Effect of loading rate, surface flaw length and orientation on strength of laser-modified architectural glass

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Abstract

The strength of architectural glass (soda-lime silica) is highly dependent on surface flaws generated during production, handling and service life. Fracture mechanical investigation of glass, however, is challenging due to e.g. the randomness of flaw size, flaw orientation and quality. Generation of radial and median cracks is inevitable while using a mechanical indenter with direct contact. These undesirable effects, along with uncertainty about the groove's depth and geometry, degrade the accuracy of results and underline the need for a more reliable tool. Consequently, this contribution focuses instead on the application of ultra-short laser as a non-contact tool, which recently has proved to be a promising solution because of its precision, high speed, and repeatability. Here, artificial grooves with a well-controlled depth are realized on the surface of soda-lime silica glass to investigate the effects of loading rate, flaw size and flaw orientation on the glass strength. Four-point bending tests are performed to assess the failure loads. The method manages to capture the results with a very low standard deviation of the failure stress (approximately 1 MPa), eliminating the need for using large series of specimens.

Keywords: Glass; Surface flaw; Ultra-short laser ablation; Fracture mechanics; Flexural strength.

1 Introduction

The use of glass in the field of construction is growing day by day. Apart from its aesthetic function and transparency, glass is subjected to loads, mostly wind and live loads. Although limited in terms of value, these loads are important and should be taken into account carefully. There are many standards and guidelines showing the appropriate ways to consider/model loads on the structure [1,2]. However, from the material perspective, glass still suffers from high scattering in its strength due to the surface flaws that have different depths, lengths, orientations, etc. These surface flaws form inevitably during production/transportation/installation and service life [3]. Furthermore, due to the subcritical crack growth [4], different loading histories cause different glass strengths [5,6]. The major challenge in exploring the effect of flaw geometries is the creation of artificial flaws. One frequently used method is utilizing mechanical indenters to generate artificial flaws [7,8], followed by strength tests. The issue with this method is that several radial/median cracks appear along with the artificial flaw, which affect the strength and degrade the reliability [9]. In contrast, laser as a non-contact tool can remove the material from the

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