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The High-Precision Machining by Ultra Sonic Vibration Cutting Method with Using Lower-Young's Tool
低ヤング率工具を用いた超音波振動切削法による高精度加工

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1. Introduction

It is necessary to establish the machining technologies for a minute hole and the groove in manufacturing the equipments for medical treatment and information instruments fields. Machining the round holes, with diameter about 30 micrometers using the method of drilling into the metallic plate has become achieved. However, the high precision level machining the irregular holes such as rectangular hole and spline hole of the parts whose sizes are below approximately 3 millimeter has not been carried out until now.

In order to machine the irregular holes, we use “Slotting” technique, which has the purpose of giving the key groove to a round hole. In slotting process, a one side of the tool is fixed, while the opposite side is used as cutting edge. A tool is attached to the machine tool and the cutting process is performed by controlling the vertical motion of the tool. Since the tool is kept as cantilever, cutting force will cause the deformation of the tool and as a result, the straightness of the machined hole or groove is deteriorates.

As a beginning, an ultra sonic vibration machining method will be applied with the aim of the reduction effect of cutting force. However, although the straightness and the roughness of finished surface are fairly improved, there is a limitation in the improvement of straightness(1). For the practical use of the slotting method assisted by ultra sonic vibration, the shape and material of cutting tool are investigated in this report.

2. Experimental conditions

In order to machine the irregular holes, the ultra-sonic vibration cutting device is chucked in the spindle of NC milling machine. The cutting tool is attached by collet chuck of the ultra-sonic vibration cutting device. The main vibration conditions are as follows: the mode of vibration is longitudinal parallel to cutting direction, 13μm of amplitude, 20±1.5kHz of frequency, 300W of maximum power.

Shown in Table 1 are the cutting conditions. The workpiece is SUS304 of austenite stainless steel; the tools are made of the sintered carbide of JIS K10, the sintered carbide composed by ultra-fine particles, and the sintered carbide composed by ultra-ultra-fine particles. These Yong's modulus is 650GPa, 550GPa, 460GPa. These tools are abbreviated to K10 tool, U tool, and UU tool. The K10 low rigidity type tool whose bending rigidity is as same as the UU tool is made with varying the shape as shown in Fig.1.

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Workpiece	SUS304	
Tool	Sintered carbide	K10 Ultra-fine particle Ultra-ultra-fine particle
	Rake angle	5°
	Clearance angle	1.2°
	Width of cutting edge	1.0mm
Cutting conditions	Cutting speed	100mm/min
	Depth of cut per stroke	10,20,30μm
	Number of stroke	10
	Length of cut	5mm

Table 1 Cutting conditions

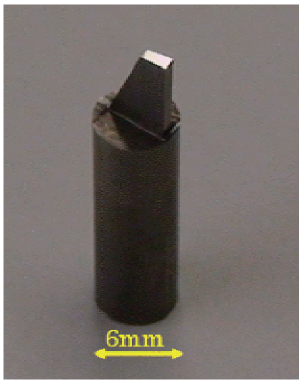

Fig.1 Used tool with low bending rigid

3. Experimental results and discussion

Shown in Fig.2 are the experimental results. In the case of the cutting with the UU tool, the straightness are more improved than the cutting with the U tool at the conditions of below 20μm of the depth of cut per stroke, although the straightness is remarkably deteriorated at the condition of 30μm. The cutting results with the K10 low rigidity type tool are not up to the cuttings with the UU tool, while those are improved than the cuttings with the K10 regular type tool. In practical use, it is possible to widely maintain the accuracy when cutting with the U tool

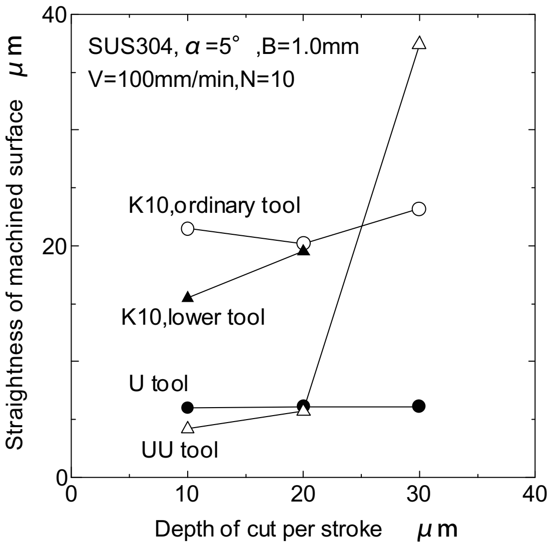

Fig.2 Influence of the slotting tools varied with tool material and tool shape on straightness

To investigate the results as shown in Fig.2, we examine the state of cutting force at high frequency component. Shown in Fig.3 are the principal cutting force and thrust force at 2.5mm from the start of cut when cutting with UU tool and K10 tool. In the case of UU tool, the thrust force is considerably varied with superimposed on approximately 1.8kHz of lower frequency variation. To the contrary, low amplitude of the frequency is observed at K10 tool, and the average value of thrust force is increased. As a result, the straightness when cutting with UU tool is improved due to decrease of the average value of thrust force with high amplitude of lower frequency.

Shown in Table 2 are the static rigidity without vibration, the dynamic rigidity of axial direction whose direction is parallel to cutting direction and thrust direction with vibrating and displacing to the depth of cut, and the increasing ratio of variable force to displacement. The increasing ratio of variable force to axial direction at U tool is larger than that of K10 tool, although the both rigidity and the increasing ratio of variable force at K10 tool are slightly large.

In the case of the tool which has low Young's modulus and low rigidity, it is easy to deform and vibrate for cutting direction instead of suppression for thrust direction when ultra sonic vibration occurs in the tool system with suffering thrust force. It may be inferred that the vibration for cutting direction is not suppressed when using the tool of low Yong's modulus due to the change of vibration mode. From this effect, the vibration for cutting direction is maintained so that the thrust force is not increased.

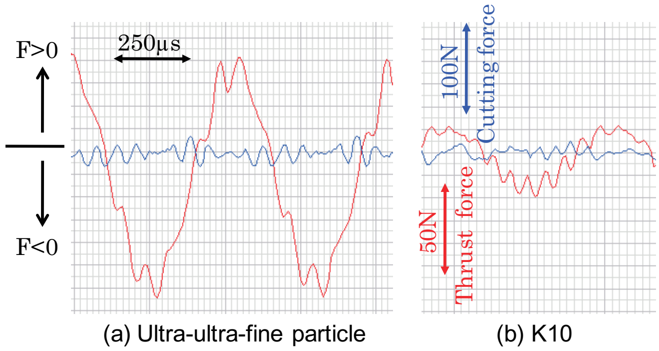

Fig.3 Variations of cutting force when slotting by UU tool and K10 tool

Table 2 Results of stiffness and increasing rate of variable force N/μm

Tool material		K10	Ultra-fine particle
Thrust direction	Static stiffness	0.97	0.91
	Stiffness with vibration	0.81	0.78
	Increasing rate of variable force	0.84	0.73
Axial direction	Stiffness with vibration	0.31	0.27
	Increasing rate of variable force	0.61	0.84

4. Conclusion

As it has been recognized that the effects of ultra sonic vibration cutting method are the sufficient vibration for cutting direction, we can elicit the more effect with actively superimposing the bending vibration. An example is given in the ultra sonic elliptical vibration cutting method[2]. It is necessary to actively introduce these method for severe machining such as the slotting method.

Acknowledgment

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