

# Research on Cutting performance of 316L Stainless Steel Based on Microstructure Tool

Qingli Zhang, Dingxin Leng, Guijie Liu, Hui Liu and Zhencong Rao

Engineering College of Ocean University of China, QingDao, China

**Abstract.** Based on carbide (YW1) as the material of surface texture cutting tool to conduct the basic experimental research on the micro-groove tool cutting 316L stainless steel under the condition of dry cutting and cutting fluid lubrication. The results show that the improved cutting effect of microstructure is not only related to texture type, but also to feed rate, spindle speed and cutting lubrication condition. Under the condition of small feed rate and fluid lubrication cutting, vertical groove has the most obvious effect, which can reduce cutting force, average friction coefficient to 19.01% and 13.39% respectively.

## 1. Introduction

316L stainless steel is widely used in marine electromechanical equipment industry because of its superior corrosion resistance to marine environment. Like other stainless steel, in the process of machining, the chip has a strong adhesive abrasion with the rake face of the tool, which makes chip flow slowly. Then the cutting heat is difficult to be carried away. And high temperature is produced in the cutting area, which aggravates tool wear and seriously affects machining efficiency and quality. In order to solve this problem, scholars at home and abroad have carried out a lot of research on the reduction of wear between cutting tool and chip. Biomimetics experts have found that there is an orderly array of micro-grooves on the fish's outer epidermis, which can effectively reduce surface friction resistance when it moves.<sup>[1]</sup> Inspired by this, Liu Zeyu and his partner.<sup>[2]</sup> used laser processing technology to make ceramic tool texture array and studied the influence of tool texture array on friction performance, the results show that the friction coefficient of microstructure tool is reduced by about 15% compared with that of ordinary cutting tool, and the performance of heat dissipation is improved. Using ylp-f10 optical fiber laser marking machine, Zhang Junsheng et al.<sup>[3]</sup> prepared micro-grooves array on the rake face of the tool and studied the influence of surface texture size on tool performance. The research shows that the larger the diameter of the circular groove, the lower the shear strength of the cutting tool-chip contact area. When the circular groove occupies more than 30%, the tool strength will be reduced. Wenlong Chang et al.<sup>[4]</sup> used focused ion beam to make three different microstructure tools, which it is Parallel, vertical and 45° to the main cutting edge. The relationship between the direction of surface texture and cutting performance was studied. It is found that when using the surface texture shape of vertical cutting, the corresponding cutting force is the smallest, which can improve the actual cutting performance. In the research of cutting 316L stainless steel, Hu Yujin<sup>[5]</sup> studied the relationship between cutting parameters and cutting force. The cutting performance is improved by optimizing feed rate and the study show that the feed rate has the greatest influence on cutting force. The increase of feed per tooth makes the temperature increase, which aggravates the wear of the tool.

Study on reduction of friction between rake face of cutting tool and the chip to improve cutting performance is the main methods to improve 316L stainless steel processing. According to principle of drag reduction based on surface texture, the surface microstructure technology is used to reduce the



abrasion of tool and the chip. And it is an effective method to increase the flow of chips on the rake face, which reduce the cutting temperature and extent life of the tool. It can be applied to 316L stainless steel cutting process. In this paper, the cutting process of 316L stainless steel is taken as the research object. The influence of texture array on the processing performance of 316L stainless steel is explored by designing the micro texture shape of different cutting tools.

**2. Experimental study on 316L stainless steel cutting**

*2.1 Design and manufacture of microstructure tool*

The tool material for 316L stainless steel cutting is YW1 cemented carbide. Some types of microstructures were made on the surface of YW1 inserts. According to the relevant literature, the surface texture shape of the rake face of the turning tool is shown in figure 1 (where No.1 is non-microstructure tool. And there are different surface textures on the rake face of the No.2-No.6 inserts). The texture depth is designed as 0.04mm. All kinds of surface texture are manufactured by F-20 type pulse fiber laser. And post-processing was carried out after the completion of the structure. HEXAGON Optiv Advance 332 image measuring instrument is used to measure and observe the cutting tool. It is used for the subsequent cutting experiments.

*2.2 Experimental equipment and scheme*

CA6136 lathe is used in the experiment. The cutting force signal acquisition system consists of the following instruments. Such as a three-way piezoelectric quartz dynamometer (YDCB III05), charge amplifier (LN

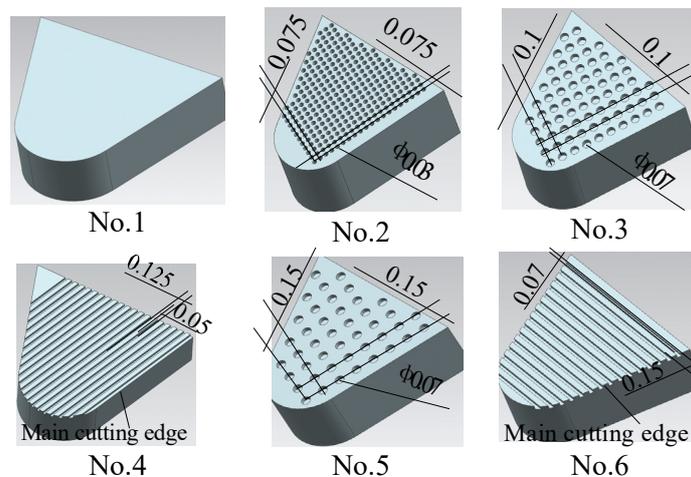


Fig.1 Texture map of rake face

5861), data acquisition card (usb-1902) and computer. The experimental system structure is shown in Figure 2. Because of the CA6136 machine tool structure problems, the experiment can only adopt spindle speed of 570r/min, 800r/min and 1140r/min. The dynamic cutting force signal collected during the experiment is shown in Figure 3. These data are mainly used to analyze the friction between rake face and chip.

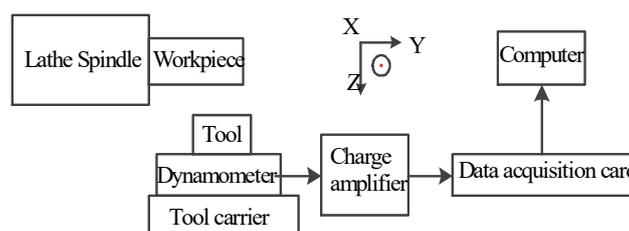


Fig2. Structure of experimental system

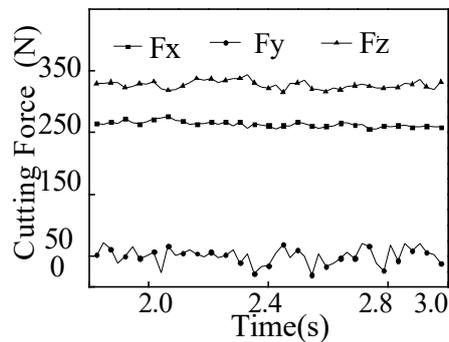


Fig.3 Dynamic cutting force acquisition diagram

### 2.3 The solution of friction coefficient

In the process of metal processing, the force of the workpiece's reaction on the tool can be decomposed into three directions. In this experiment the shear stress should be equal to the shear yield strength of the processed materials in the bonding area as shown in Fig.4. Coulomb friction law is applicable to sliding zone. Then the friction coefficient is obtained as below.

$$\mu = \frac{F_t}{F_n} = \frac{F_z \cdot \sin \gamma_0 + F_y \cdot \cos \gamma_0}{F_z \cdot \cos \gamma_0 + F_y \cdot \sin \gamma_0}$$

Where  $\mu$  is the average friction coefficient,  $F_z$  is main cutting force,  $\gamma_0$  is the tool rake angle,  $F_y$  is radial force.

The values of  $F_y$  and  $F_z$  are acquired by cutting experiments. The value of the average friction coefficient of the slip region is obtained by substituting it into the above formula. The single factor control method was used in this experiment. First, the experiment is carried out without lubrication. Then, the emulsion is used and the above experiment is repeated.

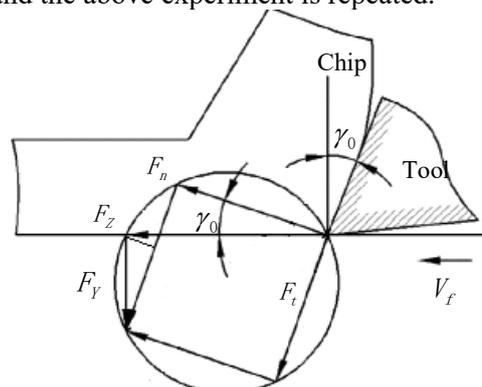


Fig.4 Force of rake surface

### 2.4 Experimental data analysis

The single factor control method is used in the cutting experiment. The actual cutting force signal measured by the dynamometer is shown in Fig. .  $F_x$ ,  $F_y$  and  $F_z$  component forces all drift to a certain extent in the blank tool stage. And the change of cutting force will be stabilized as the tool enters the stable turning stage. The method of data processing is as follows, which the average cutting force at the blank tool stage is subtracted from all cutting data in the process. Then the median filtering of the cutting force in the steady cutting process of turning tool is carried out based on the odd number of panes with length of 7. Finally, the value of repeated experiment is averaged, and the average value obtained is the final cutting force.

With or without cutting fluid lubrication, and the cutting parameters are as follows,  $f=0.1\text{mm/r}$ ,  $a_p=0.5\text{mm}$ , the change of cutting force of different types of cutting tools in 316L stainless steel cutting process is studied by changing spindle speed.

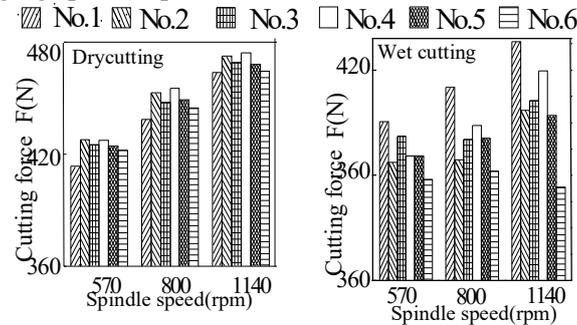


Fig.5 Comparison of cutting force in dry and wet state of different tools

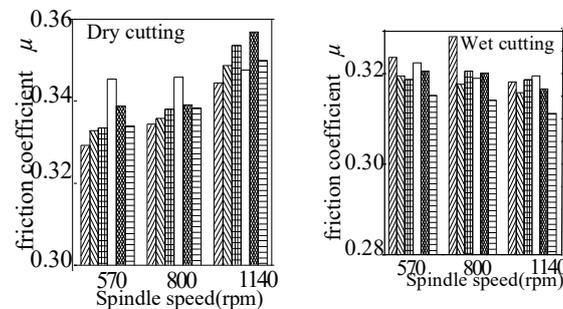


Fig.6 Comparison of friction coefficient in dry and wet state of different tools

It can be seen from Fig. 5 and Fig. 6 that, under dry cutting conditions, the force and friction coefficient of microstructure tool are higher than that of ordinary tool. The secondary friction between chip cutting and microstructure leads to greater stress, increased friction and deterioration of processing environment. After applying high pressure cutting fluid, it is found that the texture and cutting fluid form dynamic pressure lubrication, the force and friction coefficient are lower than that of ordinary tool. Among of them, the spindle speed of 1140r/min was the best, and the force and friction coefficient were improved by 19.01% and 13.39% respectively. The results show that under the condition of small feed parameters, the increase of spindle speed is helpful to reduce the friction characteristics of microstructure tool in the cutting fluid environment. The vertical groove is perpendicular to the chip flow direction, and its dynamic pressure lubrication forms "interval fluctuation", which is more easily to form chip separation.

### 3. Conclusion

In this paper, 316L stainless steel materials were processed and tested with microstructure tool. The processing performance of microstructure tool of 316L stainless steel material under the condition of small feed rate and with or without cutting fluid lubrication was carried out. The conclusions are as follows:

- The experimental data show that for 316L stainless steel materials, the microstructure tool only plays the role of reducing friction and reducing resistance under the condition of using coolant.

- Under the same cutting parameters after the coolant is applied, micro-grooves array tool has certain effect on improving the cutting process of stainless steel. For low speed and low feed parameters, the effect of vertical groove array on the cutting tool rake face is the most obvious, and the improvement effect is between 8.46% and 19.04%.

**References**

- [1] Liu Baosheng, Wu Wei, Zeng Yuansong. Application and manufacturing technology of shark skin biomimetic structures [J]. Journal of plastic engineering, 2014(4):56-62.
- [2] Qu Naiheng, Shen Xingquan, Feng Bin. Research on chip formation mechanism of EA4T steel by deep hole drilling based on BTA [J]. Machine tool and hydraulic, 2015, 43(9):100-102.
- [3] Chang W, Sun J, Luo X. Investigation of microstructured milling tool for deferring tool wear[J]. Wear, 2011, 271(9):2433-2437.
- [4] Chang W, Sun J, Luo X. Investigation of microstructured milling tool for deferring tool wear[J]. Wear, 2011, 271(9):2433-2437.
- [5] Yao Song. Simulation and numerical analysis of stainless steel material cutting process based on ABAQUS [D]. Huazhong university of science and technology, 2011.