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SOFT IMPACT OF LAMINATED GLASS USED FOR AIRCRAFT WINDSHIELDS

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1. INTRODUCTION

Front facing components of aircraft such as windshields, nose cones, wings and engine blades are always in danger of bird strike during flight time. This risk is increased at time of landing [1]. Engine ingestion is recognized as the major threat to transport jets, however for smaller aircraft, bird strike against the windshield is the main safety concern. This type of strike accounts for 52% of all fatal accidents [1]. Similar figures have been reported elsewhere in literature. Reference [2] details that amongst the 51 fatal accidents identified as being caused by bird strike between 1962 and 2009, 27 strikes were against the windshield. The majority of these fatal windshield strikes occurred on smaller aircraft. The focus of this paper is to study the impact damage of windshields caused by bird strike.

2. EXPERIMENTAL METHODS

To investigate the performance of laminated glass plates under soft projectile impact, laboratory scale impact experiments were performed using a gas gun apparatus. Projectile velocities between 100 and 180 ms^{-1} were adopted. Silicon rubber and gelatin cylindrical projectiles with flat and hemi-spherical noses were used to generate hydrodynamic loading. This is a similar type of loading to the load a windshield experiences under bird strike. A variety of laminated glass constructions, using different types of glass and polymer interlayer, were used to investigate the effects of various design parameters. The plates consist of two layers of glass and one layer of polymer which were laminated using an autoclave at Beijing Institute of Aeronautical Materials (BIAM). Two types of the strengthened alumina silicate glass were used for lamination: thermally and chemically strengthened. All tests were performed such that the target was oriented normal to the gas gun barrel. High speed 3D digital image correlation has effectively been employed to extract the full-field deformation and strain on the back surface of the specimens during impact. Finite element analysis was used to simulate the mechanical response of the laminated glass windows under impact loading. Due to symmetry, only one quarter of the target was modelled. Smoother Particle Hydrodynamic (SPH) was used for modelling the soft impact.

3. RESULTS AND CONCLUSIONS

Different phases of deformation were identified for the deformation of the laminated glass window under high velocity soft impact. Phase 1 where both displacement and strain are increasing, Phase 2 where the displacement continues to increase but the strain does not change much, Phase 3 where the displacement still continues to increase whilst strain is decreasing and Phase 4 where both displacement and strain are decreasing. The maximum strain in the center of the rear glass layer occurs early in the impact due to highly localized deformation, unlike the central out-of-plane displacement. This can be seen in the data captured by the high speed cameras shown in Fig. 1. This figure shows the results for a laminated glass sample, with a thermally strengthened front face, as often employed in the aircraft industry. Fig. 1(a) shows the deformation of the projectile. The contact duration is short and the projectile flows radially as expected. At this velocity only the front layer breaks and the rear layer remains intact. Fig. 1(b) displays out-of-plane displacement of the target calculated using DIC. Fig. 5(c) shows the major principal strain calculated by DIC.

For the laminated glass structures investigated, the damage inflicted is strongly sensitive to the nose shape of the projectile. A flat-fronted projectile causes the most damage. In addition, two threshold velocities have been identified for impact damage associated with the front-facing layer and secondly the rear glass layer breaking. The front glass layer was found to act as a sacrificial layer and protects the rest of the structure from premature failure. Additionally, the thickness of the glass layers affects the impact performance. When a thicker glass layer is placed in the front, both glass layers break. At the same impact speed, however, when a thinner glass layer is facing the projectile, only the front layer fractures and no damage appears in the thick rear glass layer. It can be concluded that the laminated glass window performs better if a thinner front layer is implemented.

Good agreement between the experimental and numerical results were observed. An example of a soft impact simulation for a rubber projectile with a hemi-spherical nose, impacting at a velocity of 158 ms^{-1} is shown in Fig. (2).

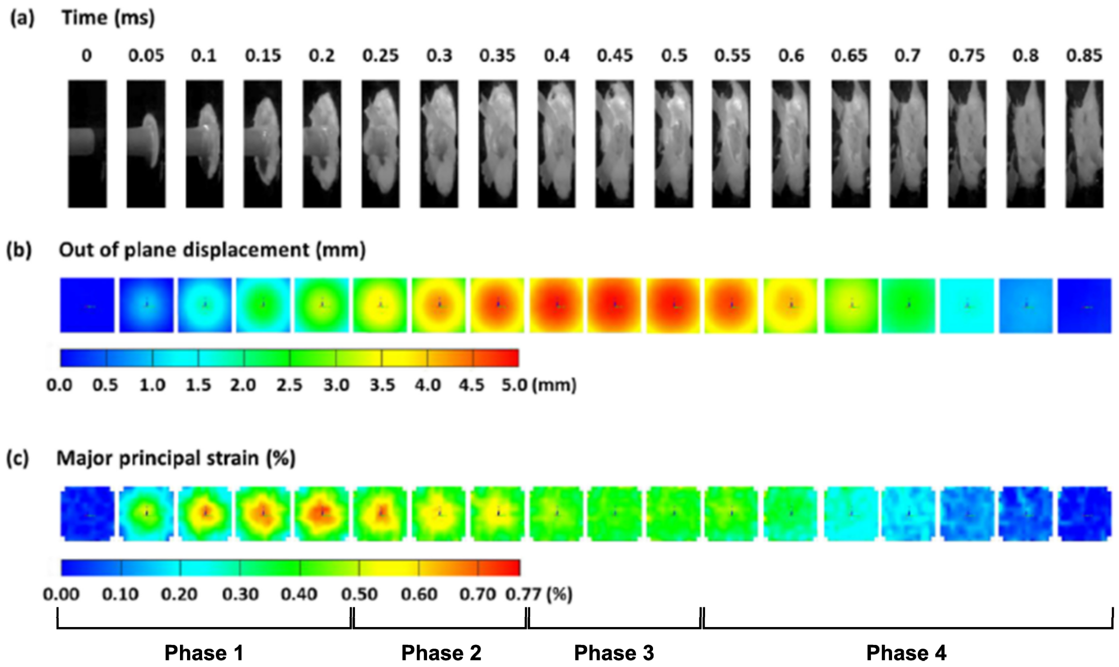

Fig. 1: Soft impact results of a laminated glass window at the velocity of 170 ms^{-1}: (a) shows the projectile deformation; (b) and (c) display the out-of-plane displacement and major principal strain contours over the observation area, calculated using DIC.

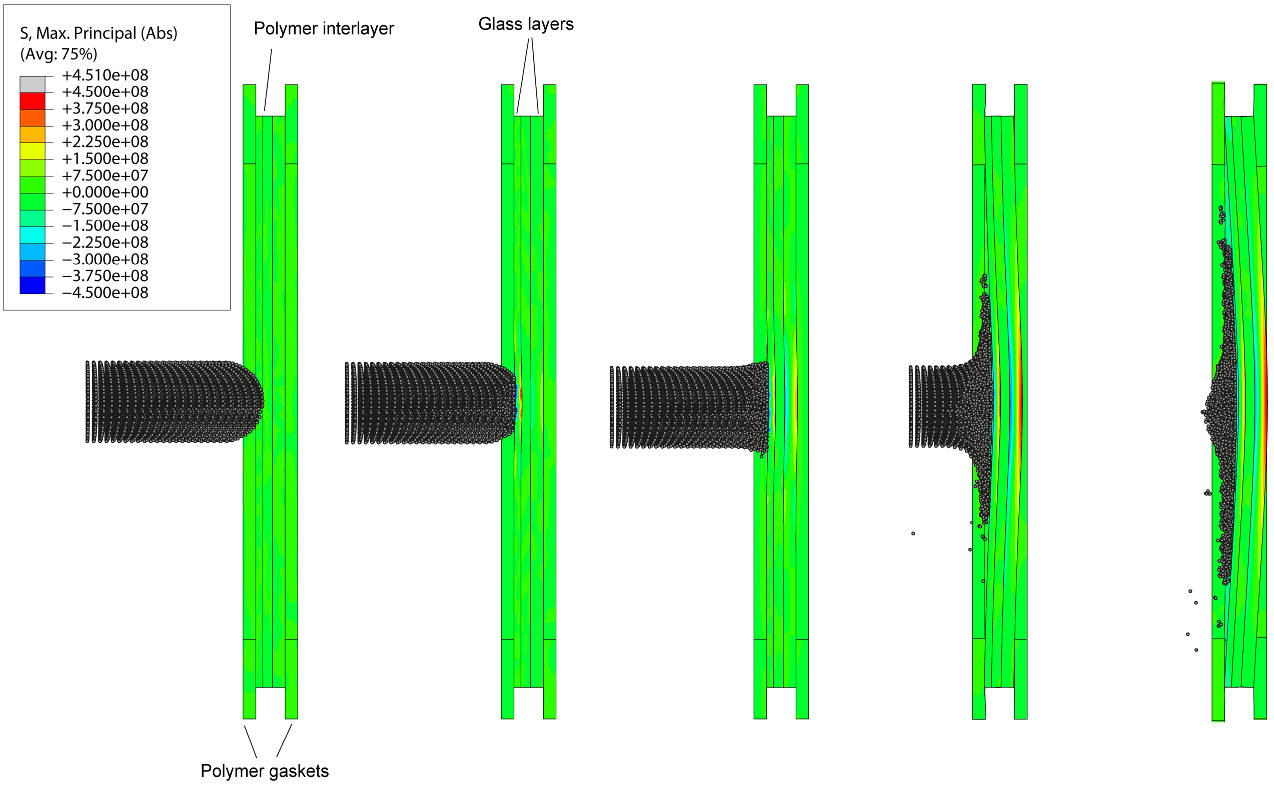

Fig. 2: Soft impact simulation on a laminated glass window impacted by a hemi-spherical projectile at a velocity of 158 ms^{-1}.

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REFERENCES

[1] J. Thorpe, "Fatalities and destroyed civil aircraft due to bird strikes, 1912-2002", *Int. Bird Strike Committee,* 2003, 26th Meet: p. 1-28.
[2] N. Dennis et al., "Bird strike damage & windshield bird strike final report", 2008.