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Proposal of fixed abrasive wire tool for thin wires considering mirror cutting

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Abstract

The development of tools that can minimize them is required to effectively utilize rare materials used in expensive parts without waste. The fixed abrasive wire tools used to cut materials, such as glass, by brittle failure have a high efficiency but produce pearskin surfaces. This situation occurs because priority is placed on the core wire diameter required to maintain the current cutting efficiency and the optimal diameter of abrasive grains fixed around the core wire. To realize mirror surface of the cutting surface, it is important to avoid brittle fracture during cutting. For that, the cutting depth of the cutting edge of nonuniform abrasive grains is necessary to make a constant. Therefore, a core wire is inserted into a polyimide tube (PIT), on which a mixture of a polyimide solution of a similar type to that of the PIT and abrasive grains was coated (tool diameter ϕ0.4-0.5mm). As a result, the following conclusions were obtained. (1) ductile cutting of glass is possible using the developed tool, (2) the combined use of a continuous air flow and intermittent misting is effective during cutting, and (3) the tool obtained by inserting a core wire into a PIT is robust against breakage and the diameter of the tool can be reduced.

Keywords: fixed abrasive wire tool, polyimide resin, polyimide chub, mirror cutting, cylindrical glass

1. Introduction

The fixed abrasive wire tools used to cut materials, such as glass, by brittle failure have a high efficiency but produce pearskin surfaces with low roughness. This situation occurs because priority is placed on the core wire diameter required to maintain the current cutting efficiency and the optimal diameter of abrasive grains fixed around the core wire. Thus far, mirror processing of glass with a rough surface has been realized using a fixed abrasive tool having a double layer structure in which hard abrasive grains are mixed with water-soluble resin [1]. In this tool, abrasive grains with a nonuniform diameter are embedded into an abrasive layer of low hardness to realize an abrasive layer with a smooth surface, leading to a uniform salient of abrasive grains. In this study, the mirror processing of a cut surface of cylindrical glass was carried out using a tool with an abrasive layer of low hardness. The abrasive wire tool was obtained by coating an abrasive grain layer around a polyimide tube (PIT) into which a core wire was inserted, and then the obtained wire tool was sintered.

2. Fixed abrasive wire tool

2.1 Outline of tool

To realize mirror surface of the cutting surface, it is important to avoid brittle fracture during cutting. An abrasive layer with low hardness, as shown in Figure 1, is effective; however, the rapid wear is leading to breakage of the wire tool. Therefore, a core wire is inserted into a PIT (Fig. 2), on which a mixture of a polyimide solution of a similar type to that of the PIT and abrasive grains was coated (tool diameter ϕ0.4-0.5mm). In order to increase the strength of the abrasive layer, the water-soluble resin was changed to a liquid polyimide resin. The basic concept of processing using this tool is the same as that in Figure 1. The

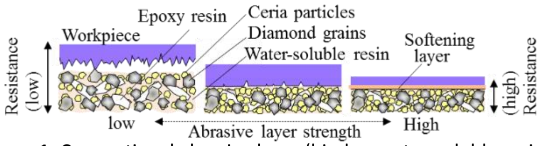


Figure 1. Conventional abrasive layer (binder: water-soluble resin)

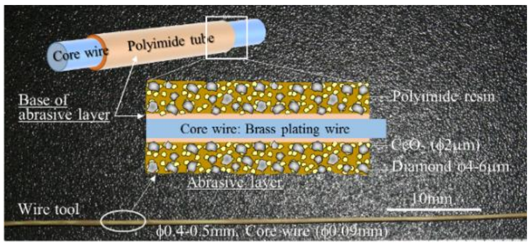


Figure 2. Proposed fixed abrasive wire tool (binder: polyimide resin)

variability in the diameter of diamond grains used as abrasive grains is large; however, the cutting resistance at the initial contact is small. Thus, the abrasive grains that markedly salient from the abrasive layer are gradually embedded into the abrasive layer without inducing a processing force. With increasing polishing resistance, the surface of the abrasive layer becomes smooth and the strength of the layer increases. At the same time, the amount of salient abrasive grains with nonuniform diameters is gradually equalized. As a result of the chemical effect of cerium oxide (ceria) particles used as a catalyst, frictional heat during cutting, and ion water during the semidry state, a softened layer is formed on the side surface of a groove of the workpiece.

2.2 Structure and fabrication of wire tool

The surface of a PIT (internal diameter, ϕ0.12mm) in which a core wire (ϕ0.09mm) was inserted was coated with a mixture of a polyimide solution and abrasive grains. A solvent was added

Table 1 Tool's specifications

	Core wire (mm)	Insert tube (internal)	Composition of abrasive layer		Baking
Tool	Brass plating (ϕ0.09mm)	Polyimide (ϕ0.12mm)	Polyimide resin + solvent	1:0.5, 1:1	Max 350℃
			Diamond (ϕ4-6μm)	0.5, 1, 1.5, 2g	
			CeO_2 (ϕ2μm)	2g	

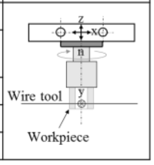
to the polyimide solution, and diamond and ceria particles were added as abrasive grains. The polyimide solution and abrasive grains were mixed to form an abrasive layer in accordance with the specifications shown in Table 1. The PIT used for the base material has two purposes. The first is to increase the adhesive strength of the abrasive layer. The second is to prevent breakage of the wire tool to suppress the embedding of the abrasive grains to the core wire.

3. Cutting of cylindrical glass

3.1 Amount of abrasive grains added and tool wear

Table 2 is a summary of the cutting conditions. The wear of the abrasive layer and the processed groove surface under these conditions with different amounts of abrasive grains are compared (Fig. 3). The tool tension was fixed at 10–11N and the cutting depth C_y was 100μm. The cylindrical glass used as the workpiece was rotated at a speed of 27000rpm and was moved reciprocally in the x direction for a distance from 0 to −40mm at a feed speed V_x of 20μm/s. Semidry misting was applied intermittently every 1mm for a distance x. The processed surface was ductile. The amount of wear depended on the amount of abrasive grains added. When the amount of abrasive grains was 2g, the amount of wear was small; however, the processed surface tended to be rough. This is because the hardness of the abrasive layer was high, leading to low dispersibility of the force. In contrast, when the amount of abrasive grains was 0.5g, the cutting depth was small because of the small number of effective abrasive grains. The optimal amount of abrasive grains added was determined to be 1g considering the quality of the processed surface and tool wear. But three types of tools, broke immediately after the wear reached the core wire. Therefore, the core wire was inserted into a PIT in the following experiment.

Table 2 Cutting conditions

Tool tension	10-11N	Cutting mode
Wire tool cutting depth C_y	100μm	
Workpiece and revolution	Borosilicate glass 27000rpm	
Moving distance of workpiece	0 ⟷ 40mm	
Feed rate (V_x) of Workpiece	20μm/s	
Mist: semidry (ion-water + aqueous cleaner)		

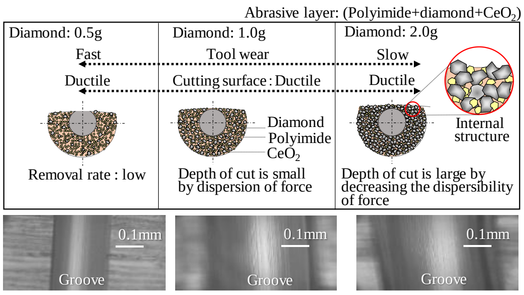


Figure 3. Cut surface of cylindrical glass (without Polyimide tube)

3.2 Causes of wear of abrasive layer

The wear of the abrasive layer is caused by the frictional heat due to intermittent misting during cutting. Because of this frictional heat, the diamond of the abrasive layer abrasion rapidly and diamond grains are easily removed from the layer. When this occurs, the surface of the abrasive layer is scraped, leading to rapid tool wear. However, the frictional heat is necessary to form a softened layer on the processed surface and to induce a chemical reaction with the help of the catalytic effect of ceria particles and ion water. At first, continuous misting of a small amount (20mL/min) of cutting liquid was applied during cutting (upper figures in Fig. 4). The structure of the fixed abrasive wire tool shown in Figure 2 was adopted, and a mixture of a polyimide solution and 1g of diamond particles was coated as the abrasive layer. Cutting that could not be realized with intermittent misting was realized with continuous misting. However, the obtained processed surface was brittle. In the case of continuous misting, frictional heat is lost and the amount of wear decreases, leading to less wear of the abrasive layer than in the case of intermittent misting. Owing to the loss of frictional heat, the softened layer decreases in thickness or disappears, which causes a brittle surface. To achieve both a mirror surface and cutting, a continuous air flow and intermittent misting, instead of continuous misting, were adopted (lower figures in Fig. 4). As a result, ductile grooves and cut surfaces were obtained. It was found that a continuous air flow and intermittent misting yield the heat and cutting liquid required to induce the chemical reaction and realize mirror cutting. The continuous air flow is considered to suppress thermal radiation. In addition, the effectiveness of the tool formed by inserting a core wire into a PIT was confirmed because this wire tool was not broken during cutting.

On the other hand, the cutting surface with the addition of Ceria abrasive grains was a ductile surface (Fig.5). But the surface texture is challenge from this. The tool diameter of ϕ0.25-0.3mm was used for processing.

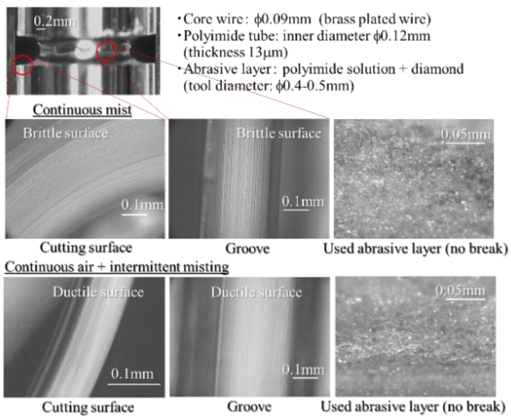


Figure 4. Comparison of cut surfaces by difference of mist supply

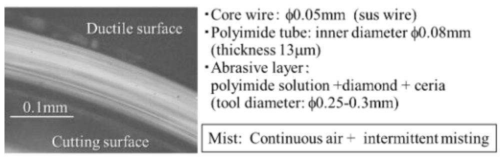


Figure 5. Cut surface by thin wire tool

4. Conclusions

We demonstrated that (1) ductile cutting of glass is possible using the developed tool, (2) the combined use of a continuous air flow and intermittent misting is effective during cutting, and (3) the tool obtained by inserting a core wire into a PIT is robust against breakage and the diameter of the tool can be reduced.

Reference

[1] Y. Kamimura, K. Tsuchiya: *Mirror-polishing of rough surface glass by soothing of abrasive layer,* eu**spen**'s 16th International Conference & Exhibition, Nottingham, UK, 2016, pp. 403-404.