Influence of Interlayer Thickness on Laminated Glass Windshields for Bird Impact

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1. INTRODUCTION & OBJECTIVE

Bird strikes have posed a significant threat to aviation safety since the early days of flight, affecting both civilian and military aircrafts [1]. Despite various scenarios of foreign object damage—such as hail, runway debris, or tire rubber impact, bird strikes account for approximately 90% of all reported incidents [2]. As aircraft speed and traffic continue to increase, the probability and potential severity of bird strikes also rise, with potentially catastrophic consequences. The forward-facing components of aircraft, especially windshields, are one of the most susceptible parts to bird strikes due to their exposure. In accordance with European and U.S. aviation regulations, these components must demonstrate a specific level of bird strike resistance during certification tests. For example, windshields should have air tightness and good visibility and are required to withstand the impact of a 4-pound (1.8 kg) bird at cruise speed without penetration (FAR/JAR/CS 25.775) [3]. Historically, the design of impact-resistant aircraft components relied heavily on iterative processes involving physical testing and redesign, which were both time-consuming and costly. To address these challenges, advanced numerical methods have been developed to optimize the design of bird-proof aircraft components more efficiently [4]. These methods allow for the simulation of extreme impact scenarios, which may not be feasible in physical experiments, offering crucial insights into the impact dynamics and potential damage mechanisms.

A crucial aspect of windshield design is the choice of polymer interlayer, which plays a significant role in enhancing the impact resistance of laminated glass systems. Polyvinyl butyral (PVB) is commonly used due to its excellent adhesion, transparency, and energy absorption capabilities [5,6]. This study aims to explore the response of laminated soda lime glass windshields to bird strikes under varying conditions, using numerical simulations to understand the impact dynamics

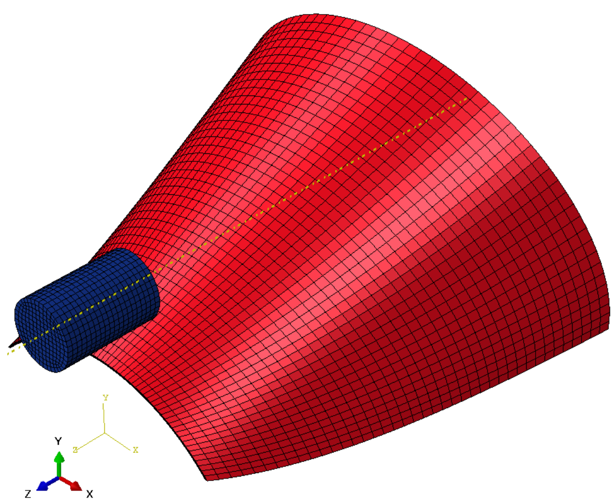

Figure 1. A representative image of the numerical model of an aircraft windshield undergoing bird impact

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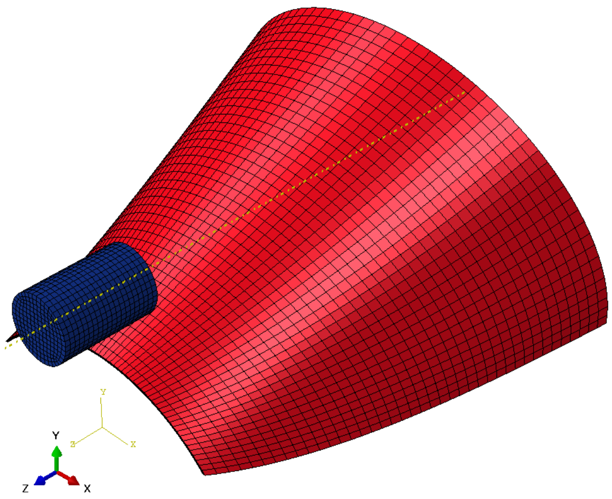

Figure *1*). It focuses on the effects of different interlayer thicknesses of PVB, angles of incidence, and impact velocities to identify optimized windshield designs that enhance resistance to high-velocity impacts, ultimately contributing to safer aviation technologies.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

In this study, the bird impact simulation model is initially validated using monolithic soda-lime glass plates with varying thicknesses. The bird is modeled as a hemispherical cylinder with a length-to-diameter (L/D) ratio of 2, using the Smoothed Particle Hydrodynamics (SPH) method to convert mesh elements into individual particles [7]. The glass plate is modelled using shell elements inclined at an angle to the vertical, with all sides fixed. The bird is made to impact the center of the plate at a velocity of 67 m/s [8]. The numerical model is implemented in Abaqus CAE.

It is observed that for the plate with the minimum thickness, separation from the supports occurs along three boundaries. As the thickness is increased, the extent of failure is found to decrease, with the plates remaining attached to the frame, except for minor separations near the top boundary. The current results are comparable to the reference, though they exhibit a slight margin of error (see **Figure *2***).

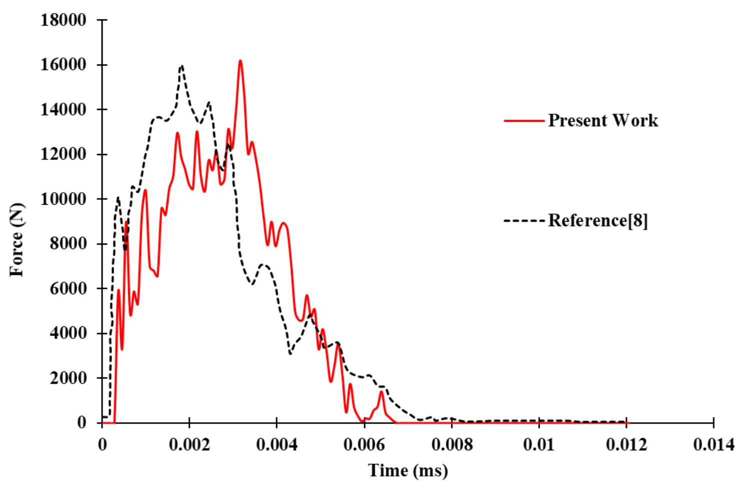

Figure 2. Comparison of the contact force on the plate due to the bird impact

Following this initial validation, the effects of varying polyvinyl butyral (PVB) interlayer thicknesses and the influence of the angle of bird impact are further investigated. The optimal thickness of the PVB interlayer and glass that can withstand bird-strike impacts at specified velocities are determined. These results will be reported in the main paper.

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