Characterization & Testing of Composites for Aerospace Structures

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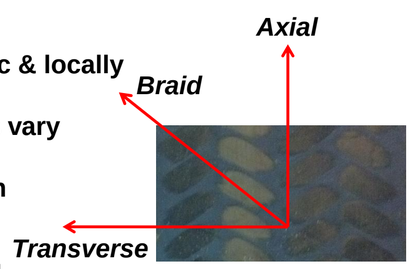
Objectives:

- **Mechanical & environmental testing of triaxially braided composites**
- **Testing & analysis of adhesively bonded load paths in fan containment structures**
- **Hybrid & monolithic cruciform biaxial testing of materials under consideration for wing & fuselage applications**
- **Bolted joint repair bearing failure mechanical testing & post mortem characterization**

Triaxial Composite Characterization & Experiment Matrix

Challenges

- Material is globally orthotropic & locally anisotropic
- Multiple damage mechanisms vary with load direction
- Complicated specimen design



Experimental Matrix

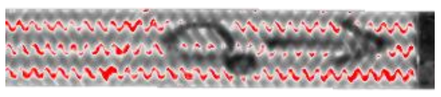
- Single & 6 ply coupons tested
- Uniaxial monotonic, load/unload, & biaxial specimens prepared
- Unaged/aged (physical), hot, & hot/wet testing conditions
- Failure & damage mechanisms captured through NDE & traditional methods

Characterization Parameters

- Volume fraction
- In-plane stiffness matrix
- Nonlinear parameters
- Elastic/Inelastic damage
- Ultimate strengths, strain to failure

Pretesting Methods & Analysis

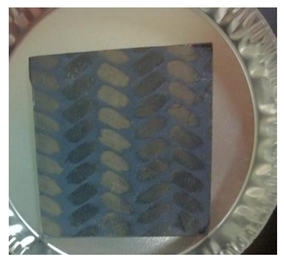
- EchoTherm flash thermography images taken to visualize any manufacturing related defects before testing
- Speckling required for proper ARAMIS strain field detection
- For aged testing, specimens weighed & placed in an environmental chamber at 60°C & 90% RH



EchoThermo flash thermography image

Volume Fraction Testing

- Burn-off tests performed using muffler furnace at 475°C
- Specimens remain in furnace until no polymer matrix remains
- Fiber volume fractions determined from mass loss & constituent densities



Before

After

Samples are 56% Volume Fraction +/- 3%

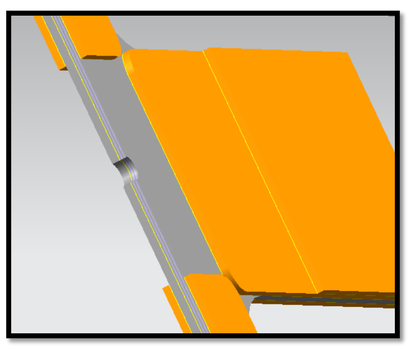
Hybrid Composite Overview

Challenges

- Characterization & comparison of hybrid fiber metal laminates
- Composite & metal failure modes in the same material

Matrix

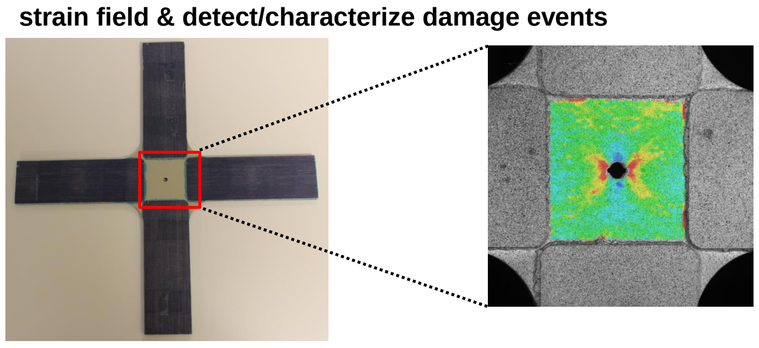
- Open-holed cruciform monolithic & hybrid composite specimens
- Design includes GLARE strap & variable fiber lamina orientations
- Fatigue & static testing for S/N curve & material properties
- Develop a failure model for implementation into commercial FEM software



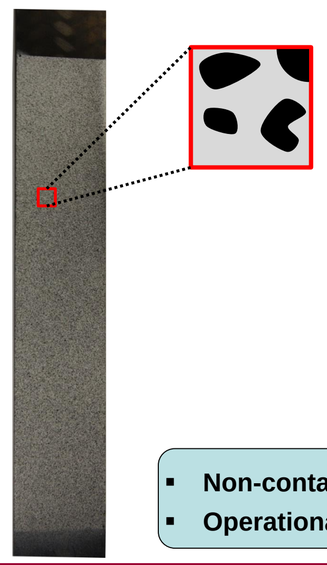
Hybrid Composite Testing

Experimental

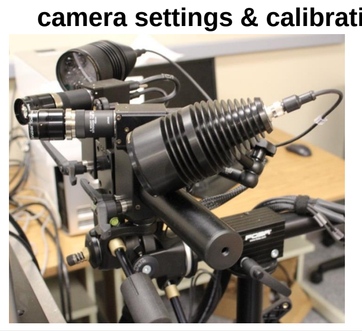
- Perform fatigue & static biaxial tensile testing of hybrid composites
- Optically track crack growth & failure progression during testing
- Use ARAMIS & acoustic emission systems to measure 3D strain field & detect/characterize damage events



ARAMIS – Digital Image Correlation



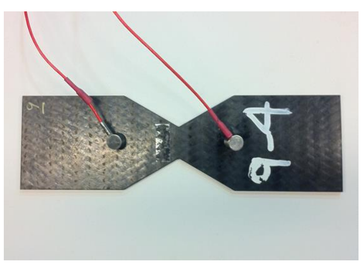
- 80 μstrain resolution
- 1 mm x 1 mm field of view
- Similar sized dots for consistent camera settings & calibration

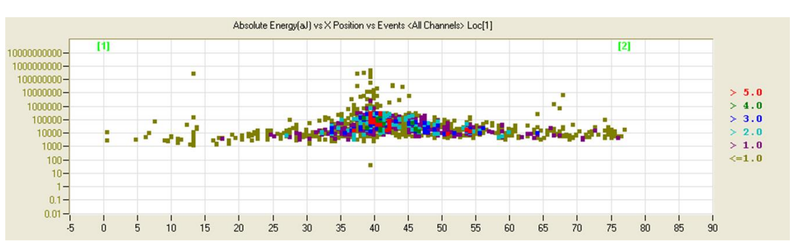


- Non-contact full field strain measurement system
- Operational through thermal chamber window

Acoustic Emission

- Useful for determining initiation & progression of matrix cracking & fiber breakage
- Sensor placement in the gage section
- High temperature sensors for thermal/mechanical testing



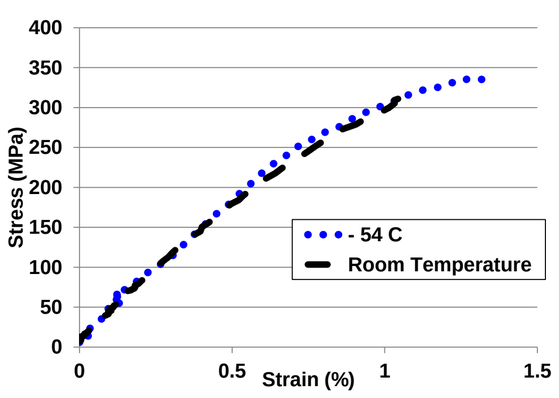


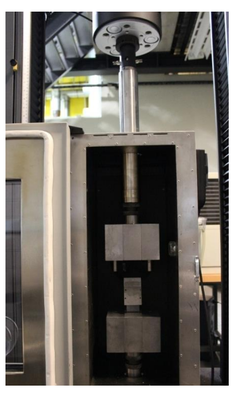
Environmental Chamber Aging

- Material performance & behavior dependent on current temperature/humidity as well as past loading cycles
- High temperatures & moisture degrade stiffness & strength but increase ductility
- Low temperatures increase stiffness & strength but reduce ductility
- Understanding true material behavior increase reliability, lowers weight, & increases efficiency

- Temperature Range: -65°C to 200°C
- Humidity Range: 0% to 95% RH

Instron Frame with Environmental Chamber





Comparison of the axial compressive response at cold temperatures & room temperature

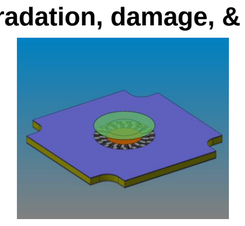
Composite Testing for Bolted Joint & Sandwich Panel Repair Analysis Tools

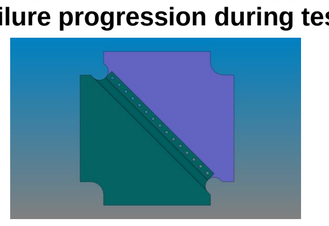
Objectives

- Multi-modal data acquisition strategy for progressive failure analysis
- Calibration, validation, & uncertainty quantification of analysis models

Key Tasks

- Design biaxial test specimens for bolted joint & sandwich repair failure analyses
- Develop multi-modal data acquisition methodology to track degradation, damage, & failure progression during testing





Validation Testing for Bolted Joint & Sandwich Panel Repair Analysis Tools

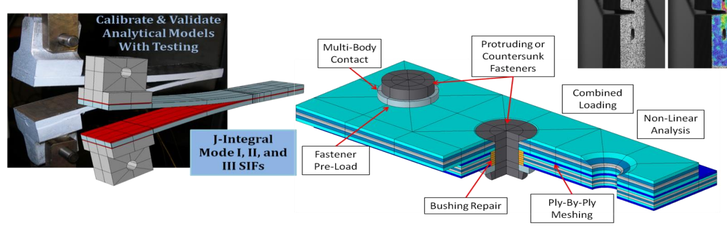
Challenges

- Digital signal processing & synergistic combination of modalities
- Generating desired degradation, damage, & failure modes in tests

Solutions

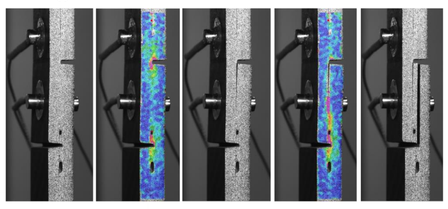
- Develop solid mechanics thermodynamic representation of each type of specimen

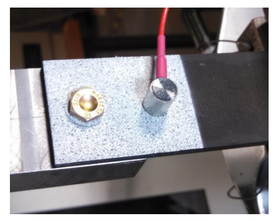
Analysis & Test

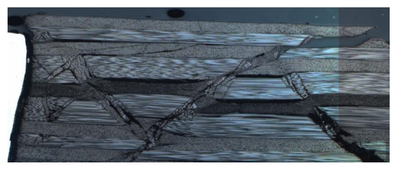


In Situ Strain Field Measurement & Post Mortem Failure Characterization

- ARAMIS digital image correlation & acoustic emission systems used to quantify strain & damage progression during loading sceneries
- Optical microscopy provides post mortem failure & damage information







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