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Application News

HPV™-X2 High-Speed Video Camera/HITS™-PX High-Speed Impact Testing Machine

Fracture Observation in Puncture Impact Testing on Glass

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User Benefits

- The system is capable of capturing images at up to 10 million frames per second, enabling detailed fracture observation on glass.
- The system is capable of testing at up to 20 m/s, sufficient to perform puncture impact testing on glass.
- The system helps to elucidate the mechanism of test results (of fracture).

■ Introduction

Glass has traditionally been used in a variety of industrial fields, including windows, lenses, and tableware. Among such glasses, chemically tempered glass produced with the ion-exchange method is used for the cover glass of smartphones. Since the surface of tempered glass is strengthened by compressive stress, the force leading to fracture may be greater than that of untempered glass. Even so, there is a possibility that the fracture of the entire glass may occur instantly, starting from a small scratch caused by an external impact. For this reason, research has been conducted to realize even greater strength and impact resistance.(1)

In this article, we introduce the results of fracture observation in a high speed puncture testing conducted on two types of tempered glass and untempered glass. The test results clarified that the maximum test force at the time of fracture increased if the glass was toughened, and that the maximum test force correlated with the number of cracks and the crack growth rate.

■ Measurement System

Using the HPV-X2 high-speed video camera and HITS-PX high-speed impact testing machine, we observed the fracture behavior of two types of tempered glass and untempered glass in puncture impact testing. Table 1 shows the test instruments. Figs. 1 and 2 show the photos and schematic diagram of the instruments, respectively. By setting up a mirror as shown in Fig. 2, we could observe the glass being punctured by the striker directly from below.

Table 1 Test Instruments

High-speed video camera	:	HPV-X2
Lens	:	105 mm macro lens
Illumination	:	Strobe
High-speed impact testing machine	:	HITS-PX
Striker	:	Φ20, 10 kN
Holding plate	:	Φ40

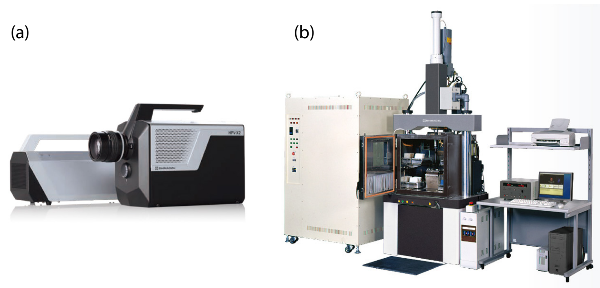

Fig. 1 Photos of Test Instruments
(a) HPV™-X2 high-speed video camera
(b) HITS™-PX high-speed impact testing machine

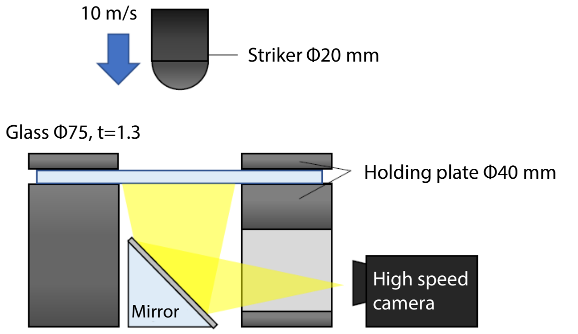

Fig. 2 Schematic Diagram of Test Unit

■ Measurement Conditions and Specimens

In this study, the glass was punctured at a test speed of 10 m/s using a 20 mm diameter striker. The recording speed of the high-speed video camera was set to 2 million frames per second. Table 2 summarizes the measurement conditions. Tempered and untempered glass specimens were prepared using commercial soda-lime sheet glass with a thickness of 1.3 mm. Two types of tempering methods were employed: electric field assistance and immersion.

Table 2 Testing Conditions

Test speed	: 10 m/s
Recording speed	: 2 million frames/s
Specimen	: Field assistance method, Immersion method, Untempered

■ Measurement Results

Table 3 shows the maximum test force and failure stress*2 of each specimen in the puncture impact test. Fig. 3 shows the test force-displacement diagram. From these results, it was found that the maximum test force of the field-assisted tempered glass was the highest.

Table 3 Testing Results

	Maximum test force [kN]	Failure stress [GPa]
Field assistance method	1.54	1.33
Immersion method	1.38	1.14
Untempered	1.09	0.90

*2 Stresses were calculated using the finite element method.

As an example of fracture observation in puncture impact testing, Fig. 4 shows how the fracture propagated on the field-assisted tempered glass. Image (1) in Fig. 4 shows the moment when the striker made contact with the glass. Then, from images (2) to (6), the cracks were observed to grow radially. The upper left corner of image (7) then shows that a crack propagated in a different direction from that of the cracks in images (2) to (6), and in images (8) to (12), multiple cracks propagated in concentric circles, showing that the field-assisted tempered glass was more finely fractured.

Fig. 5 shows, as an example, the relationship between crack length and time for the field-assisted tempered glass. Table 4 summarizes the crack growth rates calculated from the relationship between the crack length and time for each specimen. Although the obtained crack growth rates were almost similar, the tempered glass was found to exhibit a slightly higher value.

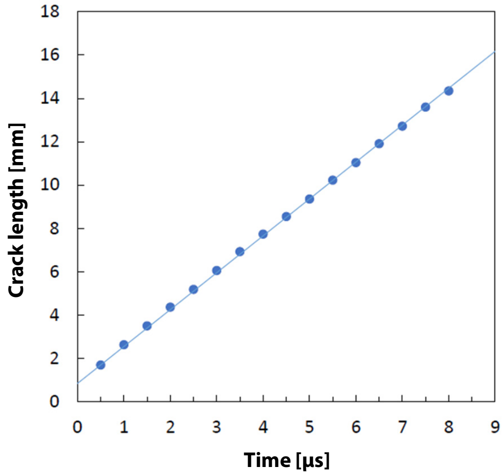

Fig. 5 Crack Length and Time in Field-Assisted Tempered Glass

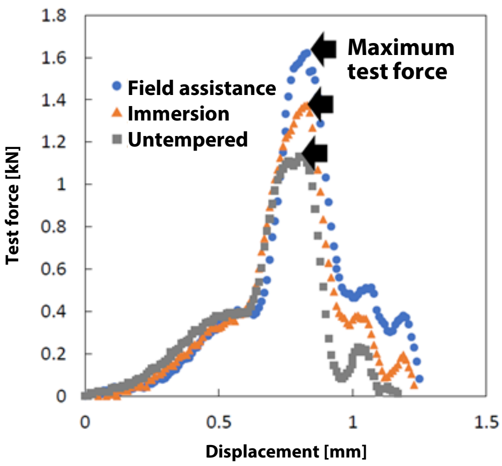

Fig. 3 Test Force-Displacement Diagram

Table 4 Crack Growth Rate for Each Specimen

	Crack growth rate [km/s]
Field assistance method	1.70
Immersion method	1.69
Untempered	1.67

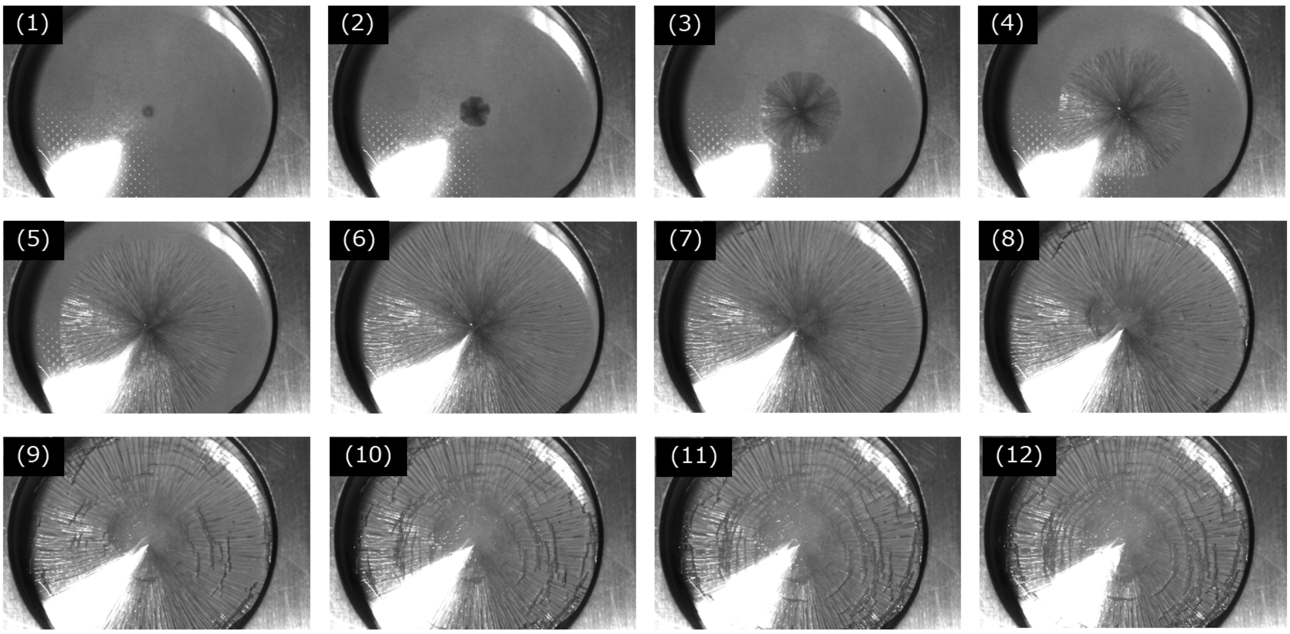

Fig. 4 Fracture of Field-Assisted Tempered Glass (time interval between images: 500 ns)

Fig. 6 shows the fracture of each type of glass. Fig. 7 shows the results of counting the number of cracks propagating radially from these images. From Fig. 7, it became clear that the higher the failure stress, the higher the number of cracks in the glass.

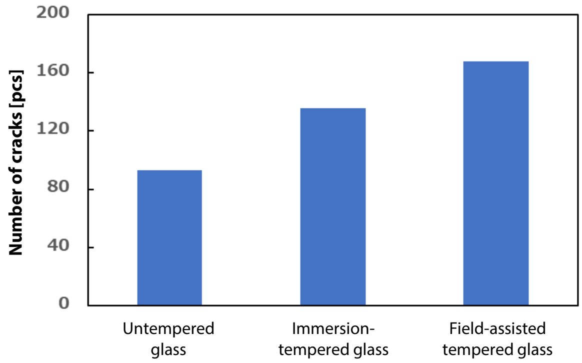

Fig. 7 Number of Cracks in Each Glass

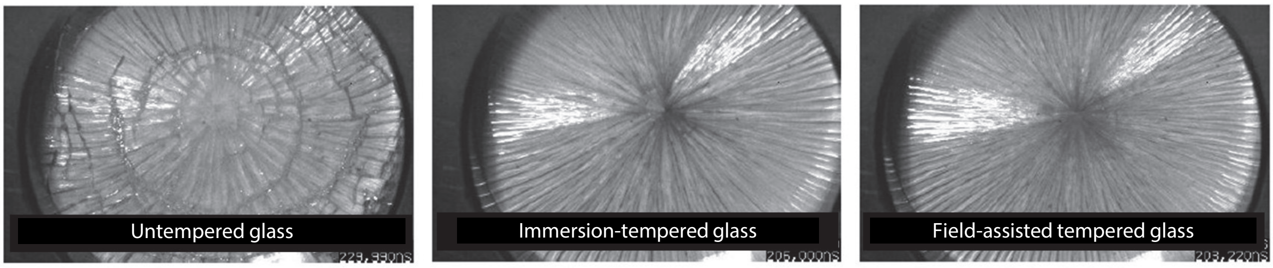

Fig. 6 Fracture of Each Glass

■ Conclusion

Using the HITS-PX high-speed impact testing machine, we conducted puncture tests on two types of tempered glass with different toughening methods and untempered glass. As a result, it was found that the failure stress of the glass was higher according to the tempering method. We also conducted fracture observation in a high-speed puncture impact testing, using the HPV-X2 high-speed video camera. The results of fracture observation clarified that tempering of the glass increased the crack growth rate, as well as the number of cracks.

We could thus confirm that the use of the HITS-PX and HPV-X2 was effective for evaluating tempered glass.

<Reference>
(1) S. Nagai, T. Kishi, N. Matsushita, T. Yano, Preprints for the Ceramic Society of Japan Annual Meeting (2018)

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