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Study of cutting chemically strengthened glass plates by a disk and penetration scoring wheel

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Abstract

Disk and penetration diamond scoring wheels are commonly used to cut chemically strengthened glass, but they typically leave cracks or flaws along the cutting edges. Cutting sheets of chemically strengthened glass that are a thinner and have a higher inner tensile stress presents an even greater challenge. Selecting a suitable cutting wheel and appropriate cutting parameters is critical for minimising cracks along the cutting edges.

This study selected ion exchanged Corning Gorilla 2320 (compressive layer: 36 µm, compressive stress: 650 MPa) and AGC Dragon Trail (compressive layer: 26 µm, compressive stress: 670 MPa) glass plates with a thickness of 0.7 mm were selected as the substrate materials. The glass plates were scribed using disk and penetration diamond scoring wheel. Because it produced more residual stress in glass, the disk scoring wheel cause heavier surface cracks or chipping in the scoring test than did by the penetration scoring wheel. The penetration scoring wheels provide relatively wider cutting conditions for cutting AGC Dragon Trail glass plates. However, the acceptable conditions for cutting Corning Gorilla 2320 glass plates remain very narrow. The effects of the thickness of the compressive layer of glass plates on the qualities of the cut glass plates were investigated.

Key words: penetration scoring wheels, ion exchanged glass, cracks, compressive stress

1. Introduction

Strengthening of glass sheets through an ion exchange process has been prevalent in the manufacture of thin glass covers for smart phones and flexible displays [1,2]. The compressive stress improves the ability of the glass surface to withstand the shock of mechanical impact [3-5]. However, the presence of the damage resistant layer makes conventional mechanical cutting of the ion-exchanged glass difficult [6]. In this context, the cutting process typically causes spontaneous glass sheet breakage or shattering. Laser cutting has been proposed by many researchers for cutting chemically strengthened glass (e.g., full sheets of ion-exchanged glass) with a very deep compressive stress layer [7,8]. However, laser cut increases the production cost substantially and sometimes results in a low yield. Another approach used a penetration cutting wheel with regular teeth or notches around the cutting edge to scribe or cut chemically strengthened glass sheets [9]. The selection of penetration cutting wheels and optimisation of cutting conditions are crucial for completing sheet glass cutting with a high quality. However, related studies are scant. This study examined using a disk and penetration cutting wheel for cutting chemically strengthened glass. The effects of the cutting conditions on the length of the cracks and the mechanical strength of the glass sheets are discussed.

2. Experiment

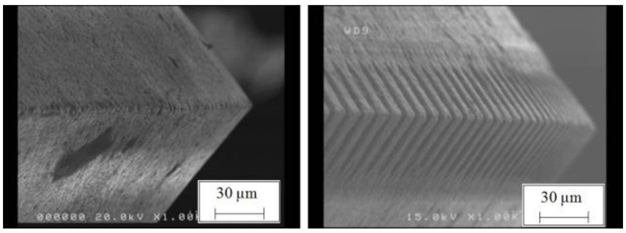
2.1. Glass materials and scoring wheels

Ion exchanged Corning Gorilla 2320 (compressive layer: 36 µm, compressive stress: 650 MPa) and AGC Dragon Trail (compressive layer: 26 µm, compressive stress: 670 MPa) glass plates with a thickness of 0.7 mm were selected as the substrate materials. The glass plates were cut into a standard size of 82 x 52 mm.

The dimensions and appearance of a disk and penetration diamond scoring wheel are shown in Table 1 and Fig. 1.

Table 1. Dimension of the scoring wheels.

Dimension of scoring wheels	Outer diameter	Inner diameter	Thick-ness	Angle	Teeth no.
Disc wheel (AA100H)	2 mm	0.65 mm	0.8 mm	105°	none
Penetrat-ion wheel (450105)	2 mm	0.65 mm	0.8 mm	100°	450



(a) (b)

Figure 1. Surface morphologies of the (a) disk (AA100H) and (b) penetration (450105) scoring wheels.

2.2. Glass scoring process

Vacuum suction equipment was used to fix glass substrate, and a single upper scoring wheel was used to scribe several straight lines onto them. The scoring parameters were set at a scribe load of 0.7-1.3 kg, depths of 0.1 mm, and a scribe speed of 100 mm/s. The glass samples were separated perpendicular to the score line to perform a cross-sectional analysis beneath the score line.

2.2. Analysis

The microstructure of the scored surface and the cross-sectional glass samples, were examined using an optical microscope and a high resolution scanning electron microscopy.

3. Results and discussion

Fig. 2 shows cross-sectional images of the corning Gorilla 2320 glass plates after the scoring test, which was performed using a disc and penetration scoring wheel at a scoring speed of 100 mm/s. The scoring test performed using a penetration scoring wheel produced a median crack length of 75 μm at an applied load of 0.7 kg. Shorter medium cracks were obtained using a disk scoring wheel under the same scoring conditions. A penetration scoring wheel with regular teeth or notches around the cutting edge which can reduce the contact area between the scribing wheels and the glass, strengthens the pressure to the glass, and increases the likelihood of propagating medium cracks. Notably, the medium cracks tended to close after a disk diamond wheel was used for the scoring test. This indicated that propagating medium cracks is more difficult or that a greater bending force is required to separate the glass plate.

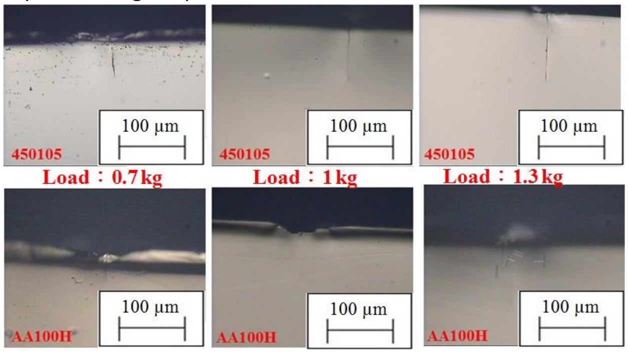


Figure 2. Cross-sectional images of Corning Gorilla 2320 glass plates after scoring tests performed using the disc scoring wheel (450105) and the penetration scoring wheel (AA100H) at a scorning speed of 100 mm/s.

Fig. 3 presents a plot of the median crack depths as a function of the scribe load and speeds created by the wheels. The median crack depths increased as the scribe loads increased because larger stress fields were generated by the higher loads.

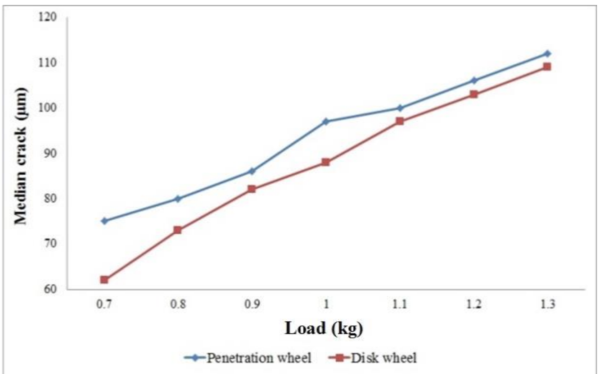


Figure 3. Plot of the median crack depth as a function of the scribe load created by the wheels.

Fig. 4 shows an optical microscope image of the top view of a scored glass sheet (Corning Gorilla 2030). The chipping width slightly increased as the applied load increased because the propagation of radial cracks or lateral cracks was suppressed by the surface compressive stress. Because it produced more residual stress in the glass, the disk scoring wheel produced heavier surface cracks or chipping than that of produced by penetration scoring wheel. Settings with an inappropriate scribing load of higher than 1.3 kg result in spontaneous glass sheet breakage or shattering.

A higher scribe speed causes low contact pressure or a low tensile stress field, which is beneficial for suppressing radial cracks but shortens the medium crack length.

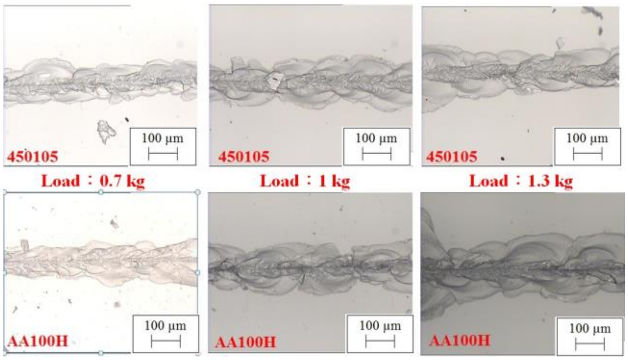


Figure 4. optical microscope image of the top view of a scored glass sheet (Corning Gorilla 2030).

After being scored under the same conditions by using the disk scoring wheel, the AGC Dragon Trail glass plates with a compressive layer of 26 μm, exhibited deeper medium cracks and heavier chipping. A smaller compressive layer facilitates crack initiation and propagation at a lower applied load. In addition, deformation and crack behaviour depend on the composition and structure of a glass plate. The deformation in the Corning Gorilla 2320 glass sheets was dominated by a densification mechanism and produced less sub-surface damage and less residual stress; therefore, the threshold load necessary to initiate cracking increased. The Corning Gorilla 2320 glass sheets required a high scribe load (1.3 kg) and low speed (50 mm/s) to initiate a deep medium crack and separate the glass sheet from the subsequent bending force. Acceptable chipping appeared along the cutting edges.

5. Conclusion

Because increased contact pressure produced less residual stress in the glass, the penetration scoring wheel produced deeper medium cracks and less severe chipping in the scoring test than did the disk scoring wheel. However, the acceptable parameters for cutting Corning Gorilla 2320 glass sheets remained very narrow.

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