Damage Tolerant Composite Design Principals for Aircraft Components Under Static Service Loading using Multi-Scale Progressive Failure Analysis

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Abstract

The overall objective of this effort was to provide theoretical prediction for damage development for a set of laminated composites using Alpha STAR Corporations' (**ASC**) commercial code **GENOA** (GENeral Optimization Analyzer) for the Air Force Research Laboratory (**AFRL**) program entitled "Damage Tolerance Design Principles (**DTDP**)". Damage progression and prediction for advance composite benchmarks were done under static and fatigue service loading using test data from Lockheed Martin Aeronautics (**LMA**) and AFRL. In current paper, the results for the static analysis are presented. Emerging and innovative Multi-Scale (**MS**) modeling using Computational Structural Mechanics (**CSM**) and Progressive Failure Analysis (**PFA**) were proven to address the Air Force's vision to perform predictive evaluation of composite materials using a building block validation strategy and certification process. Three layups were tested in tension and compression for unnotched and openhole configurations. Calibration of the fiber and matrix properties was performed using in plane, 3pt bend and DCB test data. After which, mesh convergence, solver selection based on CPU time, and mesh sensitivities was performed. The static blind simulations of strength showed an average error of 12.9% between simulation and the test data. For stiffness the percent difference was found to be 23.5% on average. Although the focus was on the ability to blindly predict test data, recalibration efforts shows an average of 9.2% difference between simulation and test for strengths and 12.4% for stiffness computations. Damage at ~60-75% and ~90% of max loading was comparable with X Ray observations of specimens set aside solely for that purpose. All simulations used the same set of inputs (constituents, voids, fiber waviness, etc) except for the noted analysis setting differences between blind and recalibration simulations. The method is consistent and follows a building block simulation approach that has an advanced yet simplistic theoretical multi-scale progressive failure analysis (MS-PFA) approach all contained in the commercial GENOA software. The method was demonstrated to work having GENOA directly run sequential NASTRAN simulations and, post project completion, with the ABAQUS solver using GENOA as a material subroutine.

Keyword: 1) Virtual Testing, 2) Static, 3) Multi-Scale Progressive Failure Analysis, 4) Damage and Fracture Evolution, 5) Progressive Failure, 6) Durability and Damage Tolerance, 7) ASTM Coupons, 8) Building Block Validation Strategy, 9) Open Hole, 10) Polymer Matrix Composites, 11) IM7/977-3