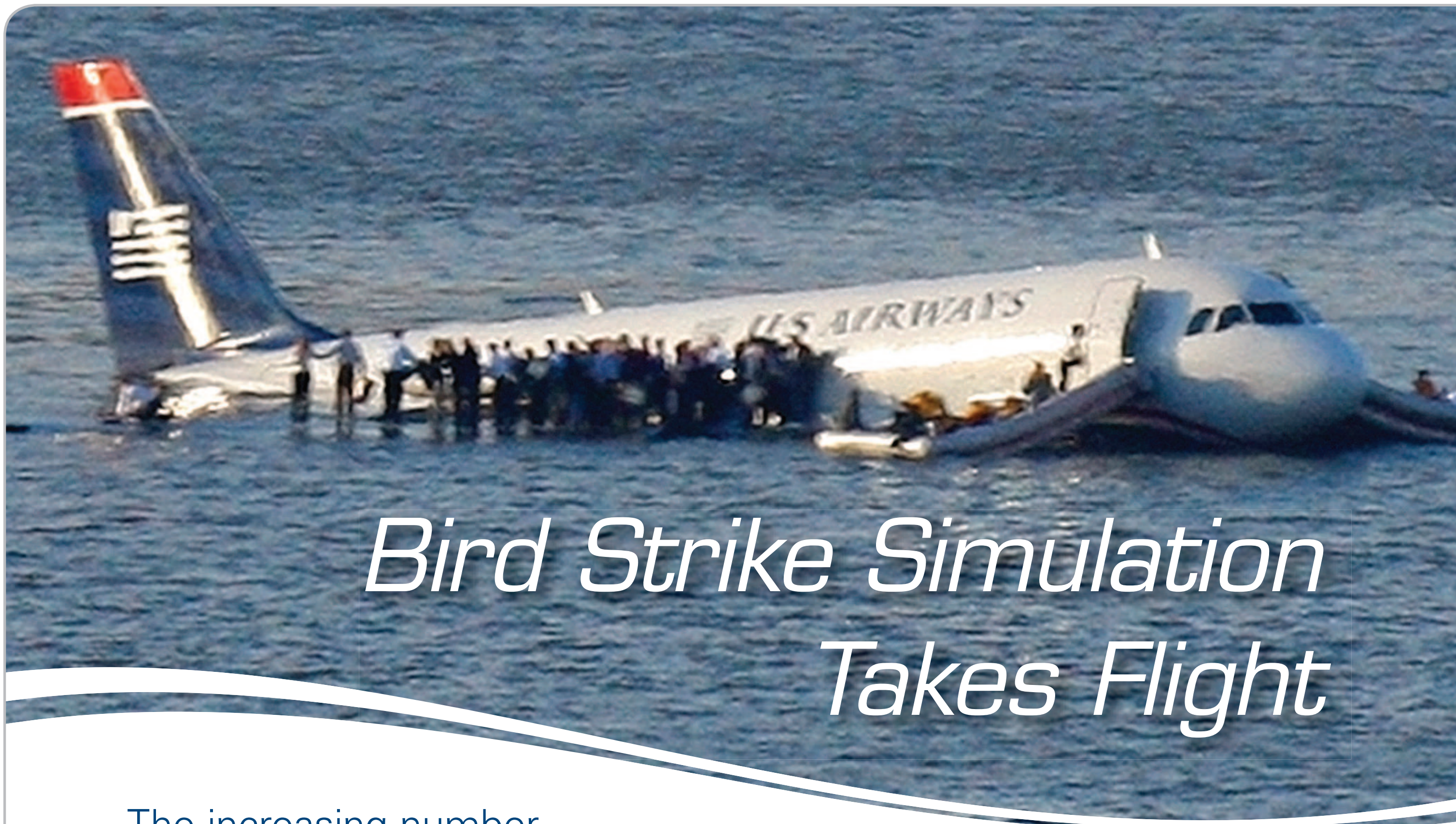


Bird Strike Simulation Takes Flight

The increasing number of bird-plane impacts gives rise to new CAE methods to address aircraft safety.

By **Robert Yancey**

Bird strikes have been occurring for more than a century. In fact, Orville Wright was the first to report a bird strike in 1905.

In the United States, the Federal Aviation Administration (FAA) notes that bird strikes occur during daylight hours, usually during a plane's approach and landing roll. Ninety-two percent of the strikes take place at or below 3,000 ft above ground level. Gulls, doves and pigeons account for approximately one-third of the encounters.

According to *USA Today*, which analyzed FAA data, severe collisions between airborne jetliners and birds have soared over the past two years. In 2009, severe bird strikes above 500 ft hit a high of 150; 2010 had a similar number of bird strikes. Although the FAA is pushing airports to do a better job of keeping birds away from runways, serious incidents above 500 ft are taking place.

The FAA certifies civil aircraft to meet a series of minimum standards. Aircraft must be designed and built to fly safely as well as survive situations in which internal or external factors – such as bird strikes – may interfere with safe operations. To address these regulatory requirements, many aircraft manufacturers are turning to simulation technology in product development.

Making an Impact

Recent events have highlighted the dangers from bird strikes in flight. The famous US Airways Hudson River emergency landing was the result of two engine failures from bird strikes (see photo above). At a minimum, bird strikes cause damage to the airframe that adds repair costs. At the other end of the spectrum, they can cause catastrophic damage potentially resulting in a crash and loss of life. Many airports are implementing changes to reduce bird populations around their facilities to reduce incidents.

The airplane manufacturers still are required to conduct bird strike tests and design structures that can withstand a bird strike event. That is why a key goal in product development is to deliver airframes and engines that pass regulatory requirements on the first test. Failure to do so results in redesign, refabrication, retesting – and lost time, money and effort.

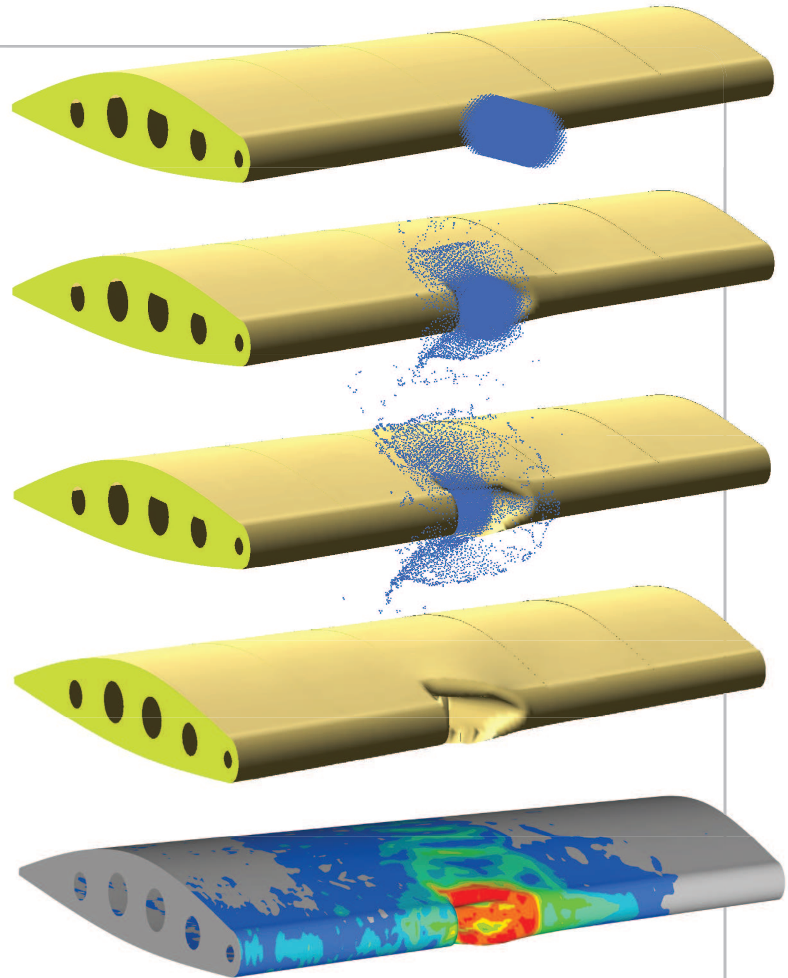
Following the lead of the automotive industry with virtual crash testing, many airplane manufacturers and suppliers are turning to virtual simulations of bird strike events. Success here with explicit nonlinear dynamic transient analysis codes such as RADIOSS from Altair Engineering can dramatically reduce costs and improve performance.

The Power of the Process

Bird strike analysis is far different than automotive crash analysis. Various finite-element methods have been used, but the method that is becoming a standard in bird strike analysis is the SPH method, based on smooth particle hydrodynamics. This technique allows the kinetic energy of the bird test article to be imparted to the structure while allowing the bird to break apart and disperse (see images to the right).

The analysis is set up to reproduce the standard regulatory test method. Some aircraft companies use gelatin to represent a bird while others employ actual test articles. As the test article impacts the structure, it disperses, much like a water balloon hitting the ground.

The SPH computational method models the bird test articles with a set of "particles" (disordered points) that intersect



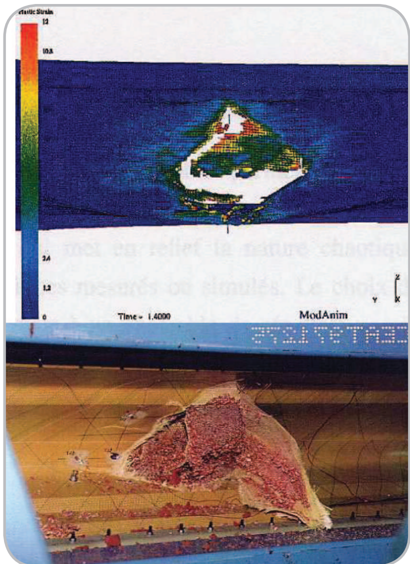
The images above depict the use of the smooth particle hydrodynamics (SPH) methods with RADIOSS software for bird strike analysis.

Optimizing Composite Underbelly Fairings for Bird Strike Events

The underbelly fairing is an area of an airplane at risk to bird strike events. As a secondary structure, lightweight composite material constructions are desired for underbelly fairings. Through a combination of advanced structural optimization capabilities in OptiStruct and the SPH computational methods in RADIOSS, both developed by Altair Engineering, Inc., aircraft manufacturers have the ability to streamline composite material designs taking into account bird strike impacts.

To incorporate a bird strike event as a load case within a composite optimization process, kinetic energy, velocity and deceleration information, together with the deformation limit desired, first need to be calculated to estimate the static equivalent loads on the structure. Using OptiStruct, an optimization analysis can then be performed to determine the optimal shape, thickness and order of each ply in the stack – taking into account the static equivalent loads for the bird strike event simultaneously with the fairing's frequency targets and static load cases.

Subsequently, one would need to consider the most critical locations for a bird strike and then add reinforcement to those areas. For example, sections of the fairing covering critical components – such as fuel tanks, flight control electronics, etc. – would need to have adequate reinforcement to withstand a bird strike event. A potential approach would be to perform the worst-case bird strike analysis, using RADIOSS, to determine a minimum thickness in those areas to ensure flight safety, then use this minimum thickness constraint in those zones in the OptiStruct optimization run.



Bird strike simulation and physical test results on a wing leading edge showing consistent failure modes.

with each other through external forces rather than connections to nodes. As such, the results are insensitive to the deformation of the birds – but provide a clear understanding of the strike impact on the structure.

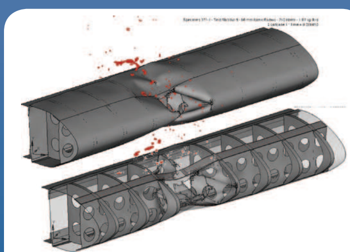
The SPH method is well-suited to hydrodynamic material (and the bird material law is mainly hydrodynamic). It's based on interpolation theory and allows any function to be expressed in terms of its values at a set of particles. In addition, it permits the motion of a discrete number of particles to be followed in time.

In the actual simulation process, the target structure is modeled from CAD data as a finite-element model. The most important features are connection characteristics (rivets) and material behavior (plasticity, rupturing).

The RADIOSS bird strike simulation process includes rupture checks and estimates on the bird's residual energy in case of penetration, number of broken rivets, and behavior of the rupture zone to predict the risk of debris separating from the structure and possibly impacting another part of the aircraft. An additional consideration is the ability of the vehicle to fly after impact despite damage inflicted (change in aerodynamic characteristics due to deformation).

Though one single simulation is not very CPU-intensive, many simulations are required to assess the sensitivity of the structure, the number of possible impacts on various zones of the structure and the dispersion of impact type (incidence). Therefore, optimization and sensitivity analysis

Aviation Research: From Lab to Industry



Bird strike impact on a metallic leading-edge structure

Initiatives to advance aviation technology are under way at the National Institute for Aviation Research (NIAR) at Wichita State University. Located in Wichita, Kan., the "Air Capital of the World," NIAR, an Altair research partner, is the largest university aviation Research & Development institution in the United States.

NIAR is able to integrate business, government and academia in cooperative efforts to advance aviation technology; a key example of this is NIAR's Computational Mechanics Laboratory. This cutting-edge laboratory provides research focused on the development and application of numerical methods in the areas of crashworthiness, structures, numerical optimization techniques, virtual product development and certification.

According to the Computational Mechanics Technical Director Dr. Gerardo Olivares, the lab is currently collaborating with an aerospace industry advisory group and researchers at NASA Glenn to develop and validate numerical modeling techniques to simulate bird impacts on aircraft structures. Additionally, current ongoing research includes a joint sponsored project by the Federal Aviation Administration, aerospace companies and seat suppliers on Certification by Analysis of Aircraft Seat Structures. The objective of this project is to develop numerical modeling techniques to support the dynamic certification process of aircraft seat structures per Advisory Circular 20-146.

The aerospace industry is conservative by nature, and Dr. Olivares notes that pressure to reduce development costs and cycles is driving companies to introduce advance simulation tools in the design, development and certification process. However, since many current engineers have not been exposed to the technology, there is a lack of qualified staff trained to apply the use of advanced analysis tools.

The Computational Mechanics Lab at NIAR plays a key role in solving this problem. It hires 12 to 16 graduate students, training them to use a combination of advanced simulation tools, analytical skills and experimental methods, all of which are critical in the aircraft design process. "From the lab, we expect the students to move into industry where they can either create or join existing advanced simulation groups and transfer the technology," says Dr. Olivares.

For more information on NIAR, visit www.niar.wichita.edu.

software may be useful to limit the number of simulations that need to be carried out and to properly assess the phenomenon involved in such events.

Typically, aircraft manufacturers build physical rigs to carry out physical testing. They marry the results of the physical and simulation testing to improve product development.

Through rigorous physical and virtual testing correlation efforts, the bird strike test articles deliver the right kinetic energy to the structure, which is important in this type of simulation. Altair provides certification correlation test results for virtual bird models of various types and sizes that can be run with RADIOSS. These results have been correlated with impacts on wings, nacelles and engines.

The Simulation Difference

In summary, many aircraft OEMs and suppliers have improved their bird strike analysis process on several fronts by using virtual simulation. Altair has been a partner with many of these companies, providing the technology and expertise to make these efforts successful. The cost of performing simulations is considerably less than conducting multiple physical tests. Additionally, a greater number of situations can be analyzed and the effects of design changes can be evaluated very quickly, allowing for the optimization of components for weight.

What's more, simulation tools have saved time in the process. Simulation provides confidence in the design so that physical testing can run in parallel with production with a high level of success. The goal is getting the design right the first time – and simulation has proven in many applications to provide the right answers before any physical evaluations are attempted.

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For more information about RADIOSS and bird strike analysis, visit www.altair.com/c2r.