Bird Strike Damage Analysis Using Coupled Eulerian-Lagrangian Method in Abaqus

Bird strike analysis of aircraft components is an important step in the process of flight certification and validation. Due to the advancements in numerical simulation technologies, it is now possible to obtain analysis results that successfully replicate the physics of the real event. The Department of Aeronautical Engineering, Faculty of Mechanical Engineering and Naval Architecture at the University of Zagreb, has developed a numerical damage predication procedure to gain insight into complex structural behavior of impacted structures without the need for time consuming and costly physical experiments. The accuracy of numerically, as well as experimentally, predicted responses greatly depends on the physically correct modeling of bird replacement models. Due to the fact that the stiffness of the impacting bodies is much lower compared to the impacted structures, bird strikes are classified as soft body impacts. During the impact, the bird is subjected to stresses that greatly exceed the material's strength. In addition, large deformation of material during soft body impacts has traditionally presented a source of numerical challenges in the finite element analyses.

The Coupled Eulerian-Lagrangian (CEL) capability of Abaqus/Explicit is a very powerful tool in overcoming these challenges. It has been applied to efficiently capture the fluid-like bird behavior upon impact. The great advantage of CEL analyses is that most of the problems associated with extensive bird mesh distortion are eliminated, as the Eulerian description allows finite elements to be fixed in space and the material to flow through these elements. On the other hand, the impacted structures are discretised by traditional Lagrange finite element formulation. The impacting forces are transferred to the Lagrangian structure through Eulerian-Lagrangian contact, which is based on the penalty contact algorithm.

The numerical bird strike simulation has been applied on a very detailed airliner flap model consisting of composite laminates, sandwich structures and metallic structural items. The model is assembled of solid, conventional and continuum shell and beam elements, while tie surface-based constraints have been employed in order to connect meshes of elements having dissimilar numbers of degrees of freedom. The Abaqus built-in progressive damage and failure model completely fulfills the requirements of the simulation and has been applied to model impact damage on the composite part of the structure.

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The composite components of the model use Hashin's failure initiation criterion and accounts for the following failure modes: fiber rupture in tension, fiber buckling and kinking in compression, matrix cracking under transverse tension and shearing, matrix crushing under transverse compression and shearing. Damage is modeled employing continuum damage mechanics principles using damage parameters which modify the initial undamaged elasticity matrix. Failure of metallic structural items has been modeled by shear failure criterion, which is based on the accumulated equivalent plastic strain and suitable for high-strain rate dynamic problems. The shear failure criterion has also been employed to predict crushing of the Nomex honeycomb core.

Bird material has been replaced with an equal mass of water, as birds mostly consist of water and air trapped in the bones and lungs. To take the trapped air into account the density has been reduced to 938 kg/m3, while the Mie-Grüneisen equation of state has been used to model constitutive behavior. The bird geometry has been replaced with a cylinder having hemispherical ends and a length-to-radius ratio equal to two, as this geometry best resembles pressure time histories of real birds during impact tests and corresponds to the geometry used in the experimental work.

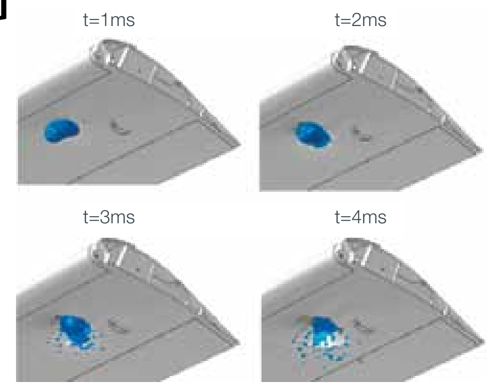

Figure 1. Deformation of a 1.81 kg bird during the impact.

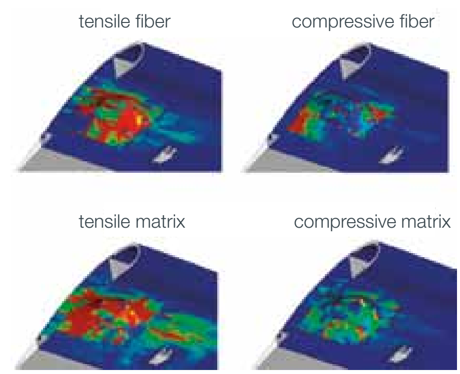

Figure 2. Contour plots of Hashin's failure criterions of lower flap skin (cross-sectional view) at an impact of a 1.81 kg bird.

The results shown in this contribution demonstrate the damage prediction capability in a simulation of a bird strike on an inboard airliner flap involving a 1.81 kg bird at 100 m/s. The kinetic energy of the impact event (Figure 1) is sufficient to cause severe damage on the flap as the bird penetrates the lower flap skin and impacts the upper skin. The dominant failure modes of the composite flap skins are tensile fiber and matrix failure (Figure 2). Although the impact in this case resulted in complete failure of the lower skin and serious damage of the upper skin, the main load carrying structural items were not affected by the impact.

Abaqus/Explicit has proven to be a very efficient and numerically stable tool. As the software has great potential in implementing new constitutive and damage models, the ongoing research will couple the effects of aerodynamic loading as well as implement other failure modes.

For More Information

http://aerodamagelab.fsb.hr/

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