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Research on Milling Performance of Micro-texture Milling Cutter for Machining Titanium Alloy Work piece

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Abstract.*Two types of micro-weave structures, micro-round holes and grooves, are machined on the front face of carbide ball end mills using laser machining technology. On the front face of carbide ball-end milling cutter. Three kinds of cutters (non-textured cutter, groove micro-textured cutter and micro-round hole micro-textured cutter) are milling tested with three milling parameters, and the milling force values of each cutter under different parameters are obtained. By analyzing the value of the milling force of three kinds of cutters and the different percentages of milling force between two kinds of micro-textured cutters and that of non-textured cutters, the cutting performance of micro-textured cutters in milling titanium alloy is studied. The results show that the milling force values of the two micro-textured cutters are lower than those of the non-textured cutters, while the milling force values of the micro-round hole micro-textured cutters are lower than those of the grooved micro-textured cutters. By comparing the different percentages, it can be concluded that the advantages of micro-texture in round holes will gradually increase with the increase of milling parameters, and the advantages of micro-texture in grooves will gradually decrease.*

Key words: *ball-end milling cutter; milling force; titanium alloy; carbide*

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I. Introduction

As a new material, titanium alloy was first used in the aerospace and military industry. It has the characteristics of high strength, good heat resistance, good corrosion resistance,and great chemical activity[1].With the continuous maturity of modern technology, titanium alloy is widely used in ships, chemical equipment, Marine, sports equipment, medical implants, automobiles, construction, daily necessities， and other fields. At present, the titanium industry is developing at an annual growth rate of nearly 8%. The annual output of titanium alloy processing materials has reached more than 40,000 tons and nearly 30 kinds of brands.

Although titanium alloy is a high-quality material, its small thermal conductivity and low elastic modulus lead to high cutting temperature in production and processing[2], Slow cutting and heat dissipation and a high surface rebound rate of the workpiece[3], therefore, this also makes the titanium alloy processing is more difficult. Pan et al.given the problems of low machining accuracy and low surface quality of die-casting aluminum alloy under the influence of cutting force, the method of machining V-type array surface micro-texture before the cutting cutterproposed. By measuring the milling force, we found that the mean of V array surface microtexture milling cutter was reduced by 8.5%, 14.3%, and 12.4% compared to the free milling cutter, respectively[4]. Zhang et al.by comparing the wear patterns of microcephalic and non-microfabricated tools, the mechanism of antifriction resistance and the failure mode of the ball head cutter are analyzed. The results showed that the wear value of the front and back knife surfaces decreased and then increased[5]. Li et al.two different cutting tools are studied, one of which is a microtexture with pits, and their properties are comprehensively evaluated comprehensively based on surfaces roughness, surface hardening, chip formation, and tool wear[6]. Yang et al.based on the control variable method, the microtexture ball end milling cutter are used to mill the titanium alloy. The influence of the distance from the edge of the microstructure, and the cutting stroke on the hardening degree of the paper shows that the results of the microstructure placement can effectively reduce the oxidation degree and hardening degree of the milling titanium alloy[7].Wu et al.by fabrication on the knife surface. The dry milling Ti-6Al-4V alloy was compared using microand conventional tools to reduce the cutting force, cutting temperature ,and power consumption by approximately 15%, 10%, and 5%, respectively. At the same time, the tool life can be increased by about 20%~25%[8].

In this paper, aiming at the problem of high milling force, the microstructure is processed on the cutting surface of the ball end milling cutter, and then the influence of microstructure on the milling performance is studied.

Microtexture parameters and its preparation

In the experiment, the carbide ball end milling cutter was selected as the experimental tool, the tool (see Figure 1) is BNM-200 (20R10) (parameters see Table 1), the special blade rod is 16R8-200L, the blade length is 200mm, the parameter of the milling titanium alloy is 90 * 50 * 40mm, the brand is TC4, and the main material is Ti6A14V.

Figure. 1. Ball end milling cutter

Table1. Basic parameters of the blade

Blade diameter	20mm
Blade thickness	5mm
Blade width	15mm
Knife beat	≤±0.010mm
Blade arc R accuracy	≤ ±0.006mm
The front corner of the blade	0°
The back corner of the blade	11°

Two kinds of micro-textures, i.e. micro-circular pit and groove, are used to study the micro-texture. The relevant geometrical parameters of micro-texture are mainly determined by the overall size of the blade and the milling area of the blade. The main parameters of micro-texture are the diameteror width of themicro-texture (D), thedepth of themicro-texture (H), the distance between micro-texture (L), and distance between micro-texture and milling edge (L_1). Two parameters of microtexture are designed according to the above two conditions (see Table 2 for data) and the location of themicrotexture is shown in Figure 2. The micro-texture was prepared on the front face of theball-head milling cutter by a ZT-Y-50W semiconductor single-mode laser marker[9](see Figure 3 for the form of themicro-texture).

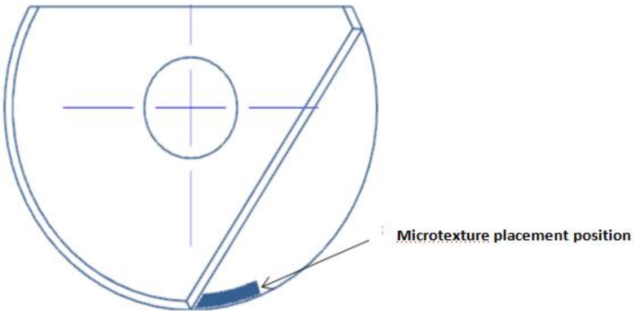
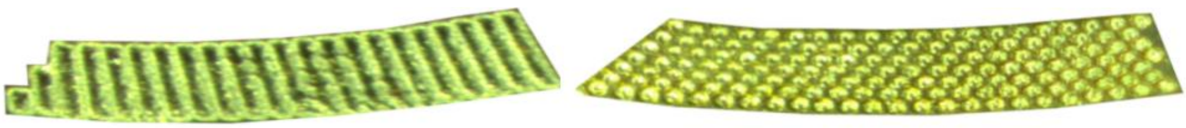


Figure. 2. Position of the microtexture

Table2. Geometric parameters of the microtexture

Microtexturetype	D/μm	H/μm	L/μm	L_1/μm
Micro-round hole	60	55	120	100
Groove	60	55	120	100



(a) Groove microtexture (b) Micro-round hole microtexture

Figure. 3. Microtexture form

Experiment and the cutting force

Experimental parameters. The experiment is a dry milling movement, and the equipment is a CNC milling machine with the model CMV-850A (see Figure 4). The main technical parameters of the milling machine are: the area of the workbench is 950 * 500 mm2, the maximum bearing capacity of the workbench is 500 kg, the travel in X, Y, and Z directions is 850 * 500 * 530 mm, the maximum speed of the spindle is 8000 r/min, the power of the spindle motor is 11/15 kw, and the cutting feed speed is 1-10000 mm/min.

There are three schemes for tool speed: 120m / min, 140m / min ,and 150m / min; the feed speed and the feed speed (per tooth) are the same, at 0.3mm and 0.08mm /z respectively. Each tool has three milling experiments under each scheme, and the data is averaged over three times to obtain effective experimental data.

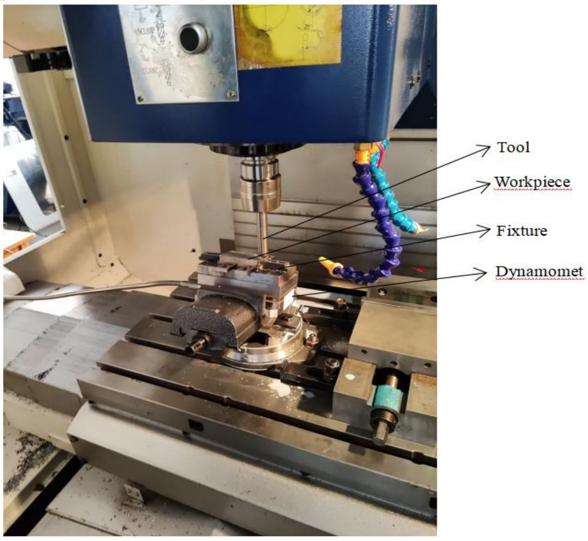


Fig. 4.CNC milling machine: CMV-850A

Milling force during the milling process. During milling, if the workpiece is placed in the zero- angle plane, the tool tip will directly participate in the milling process. Because the line speed of the milling tool tip is zero, it is easy to aggravate the tool wear and reduce the surface quality of the workpiece under this milling condition. In the study, it was found that when the inclination angle between the workpiece and the milling machine plane was 15 °, The cutting performance of the ball-end milling cutter and the surface quality of the workpiece to be milled would reach the best level. Therefore, in order to avoid the direct involvement of the tool tip in milling, resulting in the reduction of milling quality, the above research method was used for the milling force measurement experiment. Figure 5 is the schematic diagram of the milling process of the ball-end milling cutter milling titanium alloy.

The direction of the milling force in the milling process is shown in Figure 5. The milling force is obtained by the Kisster 9527B piezoelectric crystal dynamometer. The measured milling force in each round is obtained by the vector synthesis formula (see Formula 1), where F_X, F_Y,and F_Z are the forces in the X, Y ,and Z directions of the milling force in the milling process, V_f is the feed speed of the tool, and V_c is the cutting speed of the tool. See Table 4 for the final milling force resultant values obtained under F_X, F_Y,and F_Z schemes.

$$F_{\text{Resultantforce}} = \sqrt{F_X^2 + F_Y^2 + F_Z^2} \quad (1)$$

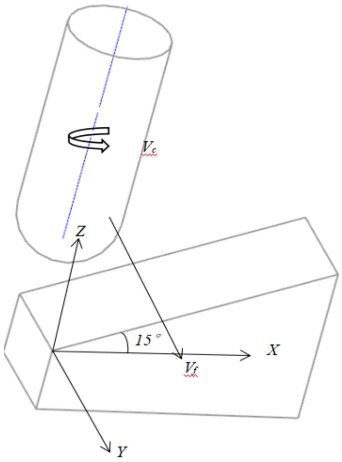


Figure. 5. Schematic diagram of the milling process

Table4. Milling force values

Microtexture type	Plan 1 / N	Plan2 / N	Plan 3 / N
Micro round hole	253.2	298.56	322.53
Groove	271.23	343.55	394.1
Non-texture	299.56	372.23	416.89

Analysis of the experimental results

The milling force values of the three tools are compared under each scheme. The method is to compare the milling force values of the three tools and the percentage difference between the milling force of the two micro-textured tools and the milling force of the non-textured tools. The formula is shown in 2, where T is the percentage ratio of the difference of the milling force, and the comparison result is shown in Figure 6.

$$T = \frac{F_{\text{Non-texture}} - F_{\text{Microtexture}}}{\text{F}_{\text{Non-texture}}} \times 100\% \quad (2)$$

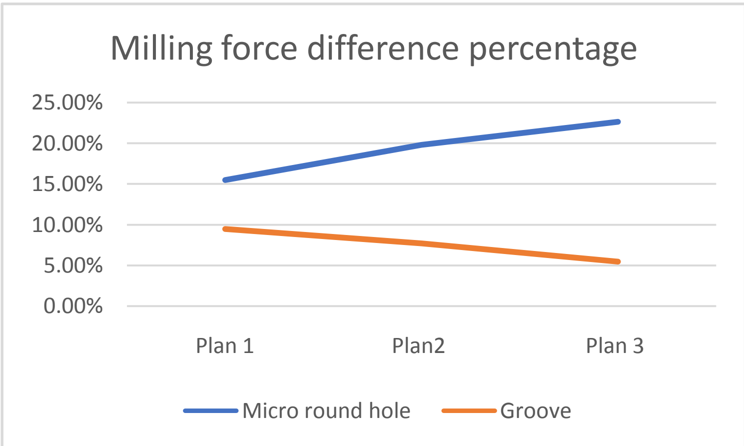


Figure. 6. Percentage figure of the milling forces difference value

Comparing the milling force values of the three tools under three milling parameters, it is found that the milling force of the micro-textured tool is lower than that of the non-textured tool under the same milling scheme, and the micro-textured tool can reduce the milling force compared with the non-textured tool, which is conducive to the growth of tool life; Compared with the two kinds of microtexture tools, the micro-round hole microtexture is superior to the groove microtexture in reducing the milling force.

Under three milling parameters, the percentage difference between the milling force of the micro-textured tool and that of the non-textured tool is compared. The difference between the milling force of the micro-round hole micro-textured tool and the non-textured tool is 15.476%, 19.79% ,and 22.63% respectively, while the difference between the milling force of the groove micro-textured tool and the non-textured tool is 9.46%, 7.7% ,and 5.47% respectively. It is found that with the increase of the milling speed, The milling performance advantages of micro-round hole micro-textured tools compared with non-textured tools become larger and larger, while the milling performance advantages of groove micro-textured tools compared with non-textured tools become smaller and smaller with the increase of milling speed.

Through in-depth study and analysis of the milling process, it is found that the micro-texture of micro-round hole and groove is helpful for milling,Micro texture improves the milling environment: (1) The existence of micro-texture reduces the contact length betweenthe chip and front face of the workpieceand reduces friction between tool and workpiece during milling. (2) Micro-texture enhances the heat flow space during tool milling, increases heat dissipation during milling ,and the restrains the generation of chip tumors. (3) The micro-texture can store the residual particles of the workpiece during milling, which reduces the wear of the tool and improves itslife of the tool.

II. Conclusion

Through theoretical and experimental analysis, it is found that the micro-texture cutter can effectively improve the milling effect.

(i) The milling force values of two kinds of micro-textured and non-textured cutters are analyzed. The different types of cutters are better or worse in reducing the milling force as follows: Micro-round hole texture >Groove micro-texture >Non-texture.

(ii) The existence of micro-texture reduces the contact length between the chip and the front face of the workpiece, increases the heat dissipation during milling, and can store the residual particles of the workpiece, thus reducing the wear of the tool and improving the tool life.

(iii) The milling performance of micro round hole micro-texture is obviously better than that of groove micro-texture cutter, and this trend becomes more and more obvious with the increase of milling parameters.

Acknowledgements

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