CORNING
Gorilla® Glass

Controlled Edge Damage by Dynamic Impact

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Abstract

Mechanical contact with glass substrates can induce visible and strength limiting damage. Glass edges are especially susceptible to such damage. Dynamic impact with a glass edge will likely produce classic sharp crack signatures.

Introduction

With glass being progressively added to today's mobile products, including phones and laptops, there has been an increasing effort to understand how glass substrates, and their edges in particular, are affected by dynamic mechanical contact resulting from drops and everyday use. Because glass is only as strong as its largest flaw, it is important to understand how edge strength is preserved after dynamic mechanical contact. Moreover, there is a need to understand if, and how, chemical strengthening techniques help minimize or reduce the effect of the induced damage. In order to effectively study this behavior, an experimental setup was devised to impart damage to an edge of a glass specimen in a controlled dynamic manner.

Drop tests, where a glass edge impacts a damaging surface by a free fall event, is sometimes used to introduce glass damage and fracture. However, this method lacks control of the impacting force and location. The impact method used in this study drives the edge of a glass specimen into an object in such a way that the impact force is controlled and the specimen is allowed to freely rebound after impact. Also, it is the aim of the study to produce "sharp" contact damage, the kind of damage where sharp, strength-controlling flaws are produced. Once produced, the specimen can then be strength tested in conventional four-point bending to assess the severity of the damage.

Experimental Method

A schematic of the impact test device is shown in **Figure 1**. A frictionless air slide is mounted to the platform of a linear drive belt slide. A glass plate with, say, finished edges, is mounted to the carriage of the air slide and can be tilted such that the impact location about the edge can be predetermined. When the belt slide achieves the desired velocity it is stopped and the carriage of the air slide is free to continue forward at that velocity until the specimen edge strikes at tungsten carbide tool insert. The WC tool insert, shown in **Figure 2**, has a 400 micron tip radius and was chosen for its hardness and resistance to being damaged. Most importantly, impact with the WC tool insert produces sharp strength-limiting flaws in glass as shown in **Figure 3**. The tool insert is coupled to a piezoelectric load cell for recording the impact force. Laser photogates are positioned orthogonal to the point of impact and, when triggered, give instantaneous impact velocity.

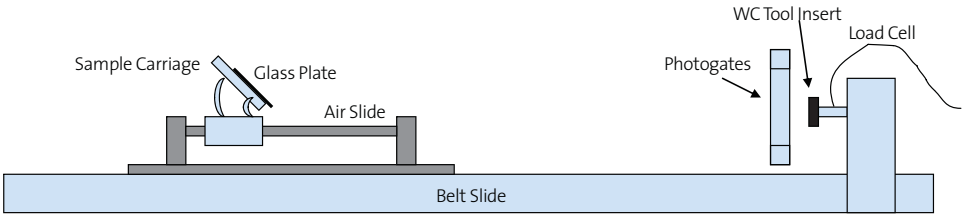

Figure 1. Impact test device

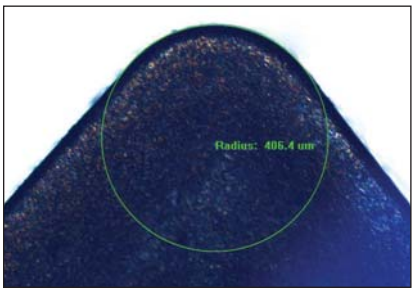

Figure 2. Tungsten carbide tool insert

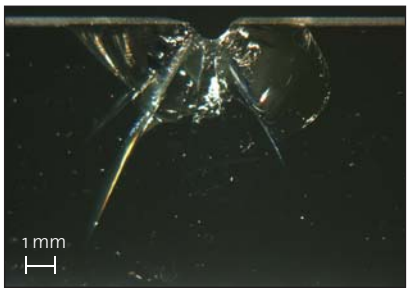

Figure 3. Crack system in NIX glass

The glass specimens used in this study consist of Corning's 2317 alkali-aluminosilicate glass, a glass designed especially for deep chemical strengthening [1], and a conventional chemically strengthened soda-lime-silicate glass (SLS). Corning's 2317 glass was ion exchanged to a depth of 44 µm and a compressive stress of 750 MPa. The SLS glass is limited to a 500 MPa surface compressive stress at layer depth of 15 µm. Specimen dimensions were 60mm x 44mm with a thickness of 0.7mm. The edges were finished to a double 45° chamfer by a grind and 600 grit polish method. The specimens were tilted during impact such that the resulting damage was located at the corner between the finished edge and the glass surface, see **Figure 4**. This allowed the damage site to experience the maximum bend-induced tensile stress of the four-point bend test.

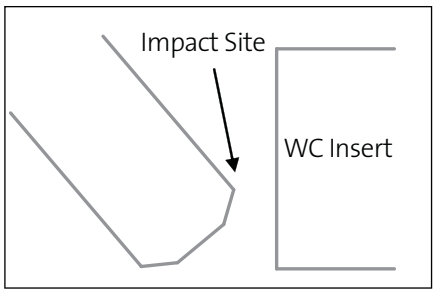

Figure 4. Edge profile and impact site

The impact force for the chemically strengthened 2317 is shown in **Figure 5** to increase in a well controlled fashion with increasing impact velocity. This meets one of the key objectives of this test development.

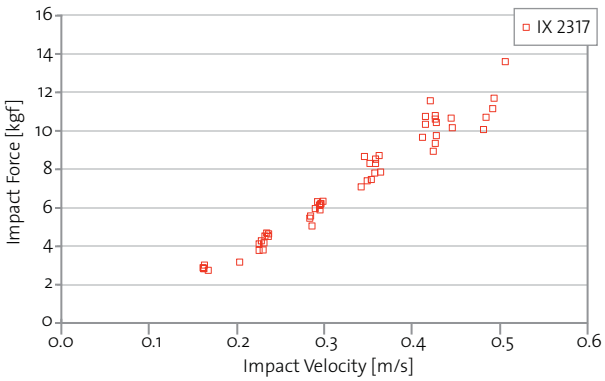

Figure 5. Impact force as a function of impact velocity for IX 2317

Results and Discussion

Figure 6 shows measured 4 point bend strength after impact as a function of impact force for three conditions: non-chemically strengthened 2317 (NIX 2317), chemically strengthened 2317 (IX 2317) and chemically strengthened soda-lime silicate glass (IX SLS). The pre-impact strength for each test condition is also shown. The results for the chemically strengthened 2317 can be separated into three regions. Region One is where the impact force is insufficient to cause any weakening of the strengthened glass. This means that despite contact with the glass being made, no strength controlling flaws were created. In Region Two, strength controlling flaws, like those in **Figure 3**, are created on a minority of the specimens and when they are created the strength drops considerably, but not to the pre-strengthening level. In the third region the impact force is sufficient to produce mostly strength limiting flaws. Soda-lime silicate glass does not have the degree of strengthening and gives up its strength at modest impact forces compared to the chemically strengthened 2317. In fact, once the strength begins to degrade, it behaves similarly to that of non-strengthened glass. This is simply due to the fact that it is easy to penetrate through the ion exchange layer into non-strengthened glass.

The pattern exhibited by the strengthened 2317 is in keeping with what is known about sharp crack formation in glass using more common quasi-static damage introduction methods on glass surfaces like indentation or particle abrasion. Glass can show a threshold for sharp crack formation. Below the threshold, no sharp cracks form and there is little impact on strength. With increased effort some damage sites transition to post threshold crack formation and weaken, others do not and remain strong as shown in Region Two. With enough impact one can consistently generate strength limiting flaws. The important observation is that chemical strengthening has a significant effect on this process. The surface compression layer acts in such a way as to increase the threshold for sharp crack formation. Secondly, and quite intuitively, the compression layer helps to keep flaws strong once they are made. This is observed quite clearly in Region Two of **Figure 6** where the strength of the chemically strengthened 2317 is degraded, but not down to the baseline level of the strengthened soda-lime silicate glass.

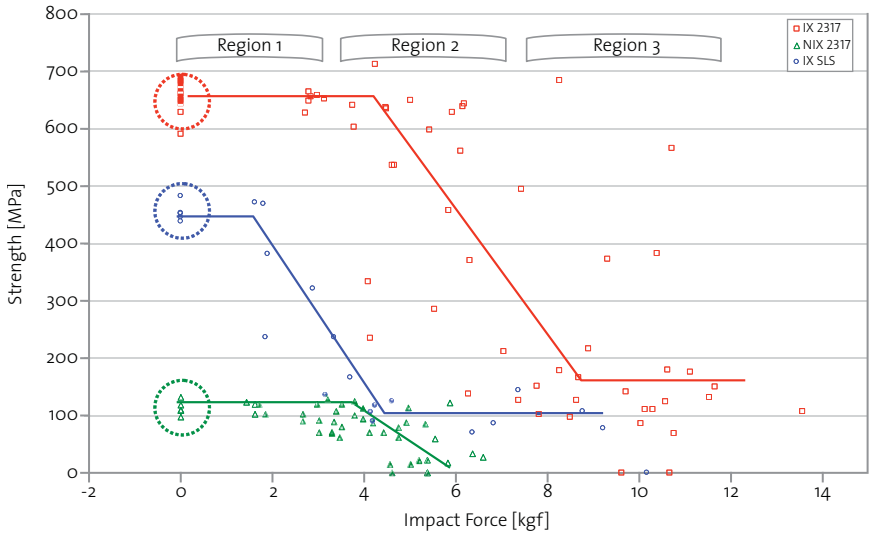

Figure 6. Retained strength as a function of impact force

Conclusion

A novel method for dynamic flaw introduction in finished glass edges shows all the characteristics of well-established quasi-static test methods. Chemical strengthening has the intended effect of inhibiting flaw formation and propagation and this effect is strongly dependent on the degree of ion exchange. These results provide a needed technical bridge between easier quasi-static tests on glass surfaces and more life-simulating drop tests. Quasi-static tests on glass surfaces may well be an appropriate surrogate for damage introduced during drop tests of glass-faced devices.

Acknowledgements

The authors are grateful for the help and guidance of Dr. Jim Price and Tim Roe of Corning, Incorporated.

[1] Martin E. Nordberg et. al., "Strengthening by Ion Exchange," JACerS Vol. 47 Issue 5, 215-219 (1963)

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