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An analytical model for deformation and damage of rectangular laminated glass under low-velocity impact

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Abstract

In this paper, an analytical model is developed for a fully clamped rectangular laminated glass subjected to low-velocity impact which is capable of capturing large non-linear deformation and glass fracture. The mathematical framework of the analytical model is based on first-order shear deformation plate theory, which incorporates the effect of bending, membrane and transverse shear and uses damage mechanics to capture the glass fracture process. A series of experiments are performed for laminated glass with two different interlayer materials, viz. polyvinyl butyral (PVB) and SentryGlas® Plus (SGP). The predicted time-history of transverse central displacement, velocity and acceleration are found in satisfactory correlation with those from the experiments. Non-dimensional parameters which govern the maximum transverse displacement and first peak contact force in the laminated glass are proposed. The analytical model developed enables quick and reliable assessment during the preliminary safety glass design where full-scale FE analysis is often too time-consuming.

Keywords: Laminated glass, Impact damage, Plate theory, Wave propagation

1. Introduction

Laminated glass has been increasingly employed for impact-resistant glass applications in automotive [1], aerospace [2] and civil industries [3]. Typically, a laminated glass comprises of two annealed or tempered glass sheets interposed by a single layer of Polyvinyl Butyral (PVB) or SentryGlas® Plus (SGP) – a thermoplastic polymer membrane with good optical properties. After large-scale fracture on both the back and front faces (also known as inner and outer glass plies), the laminated glass is capable of retaining its structural integrity through the polymer interlayer which captures the majority of the glass splinters, whilst absorbing a significant portion of the impact energy through stretching. This 'peculiar'

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