Study on Frictional Properties of Micro-texture Obtained by Ultrasonic Elliptical Vibration Cutting

Guowen Peng [1],Dong Lu [1,2*], Mingming Yang [3]and Jiang Zeng [1]
[1]College of Aeronautical Manufacturing Engineering,Nanchang Hangkong University, Nanchang, 330063, JIangxi, China;
[2]Department of Mechanical and Energy Engineering, Southern University of Science and Technology, Shenzhen, 518055, Guangzhou, China
[3] COMAC Shanghai Aircraft Design and Research Institute, Shanghai, China

Keywords: Micro-texture; Ultrasonic vibration;Friction; Feed rate; Cutting speed; Spindle speed;

Abstract: Because the influence of cutting parameters on the performance of ultrasonic micro texture of radial sliding bearing hydrodynamic lubrication is significant, this paper is concerned with the study of elliptic ultrasonic vibration cutting on $\Phi 30mm$ AL6061 bar by single factor experiment. The cutting speed, feed rate, and ultrasonic vibration direction are all taken into account, and co rotating friction wear experimental device is employed to measure the hydrodynamic lubrication friction test at different spindle speeds. The results show that the friction coefficient of the texture surface decreases significantly compared with the non textured surface, and the maximum value decreases by 34.4%. Moreover, it turns out that the increase of feed rate leads to the decrease of the friction coefficient. The final observation is that the friction coefficient will also decrease with the increase of spindle speed.

1 INTRODUCTION

Due to the advantages of aluminum alloy, such as easy processing, small density, high strength and excellent conductivity, it can be found that this metal has been widely used in many industrial fields, including Life, Military, Capital Construction, Aeronautics and Astronautics, Ship Engineering ,etc. And how to improve its service life has become a hot research topic in recent years. According to the study, it is found that the surface texture is effective in reducing friction and damage[1].

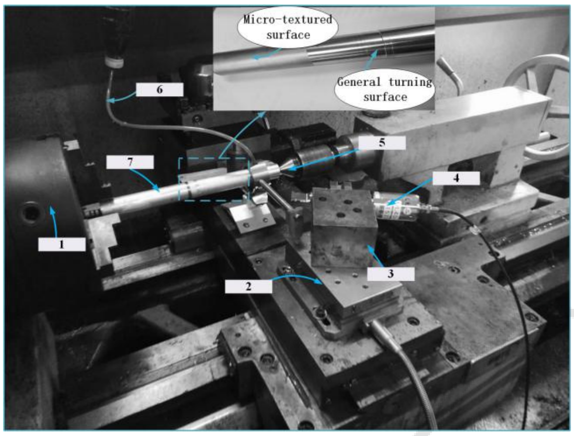
Because of the friction and wear characteristics of micro texture, micro weaving has been regarded asa current hot research direction. In the traditional tribology theory, the friction coefficient is closely correlated with the surface roughness, that is, the friction between the smooth surface and the concave convex surface will be smaller, so it will be more wearable. However, in recent years, a large number of research results showed that the formation of a micro-morphology on the surface could improve the wear resistance[2].Li Weiguang and others implemented a micro-textured hard alloy to conduct bi-rubbing tests on birch. Experiments have shown that the micro-textured hard alloy has a smaller friction coefficient, which is more than 50% smaller than that without micro-texture[3] . Hua Xijun et al. carried out a greasing and filling lubrication experiment on the GCr15 sample. The results showed that under dry friction, the friction coefficient of the textured surface decreases by 47.6% over the untextured surface, decreases by 4.8% under oil lubrication, and decreases by 17.7% under the lubrication of the filler [4].

Ultrasonic Elliptical Vibration assisted Machining (abbreviated as UEVM) can also change the distribution and size of pits by changing the amount of cutting tool eaten, feed rate, cutting speed, and ultrasonic amplitude. Therefore, different surface textures can be processed[5].

2 EXPERIMENTAL EQUIPMENT AND TEST PROCEDURES

2.1 Experimental Equipment

The experimental material used was a $\phi 35$ *40mm AL6061. The selection of experimental equipment is shown in Fig. 1, in which the ultrasonic vibration device is selected from the Japanese Yuejiang company UL40-Al, which consists of an ultrasonic generator, a transducer, and a horn. a carbide insert can be mounted on the horn, which is produced from Japan Mitsubishi. Rakeangle is 0°, Clearance angle is 11°, Corner radius is 0.4mm.And Kistler three-way dynamic dynamometer and Type5070 charge amplifier and Type5697 data collector. The choice of machine tool is CKA6150.



1-Chuck2-Dynamometer3-Tool holder4-Transducer5-Core clamper6-Tubing7-Sample

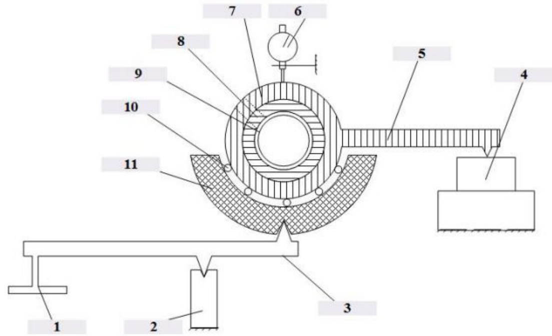
Fig.1:Experimental installation diagram.

2.2 Surface Micro-texture Prepared by UEVM

First, we drill the center hole at both ends of the AL6061 bar of $\phi 35$ *40mm, then use the claw of the three jaw chuck to fix the end. The other end of the tail seat top is tightly attached to the AL6061 bar, so that when the hand claw the claw, the top will run smoothly. Then the 2mm is cutting depthof trial cutting, the purpose of it is to reduce the impact on the experimental results because of the difference of the original surface finish. Then the carbide blade is fixed on the horn, which is shown in Figure 3 after the installation is accomplished. Next, the ultrasonic device is connected and the ultrasonic is also connected. It is appropriate to put the tweezers on the blade slightly with a clamped sound, and then turn off the ultrasonic. The ultrasonic switch is opened again, and the cycle starts. Experimental parameters are shown in Table 1.

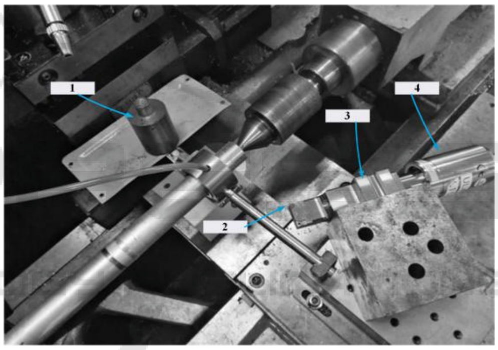
2.3 Friction and Wear Experiment

A self-made friction and wear device was used to study the friction force in the oil rich condition at different spindle speeds. The friction and wear device is made up of a shaft, an axle bush and a lengthening rod. As shown in Fig. 2 and Fig. 3.



1-Dial gauge2-Leverage pivot3-lever4-Dynamometer5-Measuring rod6-Dial gauge7-Bearing sleeve8-Bush9-Sample10-Roller11-Support base

Fig.2:Structural analysis diagram.



1-Weight2-Carbide blade(TPGX080204)3-Horn4-Ultrasound generator

Fig. 3:Physical map.

The installation steps of the friction and wear device are described as follows:

1). Put the axle bush in the axle bush fixed sleeve, fasten with the tightening screw, and connect the force rod with the axle bush at the same time.

2). After the rear seat moves, the axle bush and the bearing bush is placed on the surface of the micro texture, and the tail seat is moved forward to the fixed specimen.

3). The loading device is placed, and the modulation load is perpendicular to the positive center of the sample.

4). The roller with the support is installed in the support seat, and then the whole is placed under the axle bush fixed sleeve to connect with the load.

5). Put the weight of the weight, access the lubricating oil pipe, start the test.

During the test, the sample is clamped on the machine to limit the freedom of space movement and follow the rotation of the spindle of the machine tool. A friction pair is formed between the sample and the inner surface of the bearing shell. After the sample rotates, it drives the lubricating oil into the friction pair to generate a fluid dynamic pressure oil film. The oil film shear friction force is transmitted to the dynamometer through the bearing sleeve-measuring rod. According to the magnitude of the force, the friction force of the oil film formed between the sample and the inner surface of the bearing bush under a certain spindle speed and load can be calculated and passed through the $\mu = F/P$ calculates the friction coefficient μ value. Due to the formation of dynamic pressure oil film, the bearing bush is offset downwards relative to the fixed specimen. The dial gauge contacted with the bushing fixing sleeve shows the offset value of the bearing bush. The offset is proportional to the thickness of the oil film.

2.4 Experimental Processing Parameters

In this paper, the single factor experimental analysis of AL6061 is performed using UEVM. The AL6061 bar material with a diameter of 30 mm was selected as the experimental sample. The effect of feed rate and cutting speed on the micro-texture surface prepared by UEVM was analyzed. The hydrodynamic lubrication friction under the self-made co-rotating friction and wear device was analyzed.

Set the cutting speed to CS and the spindle speed to SS. the feed rate to f, the frequency to F, and the ultrasonic voltage power supply to the UPS.

In order to study the variation of the friction of the UEVM micromachined AL6061 under different cutting speeds and feed rates, the machining parameters shown in Table 1 were developed.

Table 1 Experimental processing parameters.

Parameter	Name	Numerical value
Cutting conditions	CS (r/min)	500/700/900
	f (mm/r)	0.03/0.06/0.09/0.12
Ultrasonic vibration parameters	F (KHz)	40.5
	UPS(%)	30
Test parameters	SS(r/min)	300/500/700

2.5 Purpose

The purpose of this experiment is to investigate how micro-textures reduce friction and wear when the workpiece is running, thereby increasing the life of the workpiece. Ultrasonic parameters and cutting parameters were used to form different micro-textures on the surface of the AL6061 rod material. The frictional performance of the hydrodynamic lubrication of radial plain bearings was measured at different spindle speeds using a self-made friction and wear device. That is, the influence of ultrasonic parameters and cutting parameters on the hydrodynamic lubrication friction of the workpiece when the workpiece is actually loaded is investigated.

3 .EXPERIMENTAL RESULTS AND ANALYSIS

3.1 The Effect of Micro-texture on The Surface of UEVM on The Friction Coefficient of AL6061

In order to explore the effect of UEVM on the surface micro-texture of AL6061, the AL6061 experimental specimens were each subjected to UEVM cutting and general turning with a feed rate of f=0.05 mm/r and a cutting speed of 300 r/min. The smooth surface of the length. Therefore, there are 3 experimental patterns with a length of 50 mm. And the use of self-made rotating friction wear test equipment to measure its hydrodynamic friction lubrication friction.The obtained experimental data can be processed Fig.4 can be obtained. Suppose normal turning is NT, ultrasonic cutting is UC, and smooth (not cutting) is S.The friction coefficient is u.

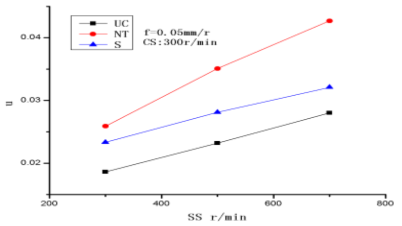


Fig.4: Comparison of the friction coefficient between ultrasonically processed micro-texture, ordinary turning and smooth.

It can be seen from Fig. 4 that the friction coefficient of ordinary turning compared to smooth surface has increased, because the surface of ordinary turning is constantly in contact with the workpiece, which leads to cutting heat and large and continuous Factors such as swarf that affect its surface roughness have a large influence, so the coefficient of friction will increase.

In Fig. 4, it can be seen that the micro-textured surface of the UEVM surface has a lower coefficient of friction than the smooth surface. According to the understanding of the conventional friction force, the smoother the surface, the smaller the friction force should be, but the experimental phenomenon is not the case. This may be due to micro-texture, under the lubrication of the oil, the pit surface may form a small dynamic pressure lubrication effect, while the role of oil storage and minor impurities, greatly avoiding the workpiece and The direct contact of the components reduces the effect of the furrows[6].

With the gradual increase of the spindle speed, the change of the friction coefficient after microtexture on the surface of the UEVM is more gentle, which shows that the surface microtexture has a better friction reduction effect than the untextured surface at high speed! And up to a drop of 34.4%.

3.2 The Influence of The Change of CuttingSpeed on The Surface Friction Force

In order to study the influence ofcuttingspeed on the surface friction coefficient of UEVM microfabricated AL6061 micro-fabric, we used them at the feed rate of 0.03mm/r, 0.06mm/r, 0.09mm/r, and 0.12mm/r. When 500r/min, 700r/min, and 900r/min cutting speeds are used to machine 3 segments with a length of 50mm, a 12-segment cutting experiment pattern can be obtained. And the use of self-made rotating friction wear test equipment to measure its hydrodynamic friction lubrication friction. After data processing, the friction coefficient changes of different cutting speeds of Fig.5.1. Fig 5.2. Fig.5.3 and Fig.5.4 are obtained.

It can be seen from Figure 5.1 that the friction coefficient increases with the increase of the spindle speed, and the rate of change of the friction coefficient under differentcutting speed cutting conditions is very small. This may be due to the fact that the micro-differential micro-texture has little effect on the liquid flow rate, and the rate of change will be basically the same. With the increase of the cutting speed, the friction coefficient decreases significantly, that is, high-speed cutting helps to improve the friction coefficient of the workpiece surface.

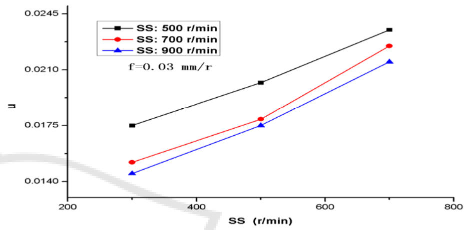


Fig.5.1: Effectof CS on Micro-texture Friction Coefficient at feed rate 0.03mm/r.

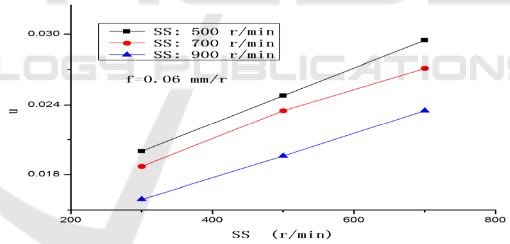


Fig.5.2:Effect of CS on Micro-texture Friction Coefficient at feed rate 0.06mm/r.

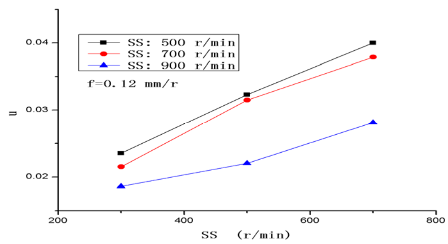


Fig.5.3:Effect of CS on Micro-texture Friction Coefficient at feed rate 0.09mm/r.

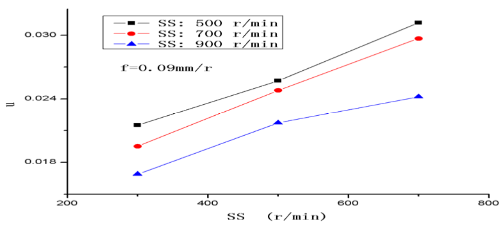


Fig. 5.4:Effect of CS on Micro-texture Friction Coefficient at feed rate 0.12mm/r.

3.3 Effect of Feed Rate on The Friction Coefficient of Micro-texture on UEVM Surface

In order to study the influence of the feed rate on the friction coefficient of the surface micro-texture, the cutting speed was 500 r/min at feed rates of 0.03 mm/r, 0.06 mm/r, 0.09 mm/r, and 0.12 mm/r, respectively, 700r/min, 900r/min and other conditions using UEVM to process three different cutting speeds and cutting length of 50mm, you can obtain a 12-segment cutting experiment. And use the self-made friction and wear test device to measure its hydrodynamic lubrication friction. After processing the data, figures 6.1, 6.2, and 6.3 are available.

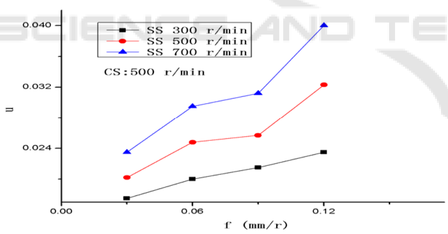


Fig.6.1:Effect of feed rate on the friction coefficient of micro-weave at CS of 500r/min.

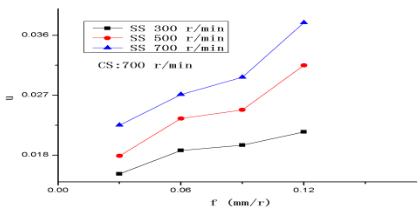


Fig.6.2:Effect of feed rate on the friction coefficient of micro-weave at CS of 700r/min.

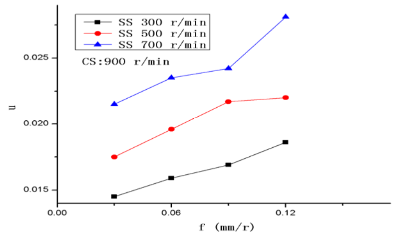


Fig.6.3:Effect of feed rate on the frictioncoefficient of micro-weave at CS of 900r/min.

From Fig.6.1,it turns out that as the feed rate increases, the friction coefficient on the surface of the AL6061 increases. And at different spindlespeeds, the friction coefficient also showed an upward trend, because with the increase offeed rate, under the action of UEVM, its effective cutting part decreased significantly, that is, the surface friction coefficient increased.

It can be seen in the comparison of Figures 6.2 and 6.3 that the friction coefficient increases with the increase of the feed rate under different cutting speed cutting action, and the friction coefficient also increases gradually during the increase of the spindle speed.

4 CONCLUSIONS

In this paper, the experimental study of AL6061 Normal Turning (NT), Ultrasonic Vibration Assisted Turning (UVAT), feed rate, and cutting speed on the surface micro-texture friction coefficient was carried out. After summarizing and analyzing, we obtained:

1. Under the precondition of cutting speed of 300r/min and feed rate of 0.05mm/s, the surface friction coefficient of AL6061 micro-textured on the surface of UEVM is greatly reduced and can be reduced by up to 34.4%.

2. The surface friction coefficient of AL6061 micro-textured by UEVM increases with the feed rate.

3. The surface friction coefficient of AL6061 micro-textured by UEVM shows a decreasing trend with the increase of cutting speed.

4. When the coefficient of friction is measured under oil-rich lubrication, the friction coefficient increases as the spindle feed increases.

5. Under high-speed lubrication, the surface friction coefficient of AL6061 microtextured on the surface of UEVM is better than that of the untextured surface.

REFERENCES

1. Sung I H, Lee H S, Kim D E. Effect of surface topography on the frictional behavior at the micro / nano - scale [J]. Wear, 2003, 254: 1 019 - 1 031.
2. Long Shishan. Experimental study on dry-cutting aluminum alloy with micro-textured carbide tool [D]. Xiangtan University, 2014
3. Li Weiguang, Zhang Zhankuan. Effect of Surface Micro-textured Cemented Carbide on the Tribological Characteristics of Birch[J]. Journal of Forestry Engineers, 2018, 3(01):103-108.
4. Hua Xijun, Xie Xuan, Zhang Peixi, Sun Jianguo, Wang Hao, Fu Yonghong. Tribological properties of micro-textured self-lubricating surfaces in oil media[J]. China Surface Engineering, 2017, 30(02):35- 40.
5. Dornfeld D, Min S, Takeuchi Y. Recent advances in mechanical micromachining[J]. CIRP Annals-Manufacturing Technology, 2006, 55(2): 745-768.
6. Wang X L, Kato K, Adachi K, et al. Loads carrying capacitymap for the surface texture design of Si C thrust bearing sliding inwater [J]. Tribology International, 2003, 36: 189 - 197.