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Experimental Study on Optimization of Surface Integrity Parameters in Machining of Porous Titanium Alloys

Rui Tang[a,*], **Yun Ling**[b]

Engineering Techniques Training Center, Civil Aviation Flight University of China, Guanghan, Sichuan, China
[a]pzhutrscu@126.com, [b]trbill@163.com
**Corresponding author*

Abstract: *In recent years, with the continuous development of my country's industrial level, people's research and exploration in the machining and application of porous titanium alloys has become more and more in-depth. In order to achieve greater breakthroughs and development in the field of optimization test research on surface integrity parameters of porous titanium alloy machining. In this paper, experiments and finite element simulation methods are used to adjust the process of titanium alloy machining by multi-step cutting and prestressed cutting, in order to control the surface quality of titanium alloy machining. Titanium alloys have superior performance and have the advantages of high strength and high corrosion resistance, but the small thermal conductivity and elastic modulus make titanium alloys difficult to cut. In this paper, a simulation model of multi-step cutting and pre-stressed cutting of titanium alloys is established, and the specific laws of multi-step cutting and pre-stressed cutting process regulation affecting chip shape, cutting force and residual stress of machined surface layer are studied. The results show that both multi-step cutting and prestress cutting can increase the residual compressive stress on the finished surface. The final results of the study showed that when the titanium alloy was cut at a distance of 4.63 mm, the corresponding machine wear was 5.41%. In the application process of porous titanium alloy cutting, the wear degree caused by titanium alloy cutting is not affected by its cutting distance, and the wear degree caused by titanium alloy cutting has always maintained an average level of about 5.5%, which is relatively stable.*

Keywords: *Porous Titanium Alloy, Machining, Surface Integrity, Parameter Optimization*

1. Introduction

Titanium alloys have excellent properties, but their machining properties are extremely poor. In the process of titanium alloy cutting, it is easy to cause the vibration of the tool, which will directly affect the surface morphology and surface roughness of the workpiece. It can be seen that the vibration characteristics have a certain relationship with the surface integrity. In order to improve the quality of titanium alloy products, the vibration characteristics of titanium alloy machining and its relationship with surface integrity were studied. The dynamic model of the cutting system is established and the vibration characteristics are changed, and then the dynamic model is verified by cutting experiments [1]. According to the vibration acceleration signal of the tool tip collected during the experiment and the surface roughness value of the workpiece after the experiment, the relationship between the vibration characteristics and the surface integrity is further analyzed.

In recent years, many researchers have explored experimental research on optimization of surface integrity parameters for machining porous titanium alloys, and achieved good results. For example, Anish M believed that when the cutting speed or feed increased, the plastic strain of the microstructure of the cutting layer intensified, and the thickness of the strained layer also increased [2]. V Veeranaath believes that the increase of cutting speed and feed will promote further grain refinement, but the effect of cutting speed on grain refinement is higher than that of feed, and cutting parameters have an impact on the orientation difference of grains [3]. At present, scholars at home and abroad have carried out a lot of research on the application of optimization test of porous titanium alloy cutting surface integrity parameters. These previous theoretical and experimental results provide a theoretical basis for the research in this paper.

In this paper, by studying the theoretical basis of the machining application of porous titanium alloys, the current optimization test of the surface integrity parameters of porous titanium alloys machining is carried out. Taking the initial surface morphology defects of titanium alloy bars as one of the factors affecting the surface integrity, titanium alloy bars with different initial surface morphology defects (the initial surface morphology generated after precision forging and rolling process) were selected. Defects) are tested to discuss whether different initial surface topography defects will affect the change law of surface integrity. Finally, according to the change law of surface integrity and actual processing requirements, determine the appropriate process parameters to meet the processing requirements.

2. Related Theoretical Overviewand Research

2.1 Surface Quality Control of Titanium Alloy Machining

(1) High Speed Cutting Test Design of Qian Alloy

During cutting, the machined surface of titanium alloy will be subjected to severe thermal stress and mechanical stress in an instant, and then quickly unloaded and cooled to room temperature. Phase transformation will occur during the transient loading and heating stage and the rapid cooling stage, resulting in the phase change of the cutting layer. The structure changes, which affects the physical and mechanical properties of titanium alloys [4-5]. The work hardening of the workpiece surface will be affected by various factors such as deformation and thermal load. The causes are more complicated, resulting in uneven hardness of the workpiece surface layer, which will affect the internal stress distribution of the workpiece material. The work hardening of the workpiece surface will promote the cutting tool. Further wear of the surface negatively affects the machined surface integrity of the workpiece and reduces the machined surface quality.

(2) Titanium Alloy Milling

In the actual milling of titanium alloys, the operator will adjust the spindle speed and feed rate override switch of the machine tool according to their own experience. When the machining materials, clamping and machining paths are determined, the problems of rapid tool wear, unqualified machining quality of titanium alloy parts, and low efficiency are mainly caused by unreasonable cutting parameters [6]. Conservative feed rate reduces machining efficiency. Too high feed rate will aggravate tool wear and affect machining accuracy. Continuous machining of large areas will aggravate tool wear, increase cutting load, and affect workpiece surface machining quality. With the goal of protecting the tool, improving the machining accuracy and improving the machining efficiency, the researchers put forward various feed parameter adjustment strategies.

(3) Titanium alloy machining and cutting experiment design and environment construction

The machining and cutting experiments of titanium alloys were carried out on a centerless lathe. Its working principle is: when the centerless lathe cuts the bar, the titanium alloy bar is fed into the hollow spindle by the front pinch device and the front guide mechanism. The tool is rotated at high speed to realize the processing of titanium alloy [7]. The acceleration sensor is a three-axis acceleration sensor, which is pasted on the surface of the lathe and can measure acceleration signals in multiple directions. The fixed acceleration sensors are connected by a data cable. When the acceleration sensor is fixed, the signal transmission data cable also needs to be fixed to prevent the signal transmission process is disturbed due to the wobble of the data line.

During the cutting process, the acquisition of the vibration acceleration signal of the machining titanium alloy is completed by the acceleration sensor, and the sensor is arranged in different places according to the working characteristics of the experimental equipment [8]. At the front bearing seat near the cutter head and the rear bearing seat of the rear guide mechanism, the vibration signals generated by the complete process system composed of a centerless lathe, a titanium alloy workpiece and a tool are collected [9]. However, in the actual processing process, internal vibration interference and external environment noise will be mixed, so the collected vibration acceleration signals need to be pre-processed such as noise reduction, filtering, and smoothing.

2.2 Introduction to Machining of Porous Titanium Alloys

With the development of the world's manufacturing industry, various fields have higher and higher requirements for the material properties of key components, and countries are developing new low-cost and high-performance titanium alloys [10]. The output of titanium alloys is growing at an average rate of about 8% per year. At present, the global annual output of titanium alloy processing reaches more than 40,000 tons. In the aviation industry, titanium alloy parts occupy an important position. They are not only numerous in number and types, but most of them have complex shapes and are difficult to process. Domestic and foreign researchers are also gradually deepening the research on the processing and manufacturing of such parts and exploring new technologies.

By considering the entire multi-step as an organic whole, the cutting parameters of multiple steps can be optimized under one or more optimization objective conditions, in order to obtain ideal machining results [11]. By analyzing the influence mechanism of multi-step machining parameters on machined surface quality, more optimized multi-step machining parameters can be obtained. The effects of two-step cutting and three-step cutting on the finished surface were comparatively studied, and the effects of roughing and semi-finishing cutting parameters on the finished surface integrity (microhardness, surface roughness) were studied [12]. Aiming at the problem of easy deformation of parts with weak stiffness, the optimization problem of multi-step cutting parameters is studied on the basis of traditional single-step cutting, and the mathematical model of the relationship between cutting parameters, cutting force and cutting heat is established and optimized. The optimal combination of processing parameters.

3. Experiment and Research

3.1 Experimental Method

The effectiveness of the cutting process depends on the cutting force, which is affected by the cutting conditions (cutting speed vc, depth of cut ap and feed f), tool geometry and the characteristics of the workpiece itself. Any method of reducing cutting forces will result in longer tool life and better accuracy of the machined part:

$$\mu = \frac{\mathrm{F}_f + F_c \tan \alpha}{F_C - F_f \tan \alpha} \tag{1}$$

$$\xi = \frac{h_{\max} + h_{\min}}{2t} \tag{2}$$

Among them, Ff is the feed force, Fc is the main cutting force, and α is the rake angle of the cutting tool. h is the maximum thickness of serrated chips.

3.2 Experimental Requirements

Contrasting dot-and-line plots of tools with different surface types as a function of cutting speed, all forces are averaged at steady state. For the variation of main cutting force with speed under dry cutting conditions, the cutting force of both untextured and textured tools decreased with the increase of cutting speed. At higher cutting speeds, higher temperatures can completely soften the workpiece material, in which case the workpiece strength deteriorates faster than the tool material, resulting in material removal. This is why the cutting force gradually decreases as the cutting speed increases. At all cutting speeds, tools with a characteristic rake face have lower main cutting forces than conventional tools, and the best performers are those with a surface coating. Having a surface coating groove texture can reduce the coefficient of friction. Discuss the wear-reducing effect of surface coating texture in actual cutting, and the tool shows chip flow scratch diagram after cylindrical turning.

4. Analysis and Discussion

4.1 Analysis of Wear Degree of Titanium Alloy Cutting Machining

In this experiment, the surface integrity parameters of porous titanium alloy machining were studied. By exploring the relationship between the wear degree of titanium alloy machining on surface integrity and the cutting distance, the experimental data are as follows, as show in Table 1:

Table 1: Analysis of wear degree of titanium alloy machining

Project name	Distance(mm)	Degree of wear(%)
Model I	3.24	5.63
Model II	5.21	5.39
Model III	9.18	5.54
Model IV	5.89	5.62
Model V	4.63	5.41

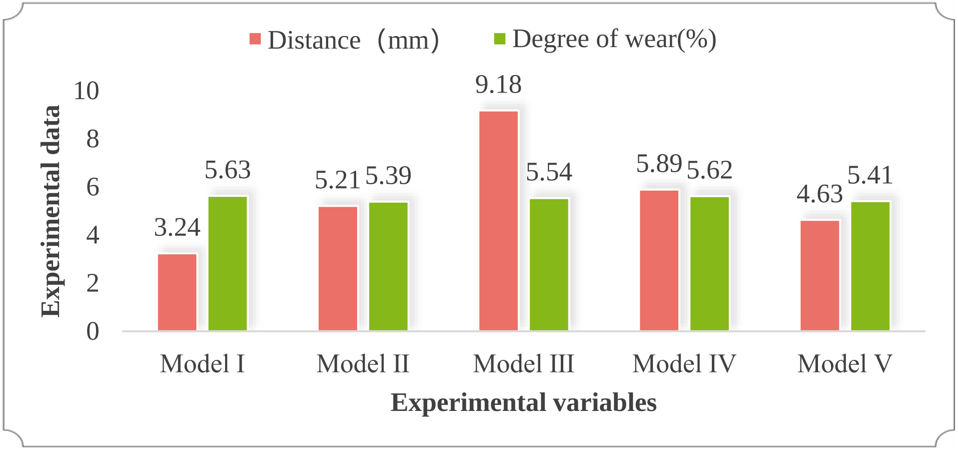

Figure 1: Analysis of wear degree of titanium alloy cutting

From the above data analysis, it can be seen from the results that when the titanium alloy cutting distance is 3.24 mm, the wear degree of the corresponding machine is 5.63%. When the titanium alloy cutting distance is 5.21 mm, the wear degree of the corresponding machine is 5.39%. When the titanium alloy cutting distance is 9.18 mm, the wear degree of the corresponding machine is 5.54%. When the titanium alloy cutting distance is 5.89 mm, the wear degree of the corresponding machine is 5.62%. When the titanium alloy cutting distance is 4.63 mm, the wear degree of the corresponding machine is 5.41%. Through the comparison of experimental data, it is found that in the application process of porous titanium alloy cutting, the wear degree caused by titanium alloy cutting is not affected by its cutting distance, and the wear degree caused by titanium alloy cutting is always maintained at an average of about 5.5%. Level and stable.

4.2 Analysis of Friction Coefficient of Cutting Machining

Using the same test and analysis methods as the turning samples, the effect of different cutting parameters on the friction and wear properties of the boring machined surface was studied, and the effect of cutting parameters on the friction and wear properties of the forged steel piston cylindrical turning and pin hole boring machined surfaces was explored. The law of action, and the cutting parameters are further optimized. The experimental data is shown in the figure 1 below:

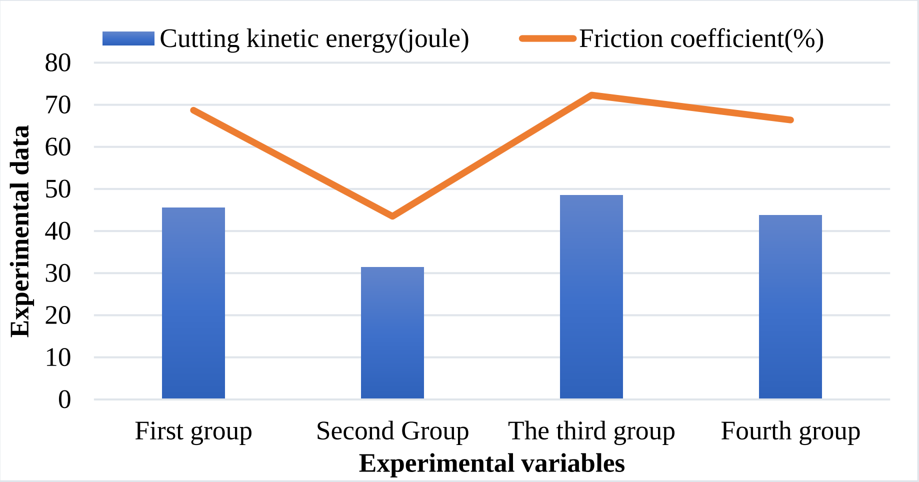

Figure 2: Analysis of the accuracy of film and television creation and dissemination

As shown in Figure 2, by comparing and analyzing the data between the cutting kinetic energy and the friction coefficient during the cutting process of porous titanium alloys, when the friction coefficients of the four groups of models are 0.687, 0.435, 0.723 and 0.664, respectively, the corresponding The consumed cutting kinetic energy is 45.6 joules, 31.4 joules, 48.5 joules and 43.7 joules, respectively. Through the comparative analysis of the data of the four groups of models, it can be seen that there is a positive correlation between the cutting kinetic energy and the friction coefficient during the cutting process of porous titanium alloys. The cutting kinetic energy also increases.

5. Conclusions

This paper firstly studies and analyzes the application of porous titanium alloy cutting, and compares the optimization test of its cutting surface integrity parameters, and through a series of experiments to prove the cutting surface integrity parameters of porous titanium alloy cutting the application has certain feasibility. Through the comparison of experimental data, it is found that in the application process of porous titanium alloy cutting, the wear degree caused by titanium alloy cutting is not affected by its cutting distance, and the wear degree caused by titanium alloy cutting is always maintained at an average of about 5.5%. level, and there is a positive correlation between the cutting kinetic energy and the friction coefficient during the cutting process of porous titanium alloys, that is, as the friction coefficient increases, the cutting kinetic energy consumed in the corresponding porous titanium alloy cutting process also increases . Under the condition of higher roughing cutting speed, the work hardening effect is weakened, so that the fine grain refinement of the finished surface is weakened, and the cutting force is reduced, which helps to improve the quality of the finished surface; however, this also makes the residual compressive stress on the finished surface. Reduced, which is not conducive to the fatigue life of the workpiece.

Acknowledgements

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