EXPERIMENTAL INVESTIGATION OF HYBRID ROTARY ULTRASONIC ASSISTED MICRO DRILLING ON CHEMICALLY STRENGTHENED GLASS

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ABSTRACT – The usage of Chemically Strengthened Glass (CSG) has steadily increased mainly for electronic devices. Due to its superior strength and crack resistance, conventional drilling process for this material is almost impossible. Considering these facts, in this paper experimental investigation of hybrid rotary ultrasonic assisted micro drilling (RUAD) on CSG were investigated. The experimental investigation covered on various aspects on drilling CSG includes ultrasonic drilling parameters, clamping jig design, cutting condition and drilling strategy.

1. INTRODUCTION

Due to its superior properties i.e. high durability and high strength, the application of Chemically Strengthened Glass (CSG) has steadily increased. Compared to the thermal tempering glass, CSG is approximately five times stronger and scratches resistance which make it as preferred material for electronic panel display devices application such as mobile phone and tablet PCs screen, camera lens, optical component, etc. [1].

However, due to the inherent properties of CSG in which stronger under compressive stress and weak under tension make it as a challenge for conventional drilling. Conventional drilling process tends to generate high tensile stress due to the thrust forces that results in poor holes quality and cracks propagation.

Chemically strengthened glass plate type Corning® Gorilla® Glass 3 with Native Damage Resistance™ with the geometry of 50×50×1 mm was used as the workpiece. The glass has a density of 2.39 g/cm3, Young Modulus of 69.3 GPa, Poisson's Ratio of 0.22 and Shear Modulus of 28.5 GPa. Table 1 depicted comparison between CSG and SLG properties. Gorilla® Glass 3 with Native Damage Resistance is 2 times harder than Gorilla® Glass 2 and 5 times of Soda lime glass.

	CSG	SLG
Density [g/cm^3]	2.39	2.5
Young's Modulus [GPa]	69.3	73
Poisson's Ratio	0.22	0.21
Shear Modulus [GPa]	28.5	30
Vickers Hardness (200 g load) [kgf/mm^2]		
Unstrengthened	534	533
Strengthened	649	580
Fracture Toughness [MPam$^{0.5}$]	0.66	-
Critical Load [N]	150	10
Load to Failure (ring on ring) [N]	1225	216
Coefficient of Expansion (0 – 300 °C) [/°C]	75.8×10^{-7}	85×10^{-7}

Table 1: Comparison between CSG and SLG

2. EXPERIMENT SET UP

A three axis vertical machining center (VF1, HAAS milling machine Co., Ltd) and five axis vertical machining center (DMU60 monoblock, Deckel Maho Gmbh) with a maximum rotation speed of 7500 rpm and 24000 respectively. An ultrasonic BT40 tool holder was employed to the HAAS milling machine spindle with frequency ranging from 20,000 Hz to 27,000 Hz that generate an amplitude vibration up to 3 μm. Figure 1 shows the rotary ultrasonic assisted machining device and experimental setup used in the experiment.

A 0.5 mm diameter electroplated diamond tool with diamond abrasive grains (#600 size 25 – 35

μm) was used in performing the ultrasonic drilling process.

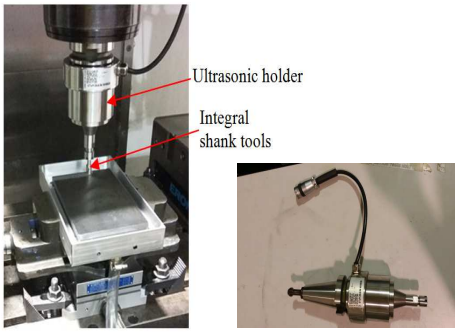


Figure 1: Rotary ultrasonic drilling setup and tool holder

The tool is constructed by a 3 mm diameter carbon steel (JIS SK5) shaft with two straight plane design for chips discharge purposes as depicted in Figure 2 [2].

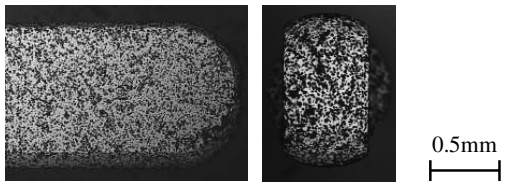
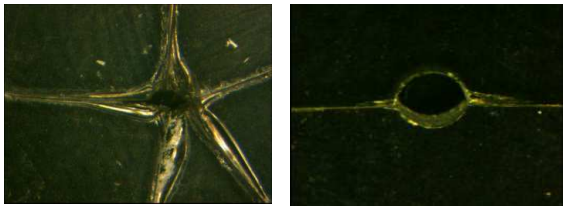


Figure 2: SEM images of the tool tip [2].

Since the CSG are stronger under compressive stress and weak under tension three jig designs to clamp the CSG were proposed namely Type 1 (Drain type with slot), Type 2 (Array type) and Type 3 (O-ring). Each types of clamping jig are design to take into consideration on both compressive stress at the entry of hole surface and tensile stress at the exit of hole surface generate from the thrust force. In addition, in this experimental work alumina oxide powder will be used with concentration between 5-15 %.

3. RESULT AND DISCUSSION

Severe glass cracked at the beginning of the peneteration as shown in Figure 3 (a). The air pressure resulting in unefficient chip evacuation and increased the compressive stress at the entry of hole surface and tensile stress at the exit of hole surface. Slow cutting force and high feed rate affected on high thrust force (a) [3-4], meanwhile slow ultrasonic frequency and low amplitude will helped with the process as shown in (b). Difference cracked pattern also identified in this study i.e webbing, scatter double line or single hair line, which is the higher impact of thrust force generated on glass surface will created more cracked line.



(a) (b)

Figure 3: Cracked pattern under lower (a) and higher (b) thrust force

4. CONCLUSION

This paper has comprehensively investigated the micro-hole drilling process of chemically strengthened glass plate using electroplated diamond tool. The added feature of Native Damage Resistance™ on chemically strengthened glass plate Corning® Gorilla® Glass 3 enhances the glass retained strength and creating high resistance to scratch and sharp contact damage. This research will be further study.

5. REFERENCES

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