Micromachining of glass with ultrasonic-vibration table

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Abstract

A soda-lime glass is machined with using an ultrasonic-vibration table and the loading of the chips to the grinding tool and machined surface quality are compared with conventional micromachining. It was found that by applying the ultrasonic vibration to the work piece, the loading and the dropout of the abrasive grain of the grinding tool is controlled and the crack size at hole edge decrease at a rate of about 10~40% .

1 Introduction

Glass is a hard and brittle material, therefore the accuracy and efficiency of the micromachining are rather low. By applying the ultrasonic vibration to the tool or the work piece, it is known that hard and brittle materials such as the glass can be machined effectively using a small grinding tool or an endmill [1][2]. Now in the industry, piled up glass sheets are simultaneously machined to enhance the productivity of small hole making process for the smartphone and tablet PC. But the glass is easy to induce clacks, in addition, chip evacuation and the coolant supply to the machining point is difficult. Then the tool life is also becomes short. Ultrasonic vibration grindings are one of the potential to solve the above mentioned problems. In this study, small holes making process with helical tool path supported with ultrasonic vibration are reported. Usually the vibration is excited on the tool and tool holder [1] [2]. Although in this case, tool geometries such as length or diameter are largely restricted to realize the resonation to enhance the vibration amplitude. On the other hand, if the thin glass workpiece is excited with the special exciting table, there are no restrictions on the tool geometry. Then the various kinds of tools can be employed to the glass machining.

However, there are few researches which report on high-aspect ratio small holes micromachining with the work piece excitation. So in this study, a soda-lime glass is machined with using an ultrasonic-vibration table and the loading of the grinding tool and machined surface quality are compared with the conventional micromachining.

2 Experiment

Figure 1 shows the experimental setup and machining strategy. Ultrasonic-vibration excitation table which can apply 20 kHz frequency and 4 µm amplitude in perpendicular to the table surface was set on the NC milling machine. A base glass sheet is attached on the ultrasonic-vibration table by vacuum chuck. Then three sheets of soda-lime glass specimen are fixed on the base glass sheet by using the thermal melting plastic. Size of the glass specimen is 150x150x1.75 mm. Diamond electrodeposited tool with #270 and #600 grain sizes are used for rough and finish machining respectively, and effective machining length of the tool was 8 mm.

Helical tool path was employed for machining the micro hole and the effect of ultrasonic vibration given on the workpiece material was evaluated. Helical pitch was 0.006 mm and the radius of circular movement was set 3% of tool diameter. Tool rotation and helical circular movement are set to same direction. Other machining conditions are shown in Table 1.

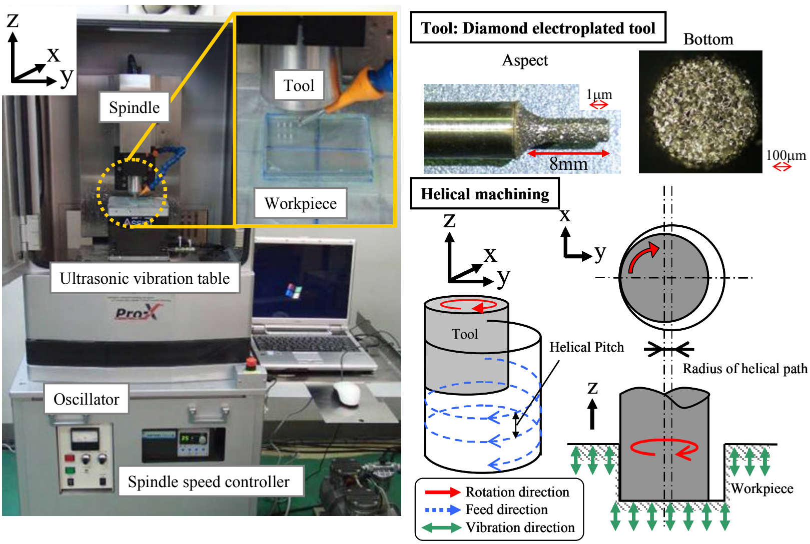


Figure 1: Experimantal set up of machining strategy usin helical tool path

Table 1 Machining conditions

Vibration		(a) On (b) Off
Ampulitude	µm	4
Frequency	kHz	20
Workpiece		Soda-lime grass
Tool		Diamond electroplated tool
Grain size		#270 | #600
Diameter of tool	mm	0.6 , 0.9

Depth of hole	mm	6
Diameter of hole	mm	0.64 , 0.96
Aspect ratio		9.4 , 6.4
Spindle speed	min^{-1}	50000 , 35000
Feed rate	mm/min	7 , 20 | 2 , 5
Radius of helical path	mm	0.02 , 0.03
Helical pitch	mm	0.006
Coolant		Water

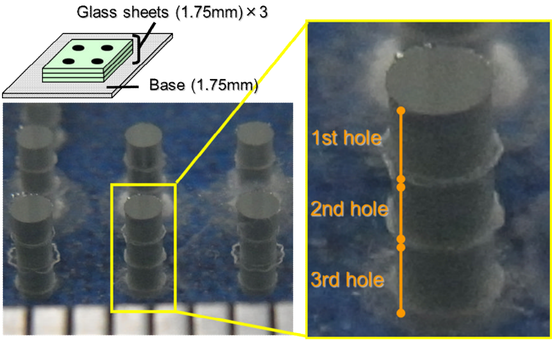
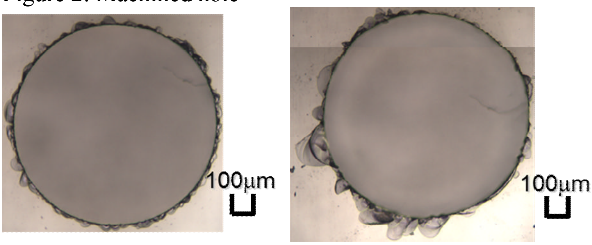


Figure 2: Machined hole



(a) With vibration (b) Without vibration

Figure 3: effect of ultrasonic vibration on edge cracks

Figure 2 shows the machined holes. Three sheets of glass plate were successfully machined. Quality of the side wall of the machined hole is good but there can be some small cracks at the hole entry and exit. Size of cracks at hole entry/exit is smaller when the ultrasonic vibration is applied as shown in Fig.3.

Figure 4 shows the average crack size at hole edges when machined hole diameter was 0.64 mm. Effect of vibration becomes large when grain size is larger.

As the number of machined hole increases tool condition changes. During the machining of the glass the small chips tend to accumulate between the grains as

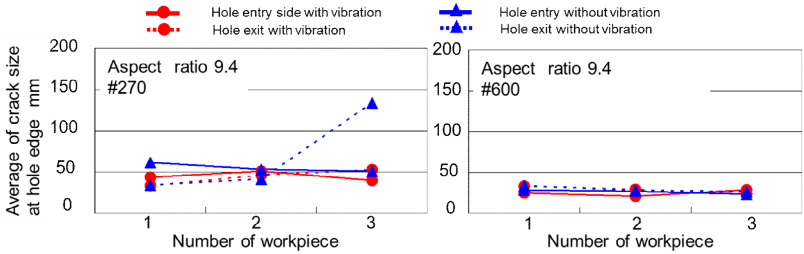


Figure 4: Effect of vibration on crack at hole entry/exit

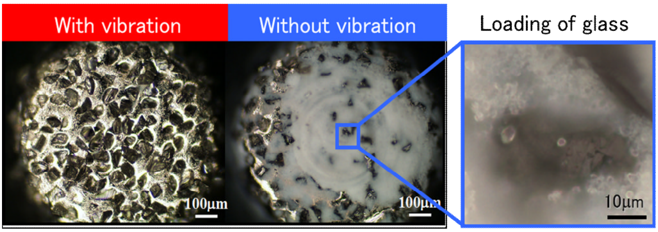


Figure 5: Effect of ultrasoic vibration on tool conditions

shown in Fig.5. But by applying the vibration these loadings can be avoided and the machining quality can be kept longer.

Summary:

Micro holes with 0.64 mm or 0.96 mm in diameter and 6.0 mm in depth are successfully machined on three sheets of piled up soda-lime grass using ultrasonic-vibration table. Edge crack was under 50µm and the higher aspect ratio is 9.4. By the assistance of the ultrasonic vibration, the loading of the chip to the grinding tool is avoided and the chip evacuation seems good comparing with the case without ultrasonic vibration. Then the dropout of the abrasive grain of the grinding tool is also controlled and the crack size at hole edge decreases at a rate of about 10~40 % comparing with the conventional ones.

References:

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