Notch Sensitivity and Damage Tolerance of Composite Sandwich Structures

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ABSTRACT

Whereas the development of testing and analysis methods for notch sensitivity, fracture mechanics, and damage tolerance of monolithic composite laminates has reached a relatively high level of maturity, considerably less emphasis to date has been placed on investigating these topics for composite sandwich structures. The primary focus of this research investigation is the development of test methods and assessment of existing numerical analysis methodologies in these areas. Research in sandwich composite notch sensitivity has focused on testing and analysis of both open-hole edgewise compression and open-hole four-point flexural loading configurations. A notched-core shear-loading test configuration as well as an open-faced sandwich flexure test were used to investigate sandwich core damage progressions from induced stress concentrations. Numerical modeling of the tests was performed to calibrate in-situ core strength and damage progression parameters for use in subsequent analyses. Additionally, best practices for modeling damage progression in sandwich core were assessed.

Several remaining issues associated with the Mode I single cantilever beam (SCB) test method have been addressed following initial rounds of ASTM subcommittee balloting. Included were the methods for fracture toughness determination associated with disbond initiation and propagation measurements. Further development of the Mode II separated end-notched flexure (S-ENF) test method as well as the sandwich mixed-mode bend (MMB) test continued as part of the recently initiated U.S.-led sandwich disbond building block activity. The SCB test method was also used to assess the residual fracture toughness of pre-crushed Nomex honeycomb core material under Mode I loading. Of particular interest was an assessment of the damage tolerance of crushed Nomex honeycomb core following a blunt-object impact that produces core crushing with minimal facesheet damage and no facesheet/core debonding.

Finally, efforts continued towards the ASTM standardization of damage tolerance test methods for both sandwich compression-after-impact (CAI) and four-point flexure-after-impact (FAI). The draft standard for the Sandwich CAI was submitted for initial ASTM balloting. To provide for calibration of damage parameters and validation of predicted failure progressions, additional edgewise compression and four-point flexure testing were performed using sandwich specimens with intentionally fabricated facesheet/core disbonds of a prescribed size and shape using Teflon inserts. Full-field strains were measured using Digital Image Correlation (DIC) for use in comparison with numerical predictions. Results are being used to assess the Riks buckling analysis methodology in ABAQUS standard in conjunction with the add-on progressive damage modeling software NDBILIN from Materials Sciences Corporation and interface cohesive elements for facesheet/core disbonding.