Tool wear analysis of lenticular shape diamond tool in micro cutting of nickel plated roll die

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Abstract

In this paper, to characterize tool wear behaviour, machining test of nickel plated roll die was performed using ultra precision lathe and lenticular shape single crystal diamond (SCD) tools. The test was conducted at various cutting pitch and cutting distances. Finite element method (FEM) simulation was also used to predict contact stress on the tool, which associated with the tool wear behaviour. For the tool wear measurement, 3D Nano View, which can generate surface topography of the tools, was used. From the experimental result, it was found that the dominant wear mechanism was abrasion due to high contact stresses on the tool.

1 Introduction

In micro cutting process for patterning roll die, which produces micro patterned film, a single crystal diamond (SCD) tool has been widely used due to its high hardness and wear resistance [1, 2]. Even if tool wear in the micro cutting is an important parameter that determines the pattern quality on the film, the tool wear mechanism has not been identified so far.

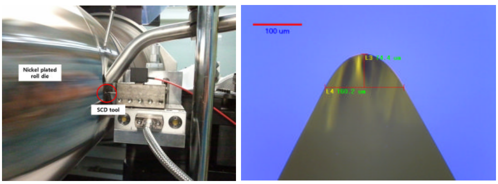
A few work studied the SCD tool wear behaviors in machining process [2-4]. A gradual groove wear was identified on rake face after cutting of 28.5km [3]. And the tool wear mechanism of SCD cutters on flank surface was abrasion and adhesion while the crater wear with small groove was formed on rake surface at longer cutting distance [4]. On the other hand, many studies have performed cutting simulation on prediction of contact stress, cutting force, chip formation, etc. FEM simulation was performed for the contact stress location which associated the wear location [5].

In this paper, micro turning of nickel plated roll die was performed using lenticular shape SCD tool in terms of cutting speed and cutting distance to understand tool wear behavior. FEM simulation was also carried out to estimate the contact stress, which can finally characterize the tool wear mechanism.

2 Expermiental work

Fig. 1(a) shows the experimental setup where ultraprecision lathe was used. The machining experiment was performed with the lenticular shape SCD tool in various cutting distances of 25km, 50km and 75km at cutting speed of 150rpm. The experiment conditions are summarized in Table 1. 3D Nano View was also used for the tool wear measurement. The 3D Nano View, which can generate cross-sectional profile of the tool, is a high accuracy non-contact surface profiler with resolution of 0.1nm and 0.2 µm in z direction and in x-y direction respectively.

On the other hand, FEM simulation was performed using ABAQUS V6.8. In the simulation, the nickel plated roll die was assumed as a deformable block while the lenticular tool was considered as a rigid body. For the work material, Johnson-Cook (J-C) plasticity model of nickel 200, commercially pure or low-alloy nickel, was adapted. The detail information can be found in the reference [6].



(a) Experimental setup (b) Lenticular SCD tool

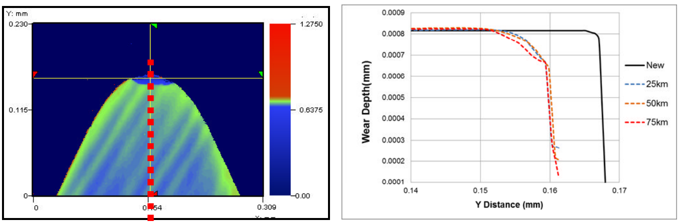
Figure 1: Experimental setup and SCD tool

Table1: Experiment conditions

Cutting speed (rpm)	150
Cutting pitch (µm)	50, 160
Cutting distance (km)	25, 50, 70

3 Results and discussions

Fig. 2(a) shows surface topography of the SCD tool obtained by the 3D Nano View equipment at the cutting pitch of 50µm while Fig. 2(b) represents the associated cross-sectional profiles at the cutting distances, which shows tool wear evolution. From the results, edge wear was observed and this might be because the contact stress was concentrated on the cutting edge, as shown in Fig. 3, which leaded to abrade the cutting edge. This phenomenon can be explained by abrasive wear model where volumetric wear by abrasion increases with the contact stress on the cutting tool [7]. Therefore, high contact stress on the edge caused the edge wear. On top of that, the SCD tool is a brittle material so the edge is relatively prone to be abraded or fractured. On the other hand, crater wear was clearly observed in machining test with the cutting pitch of 160μm as shown in Fig. 4. Again, it is true that location of maximum crater wear depth occurred should be identical to the location where maximum contact stress is generated. In fact, as seen in Fig. 5, FEM simulation results shows that the maximum contact stress occurred at the location of around 300μm away from the cutting edge, which corresponds the location of the maximum crater wear depth. Therefore, it can be concluded that a dominant wear mechanism of SCD tool is abrasion. Besides, the brittle nature of SCD tool can accelerate the edge wear.



(a) Surface topography (b) surface profiles at 'red' dot line of (a) at cutting distances

Figure 2: SCD tool surface image and surface profile

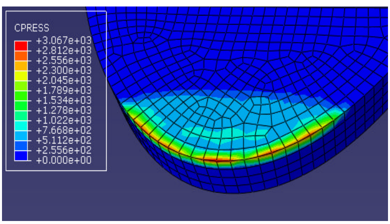


Figure 3: Contact stress by FEM simulation

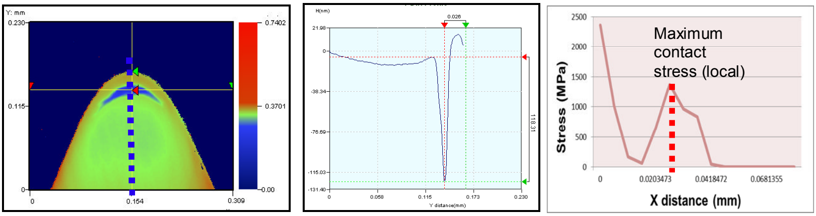


Figure 4: Surface topography (cutting pitch: 160μm), the surface profiles on 'blue' dot line and the contact stress

4 Conclusions

The wear mechanism was analyzed using abrasive wear model. The edge wear was observed at the cutting pitch of 50μm while crater wear was observed at that of 160μm. It was found that the dominant wear mechanism was abrasion by hard contact stress on the tool, which can be predicted by FEM simulation.

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