Soft Impact Damage Prediction for Polycarbonate Canopy Using Progressive Failure Dynamic Analysis

Challenge

Figure 1. F-16 canopy

Soft impact, in the form of bird strike, continues to be a concern for aircraft that use advanced composite structures. To mitigate this threat, extensive analysis and testing is conducted to ensure aircraft crashworthiness and conformance with certification standards. Designing aircraft to resist soft impact damage relies heavily upon physical testing. Full components must be subjected to high velocity impact with birds or bird surrogates. This approach is hindered by high cost, long development cycles, test complexity, and data collection difficulties due to short-duration impact, high impact forces, and potential for damage to structures and measuring equipment. As a result, alternative strategies are sought to identify damage mechanisms that cause failure and drive design efforts. Here, computational analysis involving finite element method (FEM) has shown promise but is often challenged by the complexity of composite structures, i.e. damage accumulation and concurrent failure mechanisms. What is needed is a Durability and Damage Tolerance (D&DT) methodology that incorporates Progressive Failure Dynamic Analysis (PFDA), identifies failure mechanisms and their contribution to damage evolution, and predicts the result of soft body impact on structures.

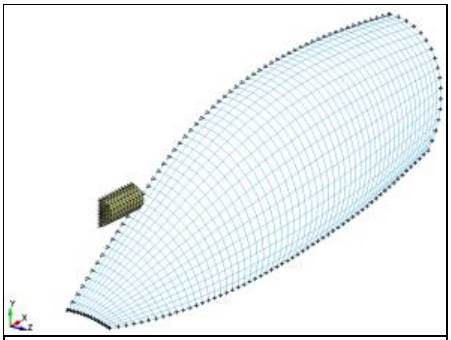
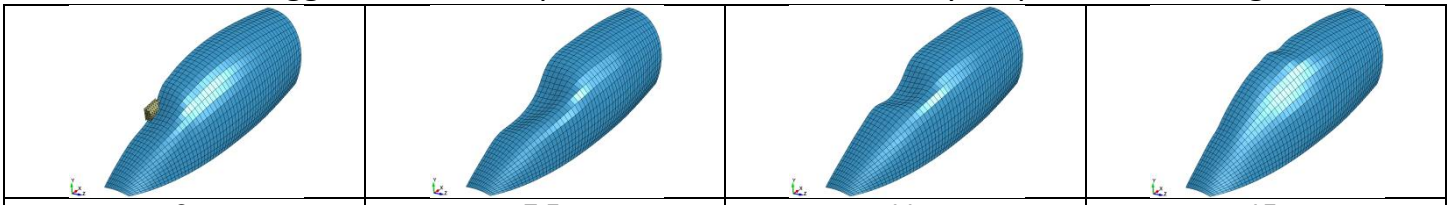


Figure 2. Symmetric ½ Model

Solution

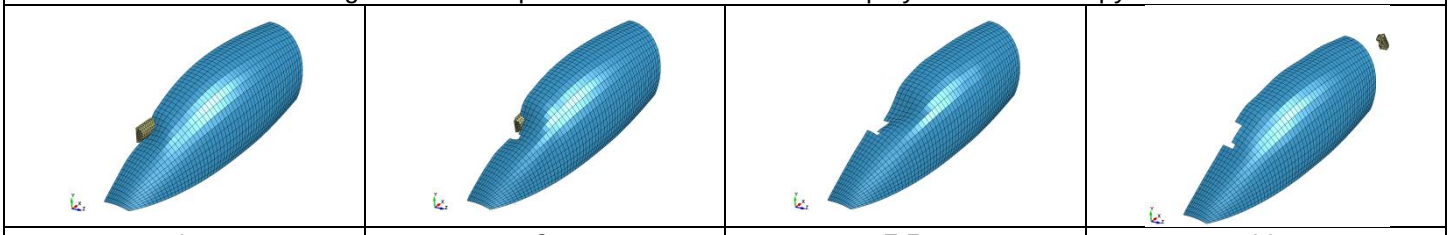
GENOA has been developed to predict the behavior of structures fabricated from fiber-reinforced composite materials. In the current effort, structural and material models of the F-16 canopy and the bird were developed for the simulation. Two initial bird velocity scenarios were modeled, i.e. 180 m/s and 230 m/s. In the simulated collision, the bird induced large deformations in the structure. For the 180 m/s case, the canopy was heavily deformed by the soft impact but did not experience stresses sufficient to cause failure. For the 230 m/s case,

the canopy experienced failure after impact, which supports experimental results. In addition GENOA identified each element subject to each damage mechanism, and the corresponding percentage contribution. For Figure 5, at t=1.1 ms, 50% of the damaged elements failed due to longitudinal tension; 50% failed due to transverse tension, and 100% failed due to the MDE criterion, which suggests that multiple failure mechanisms may be present in a single element.



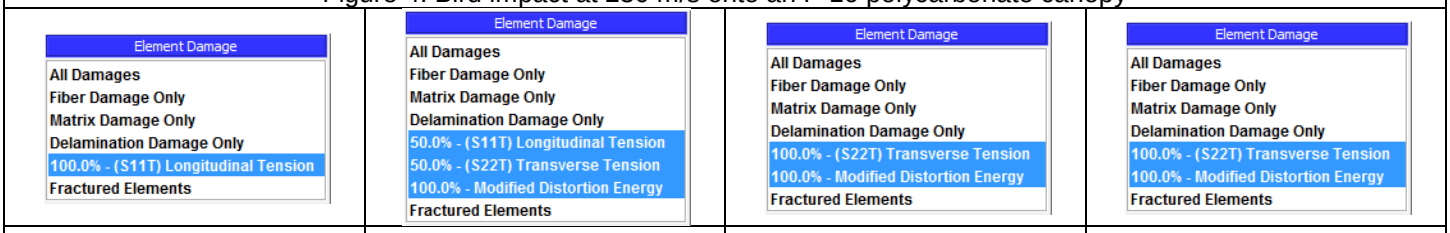
t = 2 ms	t = 7.5 ms	t = 11 ms	t = 15 ms

Figure 3. Bird impact at 180 m/s onto an F-16 polycarbonate canopy



t = 1 ms	t = 2 ms	t = 7.5 ms	t = 11 ms

Figure 4. Bird impact at 230 m/s onto an F-16 polycarbonate canopy



t = 1 ms	t = 1.1 ms	t = 1.3 ms	t = 3 ms

Figure 5. Progressive failure of a canopy impacted by a bird at 230 m/s

Results/Conclusions/Benefits

- GENOA supports component design to withstand bird strike.
- Knowledge of damage initiation and progression is critical to design.

Key Highlights
Product: MCQ-Composites, GENOA
Industry: Aerospace
Application: Soft Impact, Progressive Failure
Performance: Durability and Damage Tolerance

- To prevent failure to the canopy, redesign could be aimed towards increasing the canopy's strength or reducing stresses the canopy experiences in the longitudinal direction.
- GENOA provides a new level of information to confirm safety and performance.

Reference

Abdi, F. et al, "Soft Impact Damage Prediction for the F-16 Canopy Using a Progressive Failure Dynamic Analysis Approach," SAMPE 2011, Long Beach, CA.