Influence of plate dimensions and test configuration on the fracture behavior of glass

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Introduction

Glass is a major component in the military’s transparent armor systems. There are indications that stronger glass performs better under dynamic loading conditions which has raised an interest in different techniques that can be used to strengthen glass. At the Army Research Laboratory glass strength is usually determined using the ring-on-ring (ROR) configuration of the equibiaxial flexure strength test. In this test the “generated stresses are lowest at the specimen edges” (ASTM C1499, 2013) which reduces the potential for edge fractures because the radial and tangential stresses at the edge of a glass plate are a function of the combined effects of the plate size and ROR configuration. This is beneficial because the data collected from these edge fractures are considered invalid. Unfortunately, the higher frequency of edge fractures that accompanies higher strength glass limits the validity of strength data. It is believed that there is an optimum combination of glass plate size and equibiaxial test fixture configuration that will significantly reduce the number of edge fractures and increase the validity of the strength data. This study attempts to find this optimal combination of plate size and test fixture configuration.

Methods (cont’d)

Baseline strength testing was conducted at room temperature on the air and tin side of borosilicate and soda lime-silicate (Starphire®) glass sets with the following dimensions: 100 x 100 x 6 mm, 125 x 125 x 6 mm, and 150 x 150 x 6 mm. Sets were subjected to two ring-on-ring (ROR) configurations of the equibiaxial flexure test on a Zwick™ testing frame (Figure 1). The first configuration consisted of a ring ratio of 0.2 using a load and support ring of sizes 18 mm and 90 mm respectively. The second configuration required an 42.5 mm load ring and a 85 mm support ring which resulted a ring ratio of 0.5. Flexure testing was done in accordance with ASTM C1499. The loading rate for each specimen was 9.6 mm/s. Break force and manner of failure was then recorded.

Results (cont’d)

The results obtained agree with existing knowledge regarding to the fracture behavior of glass plates broken under an equibiaxial ring-on-ring configuration. The increase in plate size saw a significant decrease in the frequency of edge fractures. Similar results were achieved by switching the support/load ring ratio from 0.5 to 0.2. Mainly seen in the 100 x 100 mm plates, equibiaxial flexure testing with 0.2 ring ratio saw a lower frequency of edge fractures than with the 0.5 ring ratio. These results are likely due to an increase in distance between the outside of the load ring and the plate edge that accompanies a larger plate size and the 0.2 ring ratio. This allows for the further dissipation of the load ring induced stress before it reaches the edge. A reduced stress at the edge lowers the probability for fracture to initiate. The 0.2 and 0.5 ring ratios both yielded consistent strength values as plate size increased. It can be concluded that for these glasses the optimum equibiaxial test configuration consists of a 150 x 150 mm plate using the 0.2 ring ratio.

Conclusions

Graph 1 (left) and 2 (right): Comparison of percent of successful breaks during strength testing between each combination of plate size and ring ratio configuration for borosilicate and Starphire® glass. Percentage of valid breaks increases with larger plate size. 0.2 ring ratio yields slightly more valid breaks than 0.5.

Graph 3 (left) and 4 (right): Average strength values with standard deviations (black line) for different equibiaxial configurations. Shows increasing plate size produces consistent strength values.

References