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Overview of Cutting Tools and Cutting Performance of Titanium Alloy*

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***Abstract*—This paper is mainly through the analysis of previous scholars to study various materials of the tool and cutting tool optimization or different cutting conditions to explore the processing of titanium alloys, From the initial low-speed plus coolant processing to high-speed cutting performance of titanium alloys to explore, summarize the advantages of the advantages of titanium alloy cutting. Describe the research and development trend of titanium alloy machining.**

Keywords— Titanium Alloy; Cutting Peformance; Cutting Tool Optimization

I. INTRODUCTION

With the rapid development of the world economy and the continuous strengthening of the military industry, the level of science and technology in various fields is constantly improving, making the development of industry by leaps and bounds. Industry is the basis for measuring the national economy of a country, whether it is military industry, or civilian industry, or heavy industry and light industry metals and non-metallic materials. The titanium alloy material has the advantages of small specific gravity, high strength, corrosion resistance, high temperature strength and so on. It has been widely used in many fields such as aerospace, automobile, chemical industry and medical treatment [1-5]. However, because the titanium alloy also has the characteristics of poor thermal conductivity, high temperature chemical activity, low elastic modulus, and other metal materials, such as the large friction coefficient, so that in the cutting process, there is a tool blade area per unit area to withstand cutting force, cutting temperature is high, sticky knife serious phenomenon, the workpiece surface roughness, easy to cause rapid tool wear or damage and other defects [4, 5]. Therefore, titanium alloy is a typical difficult to process materials. Thus, many experts and scholars from the properties of titanium alloy material itself or to cutting titanium alloy cutting tools, machining process, environment and so on to study the cutting performance of titanium alloy, titanium alloy cutting is conducive to the conclusion through theory and practice.

II. TITANIUM ALLOY CUTTING AND HIGH SPEED DRY CUTTING

A. Titanium alloy cutting principle

There are many kinds of titanium alloy cutting in industrial production, including common turning, milling, boring, grinding and so on. The titanium alloy itself, some of the metal properties make titanium alloy processing is a difficult problem to solve. Initially the new energy equipment Co., Ltd. Zhenhe Li, et al. In the study of titanium and titanium alloy cutting work mentioned [6]: Titanium alloy between the machinability between stainless steel and high temperature alloys, processing than stainless steel, but better than high temperature alloy, hardness greater than HB350 when cutting is particularly difficult, less than HB300 is prone to sticky knife phenomenon, it is difficult to cut; Which according to the titanium alloy with a large coefficient of friction, thermal conductivity is small, the elastic modulus is small and has high temperature chemical activity, chilled phenomenon is more serious, and a series of cutting characteristics and put forward the basic principles of titanium processing: (1) To prevent excessive temperature, a lower cutting speed should be used. (2) Using a larger amount of feed. (3)Do not stop the tool during cutting tools, otherwise it will cause hardening or sintering, cracking and damage to the tool. (4) Cutting tools should be sharp. (5) Use enough cutting fluid. However, with the popularity of CNC, tool manufacturing technology to improve the metal cutting machine speed faster and faster, more and more high processing efficiency, followed by the cutting heat and tip temperature is faster and faster, more and more high [7].

B. High-speed dry turning

Therefore, compared with the previous cutting process Zebiao Chen, Zhian Tang [7] on TC4 titanium alloy high-speed dry turning research and experimental work to improve the tool life, processing efficiency is also greatly improved. Moreover, the experiments and research done are also from the tool to start, such as the use of ultra-fine particles of carbide cutting tools, and with PDV coating, so that the tool wear in the cutting process to be tested to reduce. The experimental use of air-cooled coolant is not due to high-speed cutting will have a high cutting temperature. The coolant, above all, cannot overcome the high-speed centrifugal force. Second, the rapid changes in temperature will produce stress in the blade, resulting in a knife cracked and damaged. High-speed dry cutting using air-conditioning use of the chemical activity of titanium, which oxygen and metal materials in the compound. In this way, the shape of the cutting edge of the tool becomes a high-hardness oxide film and the oxide film sticks to the cutting edge to protect the cutting edge of the tool [7]. In addition, the oxide can also have the role of lubrication, reduce the phenomenon of stick knife.

From two research experiments, from the low-speed use of a large number of coolant cutting method to high-speed dry cutting in the tool and process environment to optimize, making the titanium alloy cutting efficiency and quality improvement. But inevitably titanium alloy high-speed cutting of the high temperature caused by plastic deformation of the workpiece, and titanium alloy cold phenomenon, the accuracy of the workpiece is a series of problems. So to solve the titanium alloy cutting must proceed from a variety of factors, a comprehensive consideration, whether it is cutting process, the material itself or tool material and optimization design.

II. STUDY ON CUTTING TEMPERATURE AND PROPERTIES OF TITANIUM ALLOY

A. Cutting Performance of Titanium Alloy for High Speed Turning of Carbide Tool

For the titanium alloy cutting performance research has never stopped, because the titanium alloy itself has good mechanical properties and widely used, so the study of its cutting performance is essential. In the study of the cutting performance of high speed turning titanium alloy by li yousheng, liu hao and Chen rongde, the single-factor experiment method was adopted in this paper [8]. The high-speed dry cutting experiment of Ti-6Al-4V titanium alloy with uncoated and TiAlN coated carbide tool were carried out. The cutting performance of two kinds of cutting tools with high speed and dry cutting is obtained by analyzing the cutting force, tool life, cutting temperature and machined surface roughness during the cutting process [8].The experiment first analyzed the material of the tool and the physical and chemical properties of the titanium alloy used, and carried out experiments on the lathe. According to the analysis and calculation of different speeds, the curves of the cutting distance of coated tools and uncoated tools with the cutting speed are drawn. From that we get: The service life of the coated tool is significantly greater than that of the uncoated tool [8]; The advantage of a coated tool decreases rapidly as the cutting speed increases.[8];For the three-way cutting force, the radial force is greater than the other two forces, the tangential force is small and stable. By studying the cutting temperature, it can be seen that cutting high temperature will soften the tool material, reduce the tool strength, make the cutting performance greatly reduced, seriously affecting the tool life [9]. Analysis of cutting temperature results: Under the same cutting parameters, the cutting temperature of TiAlN coating tool is slightly lower than that of uncoated cutting tool because TiAlN coating material has the characteristics of high hardness, high oxidation temperature and small friction coefficient [7].The roughness of the surface is, of course, the surface roughness of the uncoated tool is small.

B. Cutting Temperature Analysis of High Speed Milling Titanium Alloy

Compared with single factor experiment, Liu Peng et al. Studied the cutting temperature analysis of high speed milling titanium alloy of polycrystalline diamond tool, and adopted the 2k factor experiment to obtain the main influencing factors and interaction factors. The PCD tool is used in the experiment, and the cutting temperature variation is analyzed in the high-speed lathe cutting TA15 titanium alloy. By cutting the temperature of the original signal map, the design of 2^k factor multi-factor analysis of cutting speed, cutting width, and their interaction, the impact of each tooth on the cutting temperature of the normal distribution probability diagram. The nonlinear regression is used to process the experimental data, and the surface response graph and contour map of cutting temperature, cutting speed and cutting width are obtained by the surface analysis method. The experimental results are as follows: Cutting speed, cutting width and feed per tooth are the main factors of cutting temperature, and the interaction effect of cutting speed and cutting width is the influence factor of cutting temperature [10]. The order of effect on cutting temperature is: cutting speed, cutting width, interaction factor for the cutting speed and cutting width of the interaction effect, the feed per tooth [10]. In addition, there are finite element software on the titanium alloy cutting temperature simulation and experimental research, which can be processed before the processing, through the software analysis of cutting temperature and tool stress, to avoid many of the actual processing can occur in some of the problems. But also can reduce manufacturing costs.

From the two methods used in the comparative analysis of the process and its results, we can see that 2^k factor experiment is more advantages than single factor experiments. For the titanium alloy cutting 2^k factor experimental method is more progressive. This test method can not only be used to study the cutting temperature, but also to study the other cutting properties of titanium alloy cutting. By analyzing the influence of univariate and interaction factors, it is observed that the process of cutting is to use the factors of interaction or the main factors of ineffective effect to achieve better cutting effect. If you want to study the force and machining simulation of the titanium alloy cutting tool in the cutting process, the finite element software can simulate and analyze some of the performance in the cutting process and contribute to the actual processing. However, the results obtained by the finite element and the results of the actual processing experiment error is still large, cannot reflect the exact data is the result of the actual operation and processing is essential.

III. OPTIMUM DESIGN AND CONSTRUCTION OF CONSTITUTIVE MODEL FOR CUTTING TOOL OF TITANIUM ALLOY

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A. Optimum Design of Cutting Tool for Titanium Alloy Cutting

In the cutting process of titanium alloy, the violent friction in the contact area of the chip will cause the temperature to rise continuously and the tool wear to be aggravated. In addition, the decrease of the quality of the tool surface will lead to the reduction of the cutting performance of the tool, which also becomes one of the main reasons that limit the cutting speed of the titanium alloy and affect the machining performance [11-15]. As the surface microstructure has been improved in terms of improving material handling properties, such as surface frictional properties and surface bearing capacit, has been widely recognized to improve the performance of the tool, the material properties of the tool, the processing characteristics [14]. In order to develop the excellent tool for the processing of titanium alloy, we should study and improve the factors that affect the cutting force and heat, improve the cooling effect, make the cutting force, heat drop, heat to speed up the export; Improve the rigidity of the various parts of the process system to suppress vibration; reduce the bond, to accelerate chip removal and so on [15]. The Coro Mill 690 indexable end mill with the I LOCK interface is a new tool for machining two-dimensional profiles of titanium alloy parts, recessed cavities and sidewall mills. As shown in Figure 1.

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Fig. 1. Coro Mill 690 Indexable End Mills[17].

Coro Mill 690 I LOCK technology through a unique tool interface (i.e. guideway and the knife blade pad on the match) to optimize the tool cutter blade and the cutter body interface performance, which can offset the displacement of machining by cutting force generated or rotating, so as to improve the safety of technology [17]. Therefore, from the tool's own materials and tool design research titanium alloy cutting process has great development and application significance, to improve the improvement of processing performance has an important impact.

B. *Construction of constitutive model for titanium alloy cutting*

Now for the titanium alloy cutting constitutive model is also the field of metal cutting research should be closely concerned about the problem.Yang Yong et al [18] of Qingdao University of China put forward the constitutive model of aerospace titanium alloy material based on orthogonal cutting theory. According to the principle of orthogonal cutting, the mathematical model of stress, strain, strain rate, temperature and two - dimensional cutting force in the shear zone is established. The modeling technique of the length and thickness ratio of the shear zone as the iterative variable is developed. Combined with the dynamic compression mechanics experiment (SHPB experiment) and the right angle cutting experiment. Through the mathematical solution of each deformation parameter, the constitutive model of the aerospace titanium alloy machining is established. The modeling techniques used are shown in Figure 2 below.

The optimization design of the tool and the constitutive model construction of the titanium alloy are all well studied, and there is a great trend in the future research of titanium alloy cutting.

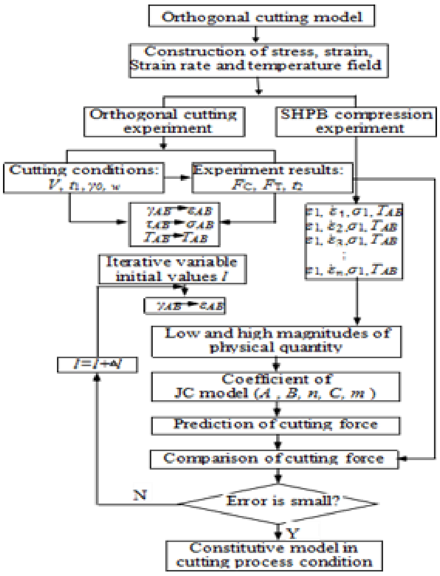

Fig. 2. Based on the orthogonal cutting theory of material constitutive model to build technical route[18].

IV. SUMMARY

Through the previous scholars' research experiments, such as cutting and processing from the initial analysis of titanium cutting factors and processing principles. After the TC4 titanium high-speed dry cutting initial research study that is changing the coolant conditions to promote the production efficiency of high-speed dry cutting conditions analysis of its processing performance of the tool PVD coating and tool life. Followed by carbide cutting tool high-speed dry-type titanium alloy, the use of single factor experimental method to obtain the impact of factors and analysis of its interests related to tool life. Compared with the single factor test method, it is better to use the 2k factor experiment to study the effect of the interaction of the cutting temperature and from the optimization design and the constitutive model of the tool. These theories and experiments have studied the cutting of titanium alloy. A certain contribution to the future research, the development of titanium alloy cutting provides a theoretical and experimental basis. However, there are still many problems to be solved in the cutting of titanium alloy. These experiments are only effective to promote and enhance the titanium alloy machining. We cannot but start from one hand, we should combine the conclusions of previous experiments, from many aspects to study and verify its cutting performance, so as to better expand the scope of the study. More factors to participate in and solve some of the problems, such as tool design, material, force, take the knife, the processing environment combined with the characteristics of the titanium material itself to comprehensive research and improve its cutting performance.

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