflection point of the three-axis linkage can be based on the angle of the space line, but how to calculate the angle between the two codes in the five-axis linkage is one of the difficulties in the study. On the basis of the original two-axis control machine tool, the double-degree-of-freedom rotary table is equipped with a type of medium and small five-axis machine tool. The disadvantage is that the platform becomes a relatively weak link. Especially when there is a need for a high rotational feed rate and acceleration, the working weight is limited. Flexible acceleration and deceleration is the most important thing to ensure the smooth operation of machine tools. The stability of acceleration and deceleration operation of machine tools is directly related to processing efficiency, quality and machine tool life. The cooling effect can also be improved by increasing air flow rate and increasing oil and gas pressure. The application of zero transmission technology in rotating axle is probably the most ideal technical route to solve the rigidity and accuracy of transmission chain. With the development of technology, the manufacturing cost of torque motor has been greatly reduced, and the market price has also been reduced. This process will greatly advance the manufacturing technology of five-axis linkage machine tools.

Another is the crane type, which is equipped with a two-degree-of-freedom rotary table to complete the rotation in two directions around the coordinate axis. The whole cross beam drives the tool head to move along three coordinate axes. Using different software, the meaning of the code after post-processing is different. Understanding the meaning of the code, we can begin to develop the corresponding NC system code. However, a common feature of these five-axis machine tools is that the CNC system used is basically Siemens 840D system, and most of its functions are properly tailored. The servo drive devices in the three directions all adopt AC servo motors with low manufacturing cost, small inertia of rotor, good dynamic response, low quality, high speed and high output power, thus satisfying the positioning accuracy requirements of five-axis CNC machine tools. Users of five-axis linkage machines equipped with the 840D CNC system are also subject to their directional use review and are subject to restrictions. Since the operation of the three-axis linkage has a real space trajectory, the motion control is relatively simple. To develop a five-axis linkage system, the smooth and high-precision control of the two rotating shafts is the key to the research.

4. Conclusions

The use of five-axis linkage machines is much more complicated than that of three-axis

machines, and the cost of use is much higher. The requirements for programming and operators are much higher. In the process of machine tool development, it is in line with the market, listening to users' opinions and working closely with users, and mastering the user's machine tool application experience. Continuously improve and improve the machine tool structure and software functions, and embarked on a correct technical route for the development of high-end CNC machine tools, providing useful experience for China's machine tool industry. In modern industry, five-axis CNC machine tools are widely used in the processing of complex parts and free-form surfaces. Because of the complexity of five-axis machining and the differences of post-processing algorithms for different types of NC machine tools, it is important to study new machine tool motion forms and corresponding post-processing methods for NC programming. Through static analysis and modal analysis of gantry structures with different spans, it is known that the rigidity of gantry structures with small spans is higher, which determines the design of gantry structures with small spans, and puts forward requirements for the next design of crossbeams and gantry structures. In the process of assembling molars, periodontal ligament and alveolar bone, the auxiliary plane and axis are defined in each part, and the final assembly results are in accordance with the actual situation through the constraint relationship.

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