Simulation of Bird Impact on an Aircraft Windshield

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The January 2009 forced ditching of US Airways flight 1549 into New York City's Hudson River served as a reminder that bird strikes on aircraft pose a serious safety threat. While this particular incident was caused by birds striking both engines, a high probability exists that birds will impact and damage aircraft windshields. To gain a better understanding of how aircraft windshields perform during a bird strike, a research team at Nanjing University of Aeronautics and Astronautics in China has published a paper that compares physical tests with Abaqus FEA results.

During the physical experiment, five impact tests were carried out on three windshields composed of 16 mm thick polycarbonate shell. The “bird,” a headless, legless, plastic-wrapped chicken with a mass of 1.8 kg, was propelled at an airplane windshield at velocities between 345 km/h and 380 km/h. Throughout the process, a high-speed camera captured the deformation of both windshield and bird. The experiment showed that the windshield survived, without obvious damage, when the bird speed was less than 345 km/h. However, when the bird speed was greater than 365 km/h, the windshield sustained serious damage. It was also observed that windshield failure did not occur during the initial impact, but rather a short time later due to the bending deformation.

These full-scale bird-strike experiments helped the researchers prepare for the structural design analyses by providing the dynamic failure position for the windshield, capturing the critical speed of the bird, identifying boundary and material properties of the windshield, and determining the degree of damage.

A finite element model of bird impact on the windshield was then established to predict the damage initiation and propagation of the windshield using the nonlinear analysis capabilities within Abaqus/Explicit combined with user-defined materials. As real birds have flesh, blood, and bones, the team endeavored to make the bird simulation as realistic as possible. The bird was modeled using a Lagrangian approach with an elastic-plastic with shear failure criteria. The shear failure criteria and the tensile failure were selected to identify the damage of bird and windshield, respectively. The supporting structure of the windshield glass was modeled with skins and rubber gaskets.

The analysis results included the instantaneous deformation of bird and windshield, the damage modes of the windshield, and displacement curves and strain curves of the measured points on the windshield. The maximum windshield displacement after bird impact exceeded 60mm—more than three times the thickness of the windshield—and the damage incurred by the simulated windshield closely mirrored the windshield from the physical experiment.

The comparison between the simulation results and the experiment demonstrated that Abaqus FEA provides a high level of accuracy in the analysis of bird strike on aircraft windshields. Now that the bird and windshield models have been established, Abaqus FEA can be used to analyze bird impact at various locations, under alternative conditions which can’t be physically tested due to cost, time, and human resource constraints. Simulation results can also be used to improve the structural response of proposed windshield designs before any physical prototyping is carried out.

This article is an excerpt from a AIAA technical paper accepted to the 2009 AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference entitled “Experiment and Numerical Simulation of a Full-Scale Aircraft Windshield Subjected to Bird Impact” by Shuhua Zhu, Mingbo Tong, and Yuequan Wang from the Key Laboratory of Fundamental Science for National Defense-Advanced Design Technology of Flight Vehicle, Nanjing University of Aeronautics & Astronautics, Nanjing, China.