Certification of Discontinuous Composite Material Forms for Aircraft Structures

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A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

CECAM center of excellence for composites and advanced materials

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- Motivation
  - Discontinuous fiber composites (DFC) are being used in aircraft and automotive structures because (relative to continuous fiber composites):
    - ease of manufacturing complex parts
    - high delamination resistance
    - near quasi-isotropic in-plane stiffness and reasonable in-plane strengths
    - high out-of-plane strength-stiffness
    - low notch sensitivity

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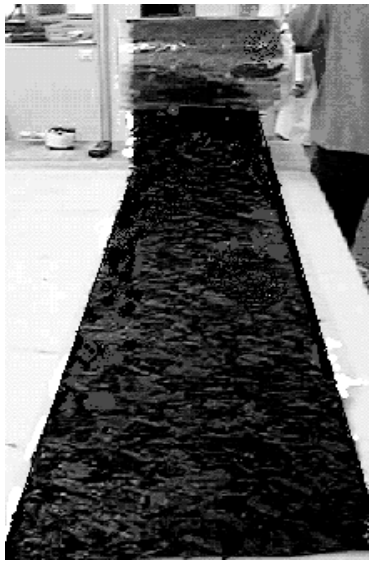
Hexcel HexMC is one type of DFC:

- AS4/8551UD prepreg is slit-chopped-randomly distributed in “new” preg roll:

chips: ~9 x 50mm
(0.35 x 2.0in)

prepreg: ~2 x 450 mm
(0.08 x 18 in)

laminate: ~35-38% RC by weight



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Rule Die Kit and Stage

Lay-in L-shaped Front and Back Rib Plies

De-mold Net Shaped Part

Prep and Heat Mold

Lay-in Flange Plies

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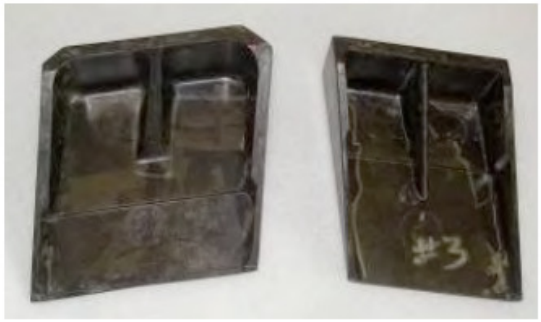
…example DCF (HexMC) parts produced using compression molding (photos courtesy of B. Boursier of Hexcel)



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- Key Issues
  - Rigorous structural analyses currently very difficult ("impossible"):
    - rel high variability in all mechanical properties
    - lack of material allowables
    - lack of standard design or analysis methods
  - Consequently certification of DFC parts currently require testing large numbers of parts ("point design")…issues:
    - Time-consuming
    - Expensive for all (material producer, part manufacturer, aircraft manufacturer, FAA)
    - Leads to suboptimal (e.g., overweight) parts

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- Overall objective: Simplify certification of discontinuous fiber composite aircraft parts

Project Information

- Personnel Involved:

  University of Washington:
  Paolo Feraboli, Tyler Cleveland, Marissa Morgan (A&A Dept)
  Mark Tuttle, Paul Labossiere, *Tory Shifman* (ME Dept)
  Hexcel (principally):
  Bruno Boursier (Dublin, CA)
  Dave Barr (Kent, WA)
  Boeing (principally):
  Bill Avery (Seattle, WA)
  FAA (principally):
  Larry Ilcewicz (Renton, WA)

- FAA Technical Monitor:

  Curt Davies (Atlantic City, NJ)

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- Objective:
  - Simplify certification of DFC structures

- Technical Approach:
  - Use HexMC as model material
  - Four-year study envisioned, although funding and specific technical tasks reviewed & (re)defined annually
  - All specific technical tasks defined with reference to the "building block philosophy" (MIL-HDBK-17)

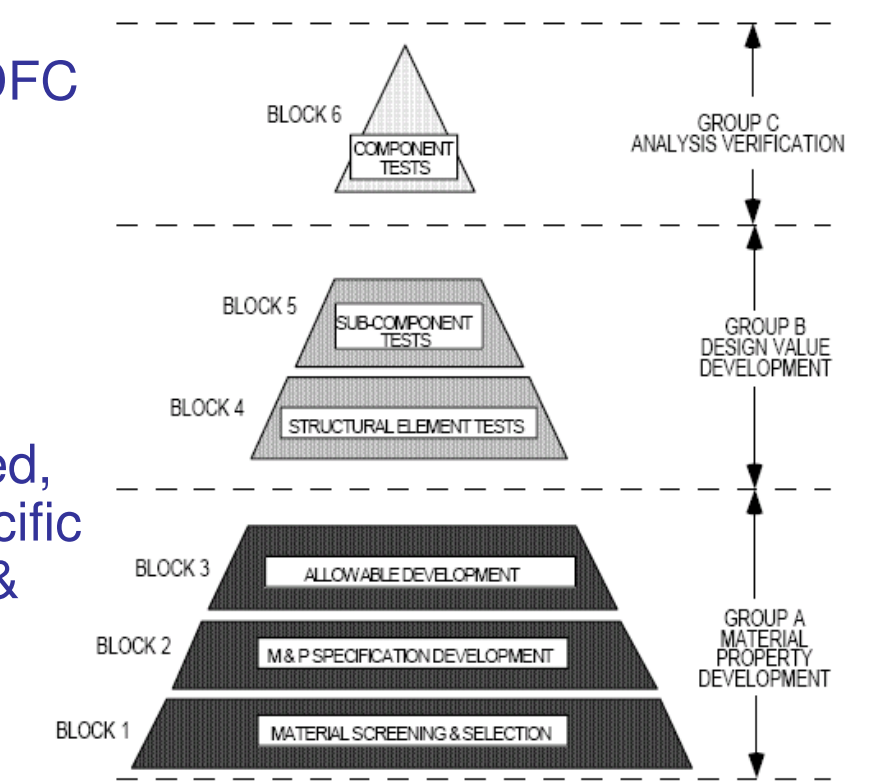

FIGURE 4.4.3.2 *Building block approach.*

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- Technical Tasks (4-year):
  - Blocks 1,2,3 :
    - Hexcel: Generate allowables database: UNT, UNC, OHT, OHC, FHT, FHC, bearing, bearing/ by-pass, etc. Fabricate panels/etc needed for coupon-level UW studies
    - UW-Tuttle:
      - Evaluate and develop understanding of effects of ply drops/adds (ply drop rate, part thickness, and molding-related issues such as high- vs low-flow areas)
      - Evaluate and develop understanding of load redistribution and failure at or near part fastener locations
      - Evaluate and understand the effect of NDI indications on properties/performance

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- Technical Tasks (4-year):
  - Blocks 4,5,6 :
    - Hexcel: Fabricate specimens-subcomponents-components as needed
    - UW-Feraboli: Develop semi-empirical analysis methods to account for features in selected aircraft part (intercostal selected for 2008-09). Features being studied include:
      - Deep-web panel bending, tension and compression, with and without lightening holes.
      - Thickness transitions.
      - Large lightening holes.
      - Damage (BVID, saw cuts or other surface nicks and embedded defects in the most critical locations)

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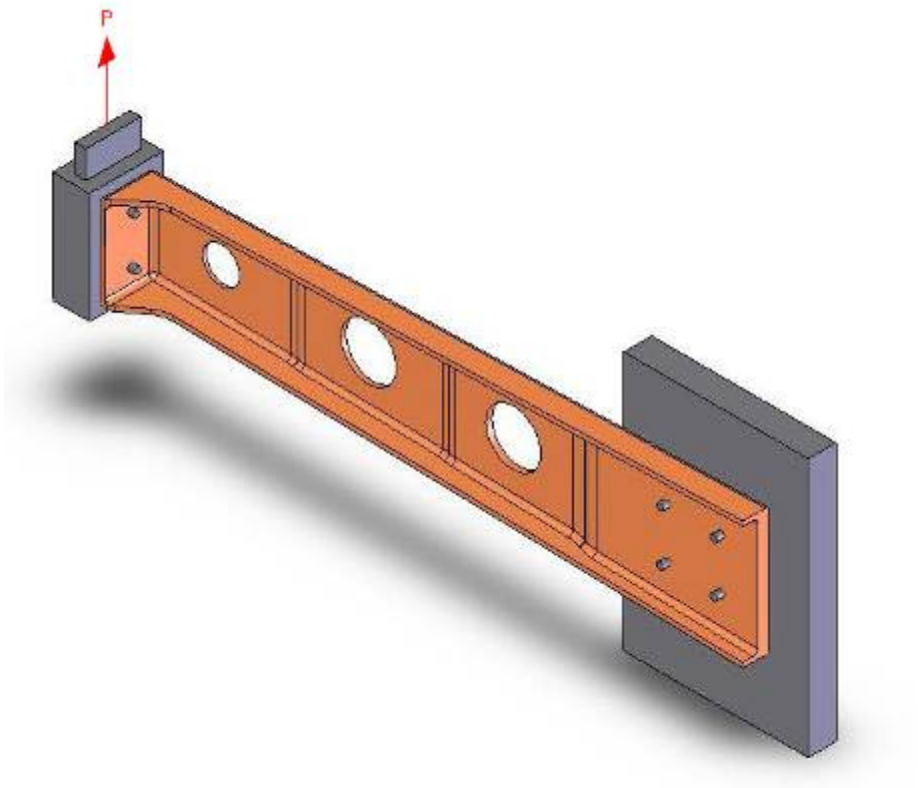
Intercostal selected for study:



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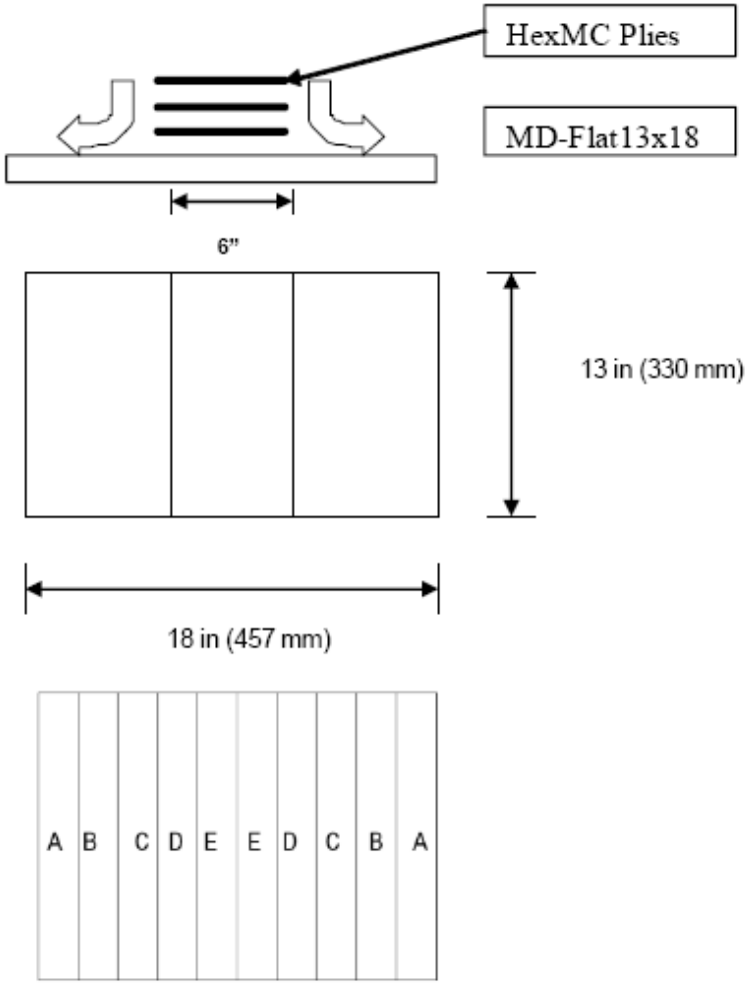
(A sampling of current activities & preliminary results):

- Characterizing structure in high-flow vs low-flow regions
- Modulus measurements:
  - Strain gages
  - Digital Image Correlation
- UNT & OHT versus UNC & OHC tests
- Beam flexural testing

High-and Low-Flow Panels

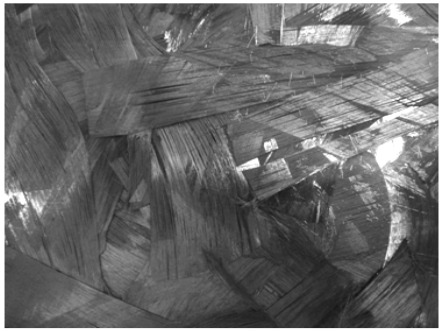
Hexcel fabricated delivered multiple panels:

- in-plane dimensions 13x18 in
- thicknesses: 0.090, 0.140, 0.230 in



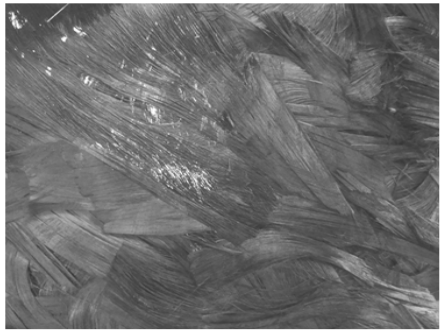
High-and Low-Flow Panels

Some initial qualitative observations



Large chip random distribution
Mostly straight fibers
Separate layering

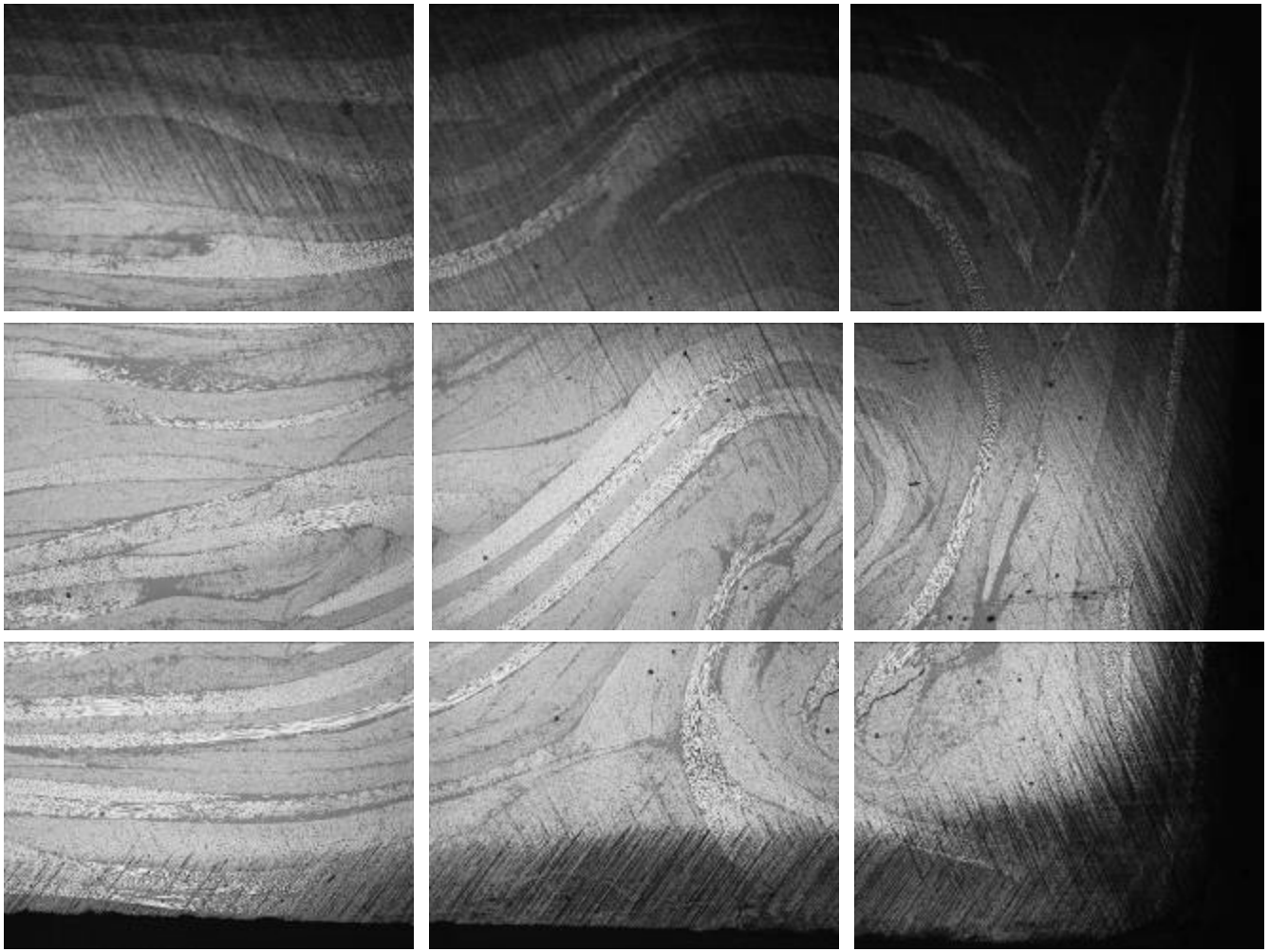
Large chip aligned distribution
Some curved fibers
Some intertwining of layers



Small chip random distribution
Significantly curved fibers
Significant intertwining of layers

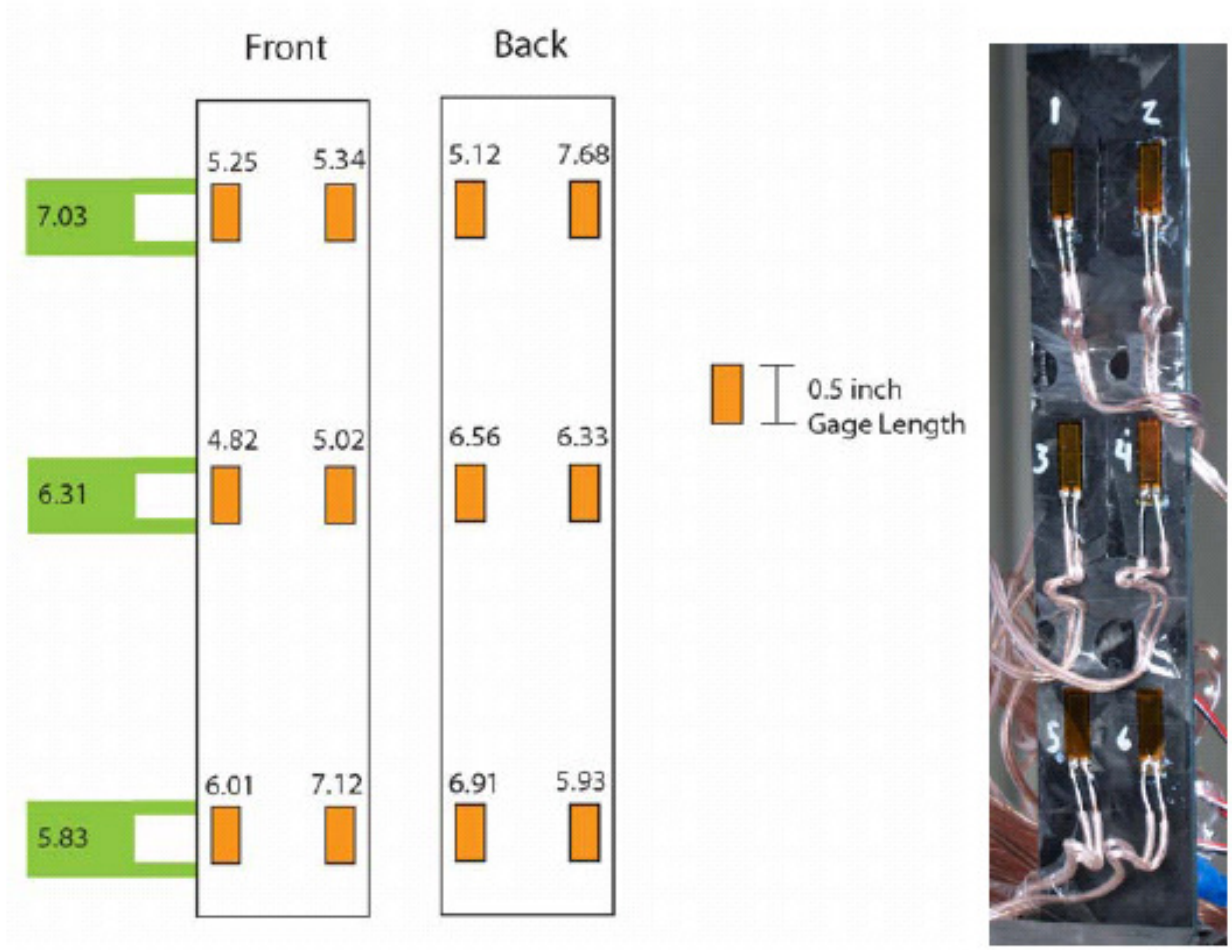
High-and Low-Flow Panels

Optical microscopic images near edge



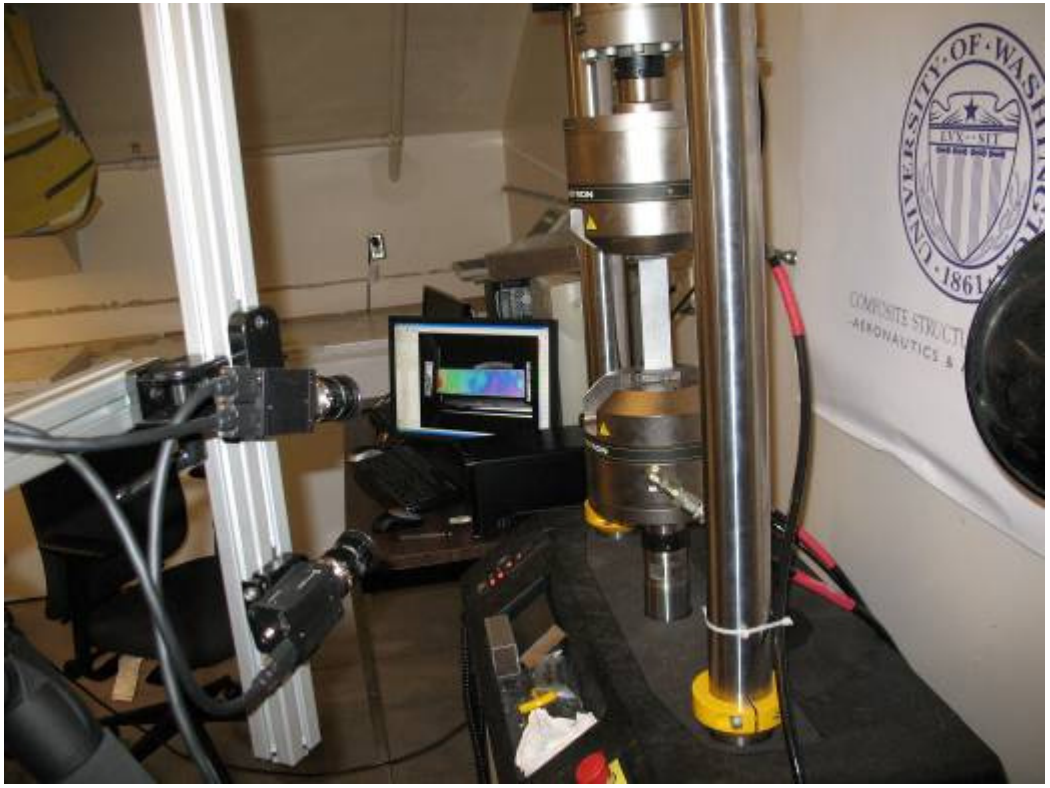
Modulus Measurements

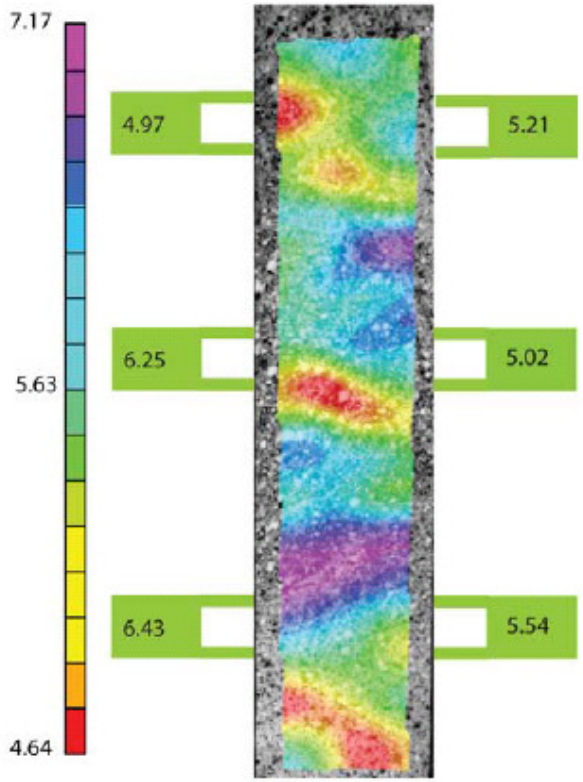
Strain gages measure "point" values



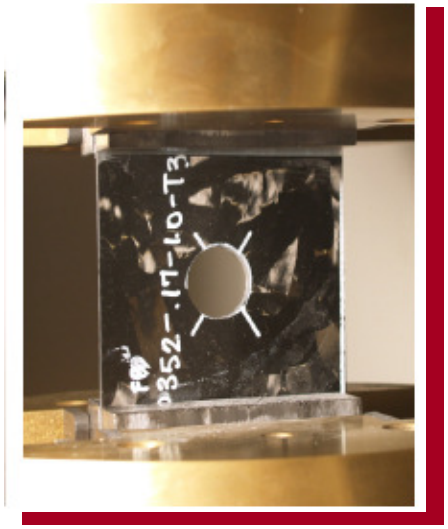
Modulus Measurements

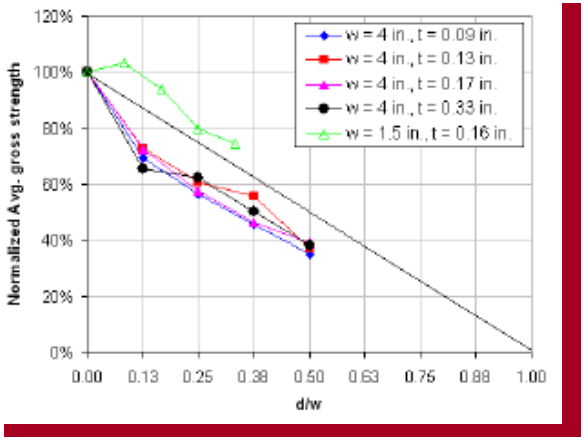
DIC measures "whole field" values





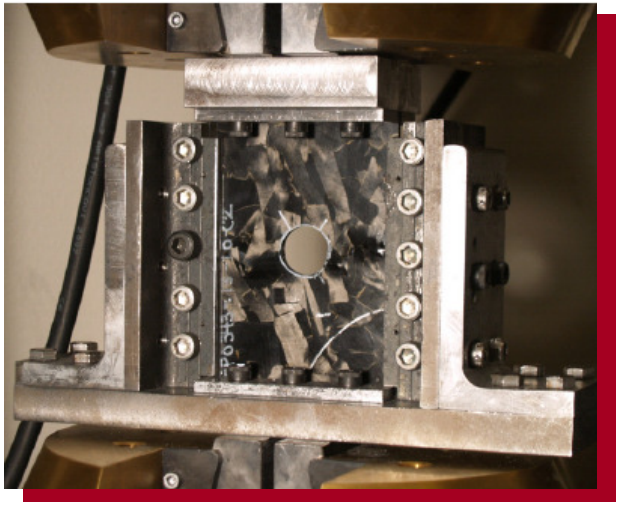
OHT Tests

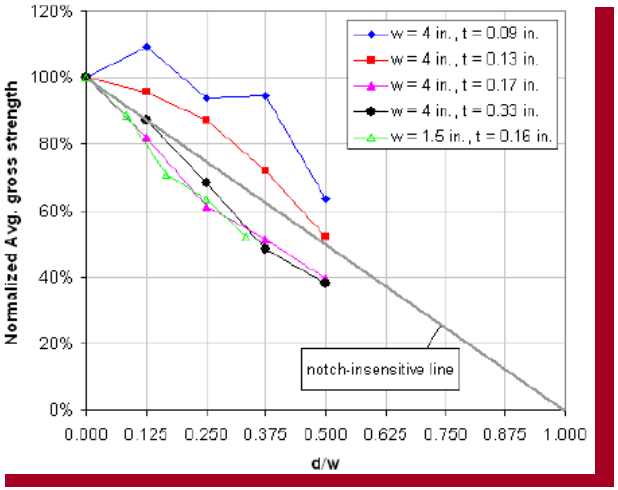




- Straight-sided tensile specimens w/square end-tabs (4 x 6 in CAI specimens)
- Five thicknesses: 0.09,0.13,0.17,0.33 in
- Four hole dia: 0.0, 0.5, 1.0, 2.0 in
- Three replicate tests (60 tests total)
- All failed at hole (or within gage)
- Gross strength independent of thickness
- Modest notch sensitivity (differs from 1.5 in coupon results)
- CoV: 2-15%, average = 9.7%

OHC Tests

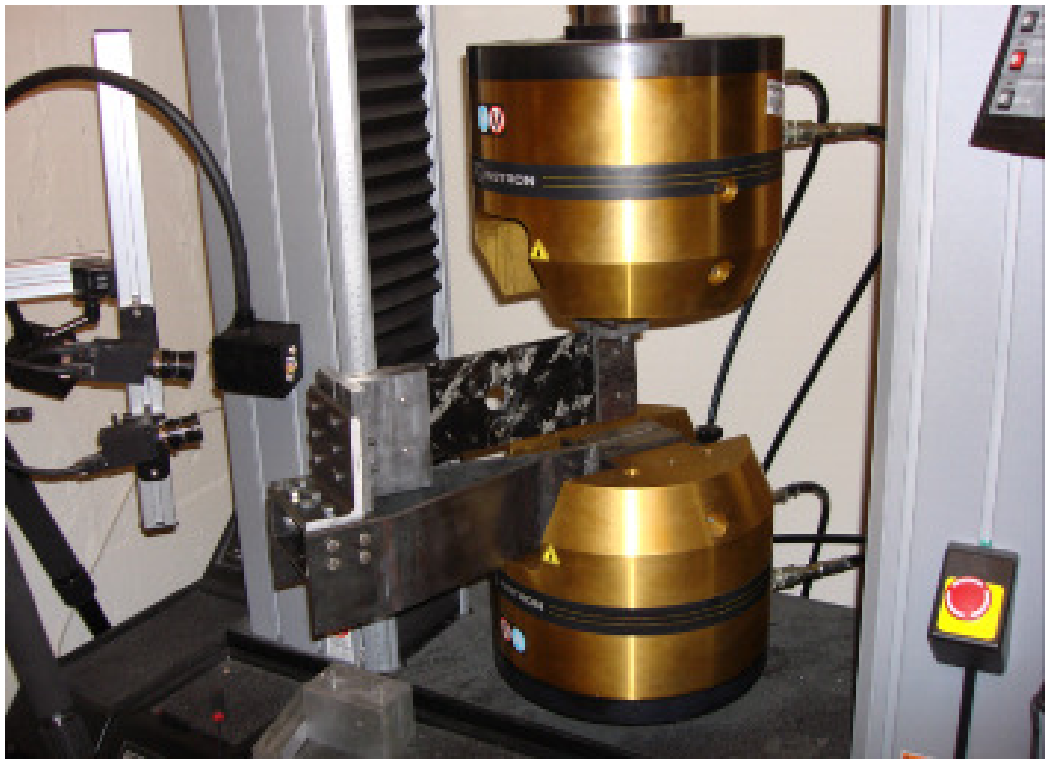




- Boeing CAI Fixture (4 x 6 in specimens)
- Five thicknesses: 0.09,0.13,0.17,0.33 in
- Four hole dia: 0.0, 0.5, 1.0, 2.0 in
- Three replicate tests (60 tests total)
- All failed at hole (or within gage)
- Gross strength thickness-dependent
- Lesser notch sensitivity
- CoV: 2-14%; average = 7.7%

Beam Flexural Testing

Fixture assembled recently, no data yet



Benefit to Aviation

FAA: Program objective supports safety regulations for design, production, and airworthiness certification of DFC parts

Industry: Program will contribute towards broader use of DFC structures at lower cost and lower weight

Academia: Represents an applied research project addressing an immediate need in industry and providing pertinent research & educational training for new aerospace engineers

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QUESTIONS ?