TO THE TEST

In the past, the only way to determine whether composite aircraft components could withstand bird strikes was with time-consuming physical tests. Now, Hindustan Aeronautics Limited engineers use simulation to get the design right the first time. Bird strike simulation saves the company design time and thousands of dollars per test of composite helicopter components.

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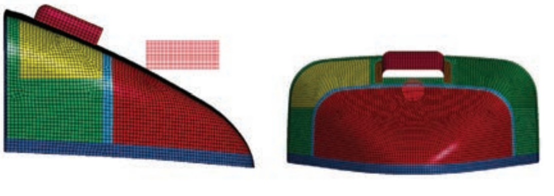
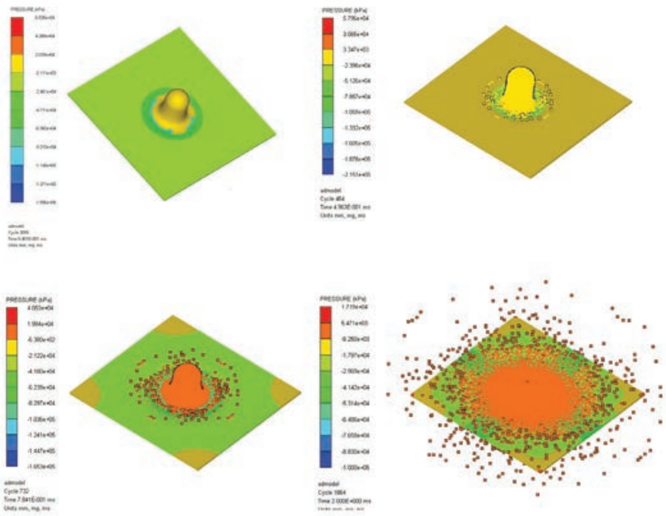
In 2014, four U.S. Air Force personnel were killed when their HH-60G Pave Hawk helicopter crashed during a training mission in Norfolk, England. The U.S. accident investigation board found that the accident was caused by geese flying through the aircraft's windshield, knocking the pilot and co-pilot unconscious. They were unable to react when another bird struck the helicopter's nose and disabled the craft's stabilization system. The result was an uncontrolled roll to the ground, destruction of a US$40 million helicopter and loss of life. This is not an isolated incident. According to the United States Department of Agriculture's Animal and Plant Health Inspection Service (APHIS), bird strikes to civilian and military helicopters have resulted in 11 human deaths and 61 injuries since 1990. [1]



^ SPH bird model with Lagrange model of cowling

In an effort to protect crew and passengers from the dangers of bird strikes, regulatory authorities, including the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA), have issued regulations regarding the ability of helicopters to survive bird strikes. For example, the FAA's 14 CFR 29.631 regulation now demands that category A rotorcraft (the highest certification standard, which requires, among other things, assurance of continued flight in the event of failure) be capable of continued safe flight and landing after bird impact. Bird strike certification has been a time-consuming and expensive process because the only way to determine whether a component could survive a bird strike was physical testing. Tests usually needed to be repeated several times because components often failed and replacements were required for each new design. Hindustan Aeronautics Limited (HAL) has substantially reduced the time and cost of certification by using ANSYS Composite PrepPost and ANSYS Autodyn to accurately simulate bird strikes. Simulation makes it possible to efficiently determine a suitable design so that only one test is required per component.



^ Simplified simulation of bird model into flat plate

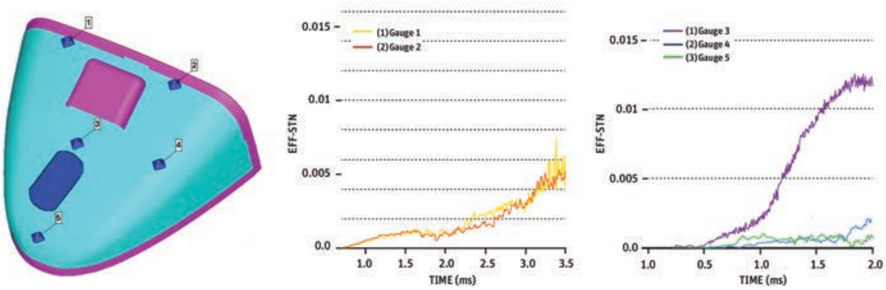
SIMULATION CHALLENGE

The components that require certification on modern helicopters, such as cowling, horizontal stabilizers and end plates, are typically made of fiber-reinforced composites. Cowling refers to detachable panels covering those areas to which access must be provided, such as the engine, transmission and other vital systems. Bird strike simulations are challenging because they are of short duration, cause large material deformation, and involve interactions between bodies with rapidly changing surfaces. The difficulty is increased by the need to model composite materials that include numerous layers, each with its own material, footprint, thickness and orientation.

As a first step to determine the validity of the model used, HAL simulated a simplified case that could easily be done experimentally. The results of physical testing were correlated with the calculations, which confirmed the viability of models used with the aircraft. The bird strike simulation consisted of an idealized geometry striking a flat plate. The bird was modeled as a cylinder with flat ends, and as a cylinder with hemispherical ends. A bird undergoing impact at high velocity behaves as a highly deformable projectile with a yield stress much lower than the sustained stress. Based on this, and also because the density of flesh is close to the density of water, it is possible to approximate the bird as a lump of water hitting the target. The analysis was carried out with the Autodyn solver using the smoothed particle hydrodynamics (SPH) method to avoid numerical difficulties associated with extensive mesh distortion. The results correlated well with the analysis of shock pressures calculated using hydrodynamic theory.

DEFINING COMPOSITE GEOMETRY

Realistically simulating certification tests requires modeling complex composite structures. HAL imported the geometry of a cowling into the ANSYS Workbench environment. The cowling comprises a Kevlar® fiber skin and a honeycomb core. ANSYS Composite PrepPost was used to define the number of layers and the shape, thickness and orientation of each layer. Compression tests on square specimens were performed according to ASTM standards to determine the properties of the core. The composite

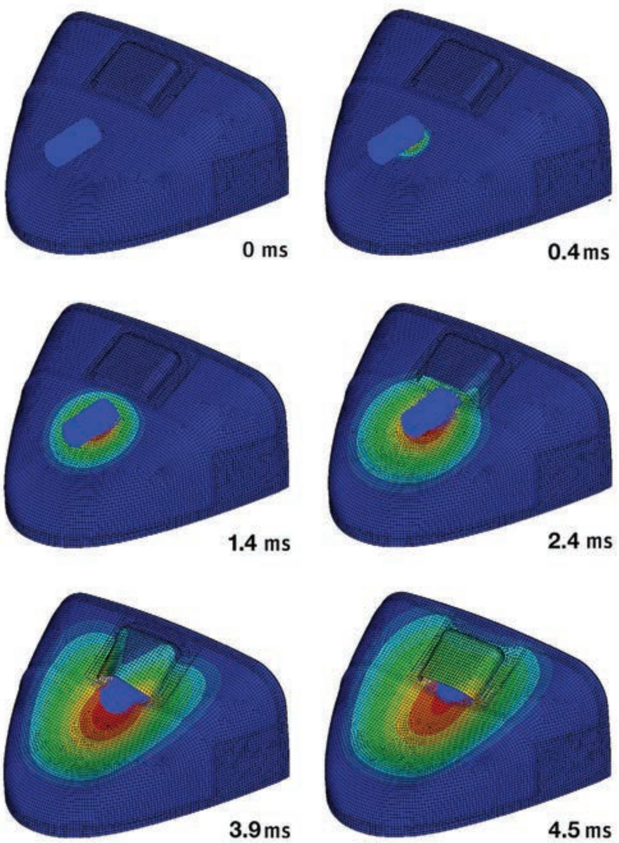


^ Effective strain plot predicted by simulation

> **“*Bird strikes* to civilian and military helicopters *have resulted* in 11 human deaths and 61 *injuries* since 1990.”**

definitions were then transferred to the finite element model and the solver input file. The material properties for each composite layer were defined with a constitutive material model inside ANSYS Composite PrepPost, with appropriate damage initiation criteria and damage evolution. Further preprocessing was done in ANSYS Explicit STR. The composite definitions from ANSYS Composite PrepPost were seamlessly transferred to Autodyn through ANSYS Workbench.

A key advantage of ANSYS Autodyn explicit solver is its ability to combine Lagrange, Euler, arbitrary Lagrange-Euler (ALE) and SPH methods in a single problem to produce results with the highest accuracy possible within a reasonable computational time. In this case, the SPH bird model was used to model the bird, while the Lagrange model, with its high computational speed, was used to represent the cowling structure. The model was set up to match the test conditions of a bird strike test conducted at a research facility, including the application of aerodynamic loading to the cowling. Virtual strain gauges were defined within Autodyn at the same positions on the cowling as those used in the physical test.



^ Cowling deformation at various time intervals

CORRELATION WITH PHYSICAL TESTING

Within each element, the Lagrange solver captured the material location of the discretized model and followed its deformation as forces were applied. The solution time was under one hour for a simulation time of 4,000 microseconds. The simulation accurately predicted the basic parameters of the test as well as the damage location and failure size.

The failure mode at different time intervals also matched well with the test results. At the early stages of impact, the mechanical response of the composite structure is controlled by the fiber–matrix interface. At the intermediate stages of impact, when the shock wave reaches the face-sheet–core interface, a negative pressure region begins to develop on the back of the face sheet, giving rise to tensile failures of fibers in this region. At later stages of impact, a substantially larger region of outer face sheet is subjected to negative pressures, causing it to fail structurally. Meanwhile, high strains are observed in the cowling surrounding the top of the projectile.

The correlation study provided a high level of confidence in the ability of the simulation to predict dynamic responses and structural failures subjected to high-energy bird impacts. With the model validated, HAL now uses it to design new exterior structural components that can pass bird strike certification tests the first time. In obtaining EASA certification for a civilian version of the HAL Dhruv Advanced Light Helicopter, simulation eliminated the need for one or two additional tests that were nearly always required in the past, saving time and thousands of dollars in testing for each component that was certified. ^

References

[1] Keirn, G. Helicopters and Bird Strikes; Results from First Analysis Available Online. blogs.usda.gov/2013/06/06/helicopters-and-bird-strikes-results-from-first-analysis-available-online (12/17/2015).

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