Bird Strike Impact on Composite Aircraft Wings: Effect of Stiffeners, Layup, and Layer Thickness

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1. INTRODUCTION & OBJECTIVE

Contemporary aircraft frames undergo thorough investigation and testing to guarantee they satisfy rigorous airworthiness and crashworthiness criteria prior to certification. The distinctive mechanical characteristics of laminated composites make them indispensable in these airframes. Significantly, the proportion of composite mass in the most recent Boeing 787 and Airbus A350 surpasses 50% [1]. Foreign object impacts pose a significant risk to the structural integrity of forward-facing laminated composite components, such as wing leading edges. To meet damage tolerance certification criteria, the aircraft design process must include safeguards for wing leading edges to prevent possible severe damage from flying objects. Despite the presence of other foreign object impact hazards, records reveal that bird hits constitute 90% of all such crashes affecting exterior aircraft structures [2]. To guarantee safe flight and landing following contact, it is imperative that the front spar remains intact even if the wing leading edge is penetrated. Moreover, the high-lift devices installed on the leading edge must possess resistance against bird impacts to provide safety during both take-off and landing cycles while these devices are extended. It is imperative to engineer wing leading edges to withstand severe damage, ensuring that any damage is readily identifiable and can be repaired.

Prior to entering service, aviation authorities mandate that wing leading edges must undergo certification tests to show their ability to withstand bird strikes. According to Federal Aviation Regulations (FAR), wing leading edges must withstand the impact due to an 8-pound (3.6 kg) bird at operational speed [3]. Although this testing is usually carried out using actual birds (such as deceased or anesthetic chicks) [4], it is expensive and susceptible to inconsistency. Since the last few decades, computational approaches have been employed as a more efficient alternative [5].

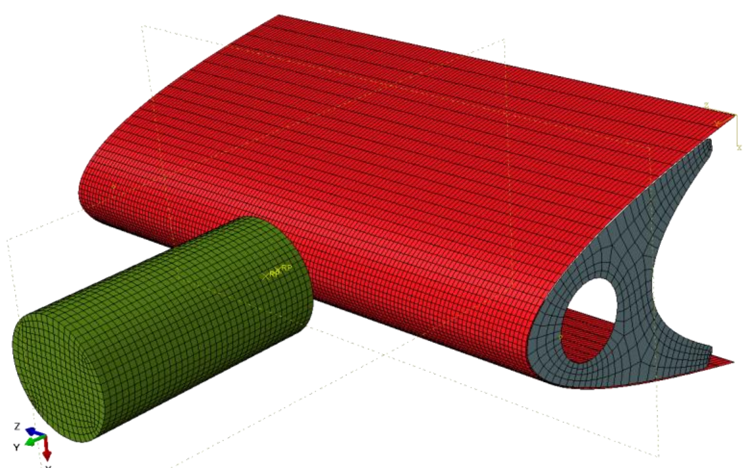

Figure 1. A representative image of the numerical model of the leading edge of an aircraft wing undergoing bird strike impact

This study numerically investigates the structural response of an aircraft wing's leading edge subjected to bird strike impacts. It also evaluates the potential performance enhancements resulting from the incorporation of stiffeners in the wing structure. Additionally, the effects of composite layup and layer thickness on the wing's performance are examined.

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2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

In this study, the bird strike impact analysis is modelled using ABAQUS CAE. The model is validated by modelling the leading edge of a wing with layers of varying thickness. The bird is represented as a cylinder with a length-to-diameter ratio of 2, measuring 134 mm in diameter and having a mass of 3.68 kg with a density of 946.6 kg/m³. The Smooth Particle Hydrodynamics (SPH) [6] approach employs 12,640 particles to represent the bird, converting the mesh elements into particles. The impact velocity is set at 129 m/s to simulate the bird's relative velocity. The leading edge is modelled with a composite layup consisting of three layers: aluminum (for the outer and inner skins) and honeycomb structure in between. The wing structure is reinforced with a rib support system, with the longitudinal sides fixed (see **Figure *1***).

The center displacement of the leading edge due to the bird strike is calculated and found to be close to 350 mm, which aligns with the reference results [7] (see **Figure *2***). Further investigation will explore different support system configurations, as well as the effects of layer thickness and layup sequence. The optimal support system of the wing structure is assessed, and the layer thickness of both the aluminum sheets and the honeycomb core is evaluated based on the bird's relative velocity. These important findings will be reported in the main paper.

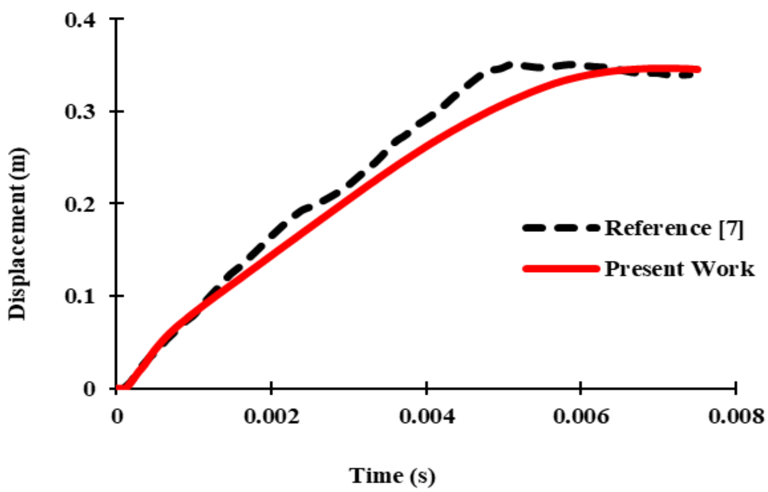

Figure 2. Comparison of the central deflection of the wing leading edge due to the bird impact

REFERENCES

[1] M.R. Kessler. (2012). Polymer Matrix Composites: A Perspective for a Special Issue of Polymer Reviews. Polymer Reviews, 52 (2012), 229–233

[2] S.A. Meguid, R.H. Mao, T.Y. Ng, FE analysis of geometry effects of an artificial bird striking an aeroengine fan blade, International Journal of Impact Engineering 35 (2008) 487–498.

[3] S. Heimbs, Computational methods for bird strike simulations: A review, Computers & Structures 89 (2011) 2093–2112.

[4] John P. Barber, H.R. Taylor, J.S. Wilbeck, Characterization of Bird Impacts on a Rigid Plate: Part 1, (1975) Technical Rep. AFFDL-TR-75-5, National Technical Information Service, U.S. Dept. of Commerce, Springfield, VA, (1975).

[5] H.C. Teichman, R.N. Tadros, Analytical and Experimental Simulation of Fan Blade Behavior and Damage Under Bird Impact, Journal of Engineering for Gas Turbines and Power 113 (1991) 582–594.

[6] J. Liu, Y.L. Li, F. Xu, The Numerical Simulation of a Bird-Impact on an Aircraft Windshield by Using the SPH Method, Advanced Materials Research 33–37 (2008) 851–856.

[7] M. Cihan Tezel, Y. Yamaner, B.A. Çoğuz, E. Acar, Exploring Design Options for Wing Leading Edge Against Bird Strike, Journal of Aircraft 60 (2023) 66–80.