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A method to recognize the contact area of tool-workpiece on the diamond cutting tool

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Abstract
Diamond tools degrade whilst machining some specimen resulting in poor quality surfaces and extensive subsurface damage. To understanding the mechanisms, the wear of diamond cutting tool is focused by many researchers. In the study of diamond wear, adequate characterization of tool-wear behavior is crucial. The tool-workpiece contact area is very tiny in cutting process. And for certain instance, e.g. Diamond fly cutting of KDP (Potassium Dihydrogen Phosphate) crystal, the nose radius of the diamond cutting tool is in the magnitude of 5 mm. Under this condition, especially when the tool wear is not significant, we must recognize the tool-workpiece contact area in size of tens of microns on the several millimeters long cutting edge in the wear test experiments, or else we cannot identify the wear area of interest after the tool is removed from the tool chuck. In this paper, we present a method to recognize the contact area of tool-workpiece using the FIB (Focus ion beam) etching technology and an artifice of cutting practice. With this method the tiny contact area can be well found under SEM or other microscopes to carry out the wear measurement of the diamond tool.

Keywords: cutting; diamond; measurement; wear

1. Introduction

The recession of the diamond cutting tool has a great important influence on cutting quality. In practice of tool application, our focuses are the performance and lifetime of the tool. The answer to these two focuses is based on our grasp of diamond tool wear regularity and mechanism. In the wear test experiment, if the wear region is large enough, the wear can be measured under the microscopy easily. However, if the wear region is tiny and that the nose radius of the tool is large, we will be unable to find the wear area under the microscopy. Taking the KDP fly cutting as an example, the nose radius of the diamond cutting tool is about 5 mm and that the contact area of tool-workpiece on the diamond cutting tool is very small due to several micrometres cutting depth. So, we must make sure where is the wear region on the edge of the cutting tool under the microscopy.

In previous work, the diamond tool wear is wildly focused on. Durazo-Cardenas [1] directly examined the tool wear using FEI XL30 environmental scanning electron microscope (ESEM). In addition, they also examined the recession of the diamond tool by measuring the plunge "imprint" profiles via Talysurf surface profilometer. Asai [2] remodelled the conventional SEM to make it have two secondary electron detectors, through which the cutting edge shape was figured out from the difference in SEM image signals. Drescher [3] developed a method using the contamination in the SEM resulted from polymerization by electron beam of hydrocarbons in the vacuum chamber, or EBID (electron-beam-induced deposition) to obtain the tool profile from the geometry. Shi and Lane [4, 5] also used the EBID of SEM to measure the wear of diamond tool. Wang [6] observed the flank wear and the micro-fracture of diamond tool using the SEM directly. The SEM has the resolution of nanometre, but the tool measured has to be put in a vacuum chamber. Moreover, the SEM cannot measure the 3D profile of tool edge due to its 2D projection image of a 3D object.

Compared with SEM and other microscopy, atomic force microscopy (AFM) can measure the 3D profiles of micro objects with nanometre resolution [7-10]. Gao [11] added an optical sensor to the AFM unit for alignment of AFM probe tip through which the top of the diamond tool cutting edge can be easily found and measured. Li [12] copied the profile of cutting edge by indenting the tool cutting edge into the surface of a copper, and then measured the copy of the profile by AFM.

The methods above are suitable for the wear region which is easy to be found under the microscopy. However, if the wear region is tiny on a long cutting edge of the diamond tool, and if the tiny wear region is unobvious that is similar with the rest region of the cutting edge, the new method should be developed. Otherwise, it is not sure that the tested region under the microscope is indeed the wear region in contact with the workpiece.

In this paper, we give a novel technique to solve the problem of finding an interesting tiny area on the long cutting edge of diamond tool, which is convenient to measure the wear of a certain point on diamond cutting tool edge.

2. Method

To recognize the tiny wear region, or the contact area of tool-workpiece, on diamond cutting tool edge, two problems are faced: 1) finding the wear point before the actual cutting experiment; 2) marking out the wear point.

2.1. Finding the wear point

The wear point is the contact area of tool-workpiece on the diamond cutting tool. Taking the posture of the tool fixed on the tool chunk into account, it is difficult to determine the tool-workpiece contact area based on the geometry of the cutting tool. So, a method of test-cutting is adopted in our experiment, as shown in Fig.1. At first, a small surface is cut, and then the cutting tool retracts, after which a marker (made by TRUE Color, China) is used to smear the surface. Before the ink smeared by the marker is dry, it is cut by the diamond cutting tool. The eventual influence of capillary effects on the transfer of ink to the tool is very little. In this way, the tool-workpiece contact area is marked by the ink, and the wear point is found on the cutting edge, as shown in Fig.2.

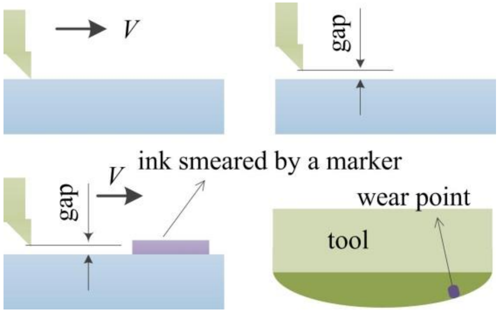

Figure 1. Test-cutting experiment for finding the wear point

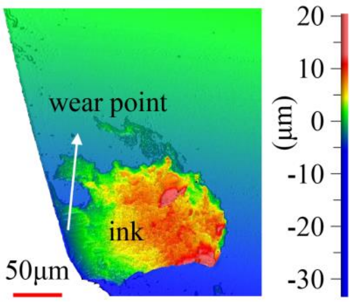

Figure 2. The white light interference image of wear point marked on cutting edge

The advantage of this method of finding the wear point is that it is easy to operate on any ultra-precision lathe or the other cutting machines. And the most important is that the test-cutting of ink smeared by a marker has no harmful effect on the new diamond cutting tool edge.

2.2. Marking out the wear point

The wear point or tool-workpiece contact area marked by the ink cannot resist the erasing of flowing chip in cutting process. In order to prevent the ink mark of wear point from disappearing, a fixed measure is taken. In our study, the FIB etching technology is used to fix the mark of tool-workpiece contact area on the diamond tool. The SEM image of the wear point or tool-workpiece contact area marked by the ink is shown in Fig.3. The micro pit etched by FIB (made by ZEISS) is shown in Fig.4. In FIB etching the gallium ion source is used. And the milling current of the FIB is set as 30kV:4nA.

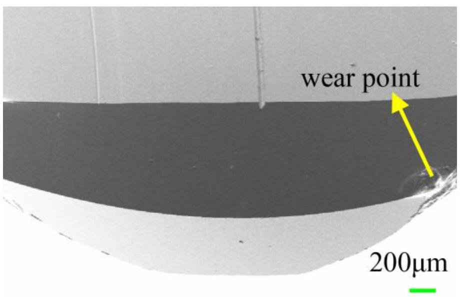

Figure 3. The SEM image of wear point found on the cutting edge

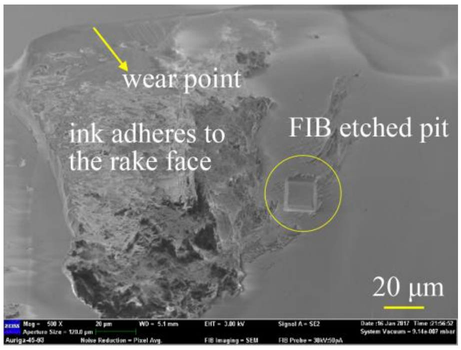

Figure 4. The micro pit etched by FIB

3. Conclusion

In this paper a method to recognize the contact area of tool-workpiece on the diamond cutting tool is presented. Taking advantage of our work, the tiny wear area on a long cutting edge of diamond tool or any other tools can be easily marked, which enables researcher to find the wear point under many kinds of microscope. Our work is especially important for the wear test of mild wear at a certain tiny point on a long cutting edge.

4. Acknowledgement

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