Efficient simulation of the through-the-thickness damage composition in composite aircraft structures for use with integrated SHM systems

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Abstract

Fiber-reinforced composite structures are a key technology in modern aircraft design due to their high stiffness and strength values at low weight and the increasing demands on CO-2 emissions. Disadvantageous is their vulnerability to impact damage caused by e.g. hail or ice shedding during operation of the aircraft or accidental tool-drop during maintenance. These events lead to so-called BVIDs (Barely Visible Impact Damage), which can be reliably detected using SHM (Structural Health Monitoring) systems. This is true for the location and the size of the damage rather than its kind. The information about the through-the-thickness composition of the damage is lost, which is a major drawback when it comes to damage assessment.

However, SHM systems can be used also to gather information about the impact event itself, such as its amplitude and duration. Under the assumption that an integrated SHM system can provide this or similar information, a low-fidelity finite element (FE) simulation methodology has been developed to derive the time-variant pressure distribution acting on the structure during the impact.

The methodology is implemented as a FORTRAN library compatible with the commercial FE program ABAQUS. The computational effort is reduced by discretizing the impacted structure with a single layer of 8-noded quadrilateral shell elements. The three-dimensional stress-state in each ply is recovered at the start of each increment, allowing the usage of modern three-dimensional failure criteria. The damage initiation is subdivided into fiber, matrix and delamination, and the damage evolution is described by a set of increment-wise linearized functions. Selected results are compared to numerical and experimental data from literature to highlight the potential and validity of the proposed approach.

In conclusion, the methodology gives a fast impression of the through-the-thickness damage composition by using a low-fidelity FE simulation. Subsequently, this information can be used to assess the severity of the damage directly or serve as input for a more detailed FE analysis. The feasibility of the approach is presented and discussed by the example of a fuselage section.

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