초정밀 가공에서의 경사각 영향에 대한 연구

Study on the rake angle effect in ultra precision machining

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1. Introduction

In recent years, ultra-precision machining with diamond tools has been rapidly growing in the manufacturing of high precision machined parts for advanced industrial applications. The development of ultra-precision machining technology relies on the efforts of tools such as single-crystal diamond tools and machine elements [1-2]. Single crystal diamond tools are exclusively used for their nanometric edge sharpness, form reproducibility and wear resistance [2]. Electroless nickel is one of machinable materials which exhibits excellent properties such as hardness, corrosion resistant, and more importantly it can be machined effectively by diamond turning [2].

Dependent upon workpiece material and geometry to be desired, cutting forces have important influence on determining of machining cost related to cutting speed, feed rate, undeformed chip thickness, cutting tool material, geometry and rake angle [3]. Cutting forces can cause deflections that lead to geometric errors and difficulty meeting tolerance specifications. Thus, predicting forces is one of the most common reasons for modeling machining processes [5].

There have been many studies concerning the effect of cutting parameters and tool parameters on the ultra-precision machining of electroless nickel [2,4]. Plus, there are also many studies focusing on the effect of tool rake angle on the cutting force [3]. All results yielded from all these studies have been evaluated. However, there is no known reported study on the relationship between the cutting force and tool rake angle in ultra-precision machining of electroless nickel. The objective of this study is to compare and investigate the cutting force with various rake angle for micro machining on electroless nickel workpiece

2. Theoretical determining the cutting force with various rake angles

Model for the mechanics aspect of ultra precision machining is classified as three dimensional cutting. For idealization the mechanics, the horizontal feed direction is chosen;.

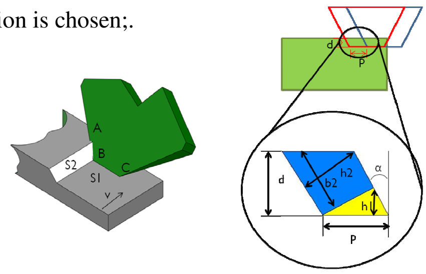

Fig. 1 a) 3-D machining; b) Divided uncut chip

For simpler in cutting force determining, the uncut chip is divided into two parts (Fig.1.b). The equations (1) and (2) are used for calculating cutting force vectors in orthogonal cutting and oblique cutting [5].

$$\vec{F} = \begin{bmatrix} F_c \\ F_t \end{bmatrix} = \begin{bmatrix} \dfrac{\cos(\beta-\gamma_o)}{\cos(\phi_o+\beta-\gamma_o)} \\ \dfrac{\sin(\beta-\gamma_o)}{\cos(\phi_o+\beta-\gamma_o)} \end{bmatrix} \frac{\tau_s A_1}{\sin(\phi_o)} \quad (1)$$

$$F_p = \begin{bmatrix} F_c \\ F_t \\ F_r \end{bmatrix} = \begin{bmatrix} \dfrac{\cos(\beta_n-\gamma)\cos(\eta_s)\cos(\gamma)+\cos(\phi+\beta_n-\gamma)\sin(\eta_s)\sin(\lambda)}{\cos(\phi+\beta_n-\gamma)} \\ \dfrac{\sin(\beta_n-\gamma)\cos(\eta_s)}{\cos(\phi+\beta_n-\gamma)} \\ \dfrac{\cos(\beta_n-\gamma)\cos(\eta_s)\sin(\gamma)+\cos(\phi+\beta_n-\gamma)\sin(\eta_s)\cos(\lambda)}{\cos(\phi+\beta_n-\gamma)} \end{bmatrix} \frac{\tau_s A_2}{\sin(\phi)\cos(\lambda)} \quad (2)$$

By applying the certain values of the feature parameters such as uncut chip dimesion, friction coefficient, shear plane angle to these equation, the relatioships between tool rake angle and cutting force for each surface S1 and S2 can be achieved. After obtaining that, by combining the cutting forces of the surface S1 and surface S2, the total cutting force can be determined.

Figure 2 is an example of the curves of three components of cutting force (cutting force, thrust force and radial force). This figure show us that the cutting force decrease during increasing of rake angle.

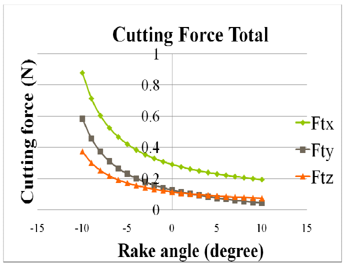

Fig. 2 The theoretical curves of cutting forces on rake angle

3. Experiments

In this study, the experiment were carried out on a KITECH's ultra precision turning. The material of workpiece is electroless nickel and the experiment was operated with three diamond tools which have difference tool rake angle (-10, 0 and 10).

The machining conditions are showed in table 1.

Table 1. Machining conditions		
Rake angle	-10;0;10	^{0}
Depth of cut	5;10;20	µm
Pattern pitch	5;10;20	µm
Cutting speed	120,150,180	rpm

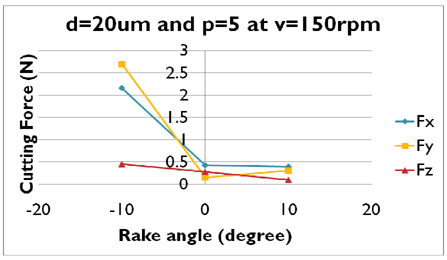

Figure 3 : The practical curves of cutting force on rake angle

Figure 3 is one of many figures we obtained from result data. As we see, these curves are similar to the theoretical curves. But the difference is that the smallest cutting force is obtained with zero rake angle.

4. Conclusion

Based on theoretical analysis, if the rake angle increases, the cutting force will decrease; hence, with the 10^o rake angle tool, smallest cutting force will be obtained. But, in practical, the tool with zero rake angle always gave us the smallest cutting force for all cutting speed, cutting depth and pattern pitch. Once again, we have to admit that the physics of the ultra precision machining on electroless nickel workpiece is not easy to well understand. From the result of this study, for approaching more closely to the mechanics of ultra precision machining, new approaching method is required.

후기

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