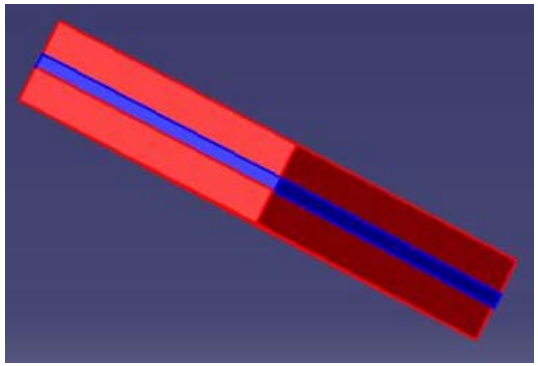
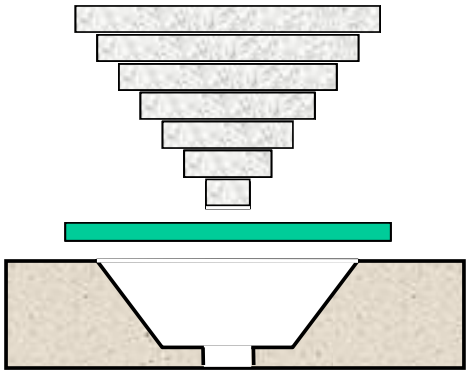
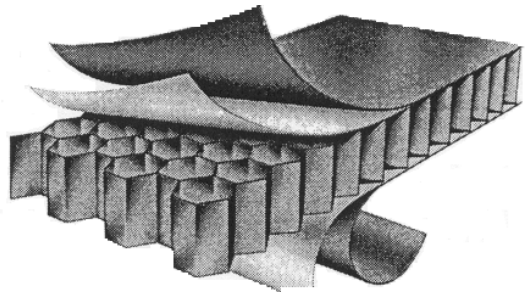
Improving In-Service Inspection of Composite Structures

CACRC Damage Assessment & Quality Inspection Task Group Update







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ITG Team Participants

CACRC Inspection Task Group Members:

John Hewitt – Airbus (Co-chair)
Jim Hofer - Boeing
Jeff Kollgaard – Boeing
Kirk Rackow - Sandia Labs AANC
Dennis Roach - Sandia Labs AANC (Co-chair)
Glae McDonald - US Airways
Darrell Thornton – UPS
Richard Watkins - Delta Air Lines
Bob Stevens – United Airlines
Eric Bartoletti – American Airlines
Alex Melton - Northwest Airlines
Ana Tocalino - Embraer

Dave Galella, Al Broz, Rusty Jones, Larry Ilcewicz – FAA

CACRC Inspection Task Group Activities

- **Composite NDI Handbook**
  - Complete (SAE ARP5089); requires update
- **Industry wide NDI Reference Standards**
  - Complete (SAE ARP5506 & 5507; DOE report distributed in June 2004)
- **NDI Assessment: Honeycomb Structures**
  - Experiments completed in 2007
  - DOT report in progress
- **NDI Assessment: Solid Laminate Structures**
  - Experiment development completed
- **Miscellaneous Ongoing and Planned Studies**
  - Detection and quantification of weak bonds
  - Affect of porosity, repairs & other impediments on NDI
  - As required to support main tasks & other task groups

Composite Inspection Reference Standards

- Industry-wide composite reference standards developed to support damage assessment & inspection – honeycomb & solid laminate
- SAE Aerospace Recommended Practices (ARP 5605 & 5606) - adopted into Boeing and Airbus NDT Manuals
- Improve inspections of composite structures via introduction of advanced NDI methods
- Provides consistent approach to composite inspections - harmonized approach by OEMs worldwide

Assessed all construction scenarios and determined the variables that affect NDI – final NDI Reference Standards designed accordingly

Optimized NDT Reference Standards

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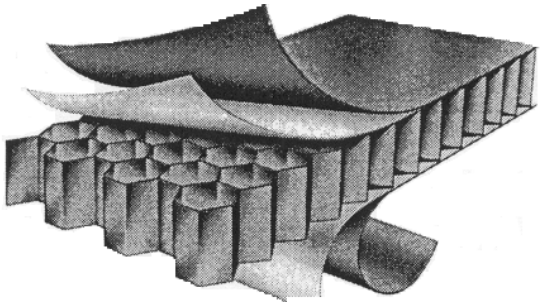
Composite Honeycomb Flaw Detection Experiment

Utilize airline inspectors to establish industry-wide performance curves that quantify:

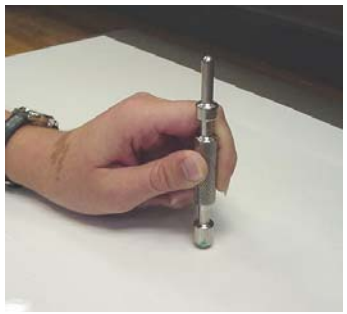
1) **how well current inspection techniques are able to reliably find flaws in composite structures**

2) **the degree of improvements possible through the integration of more advanced NDI techniques and procedures.**

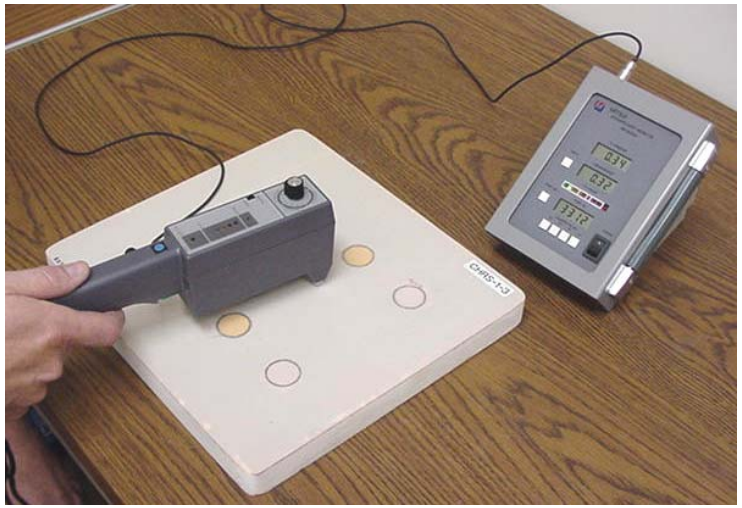
- **Statistically relevant and realistic flaw profiles**
- **Blind application of techniques to study hits, misses, false calls, and flaw sizing**



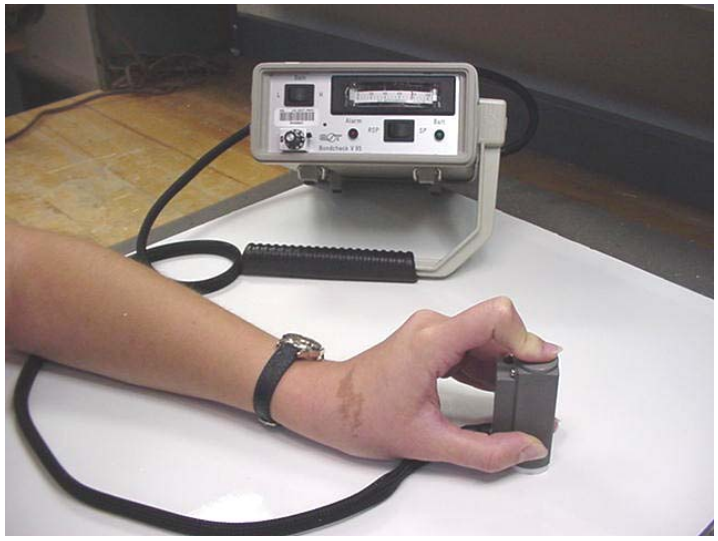
Conventional NDI Devices



Manual Tap Hammer



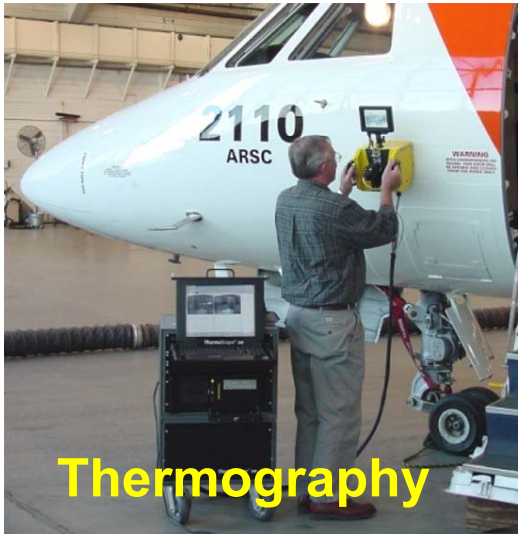
Automated Tap Hammer



V-95 Mechanical Impedance Analysis

S-9 Sondicator (LFBT)

Wide Area and C-Scan Inspection Methods



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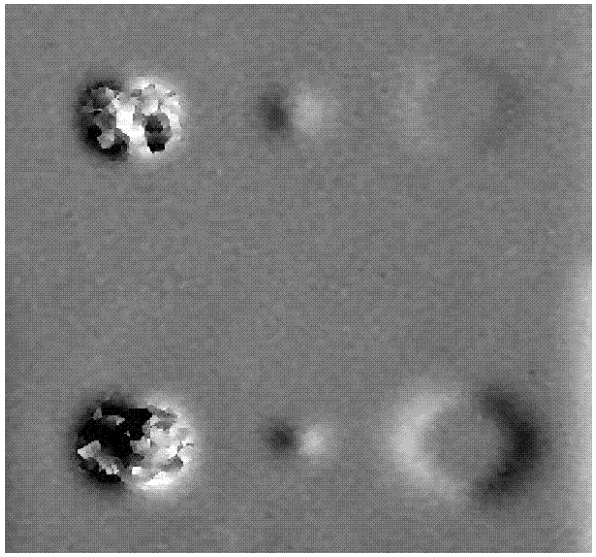
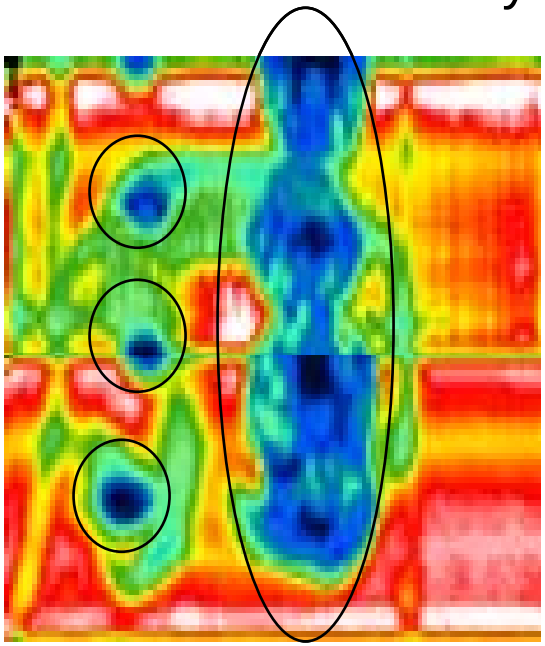
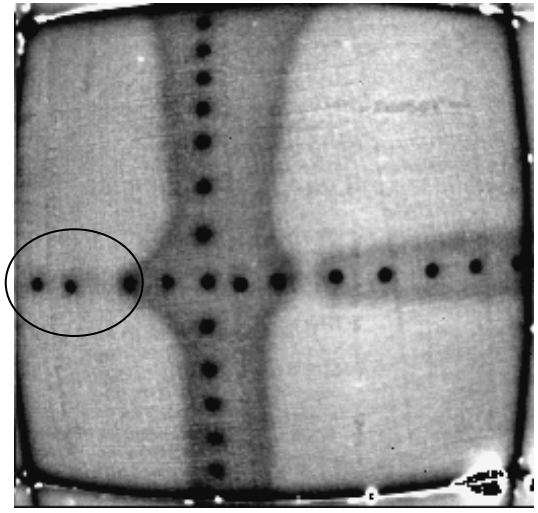
Shearography (LTI) Image

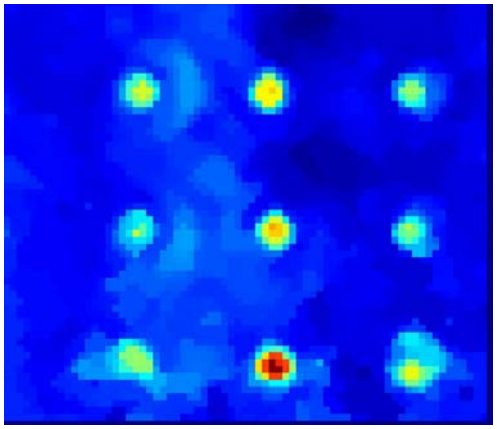


Ultrasonic Wheel Array

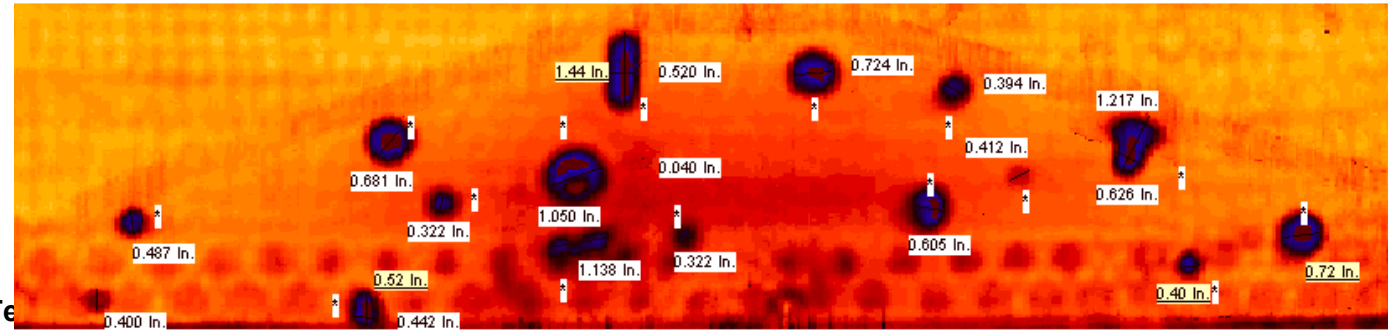


Thermography (TWI) Image





SAM Image



MAUS Image

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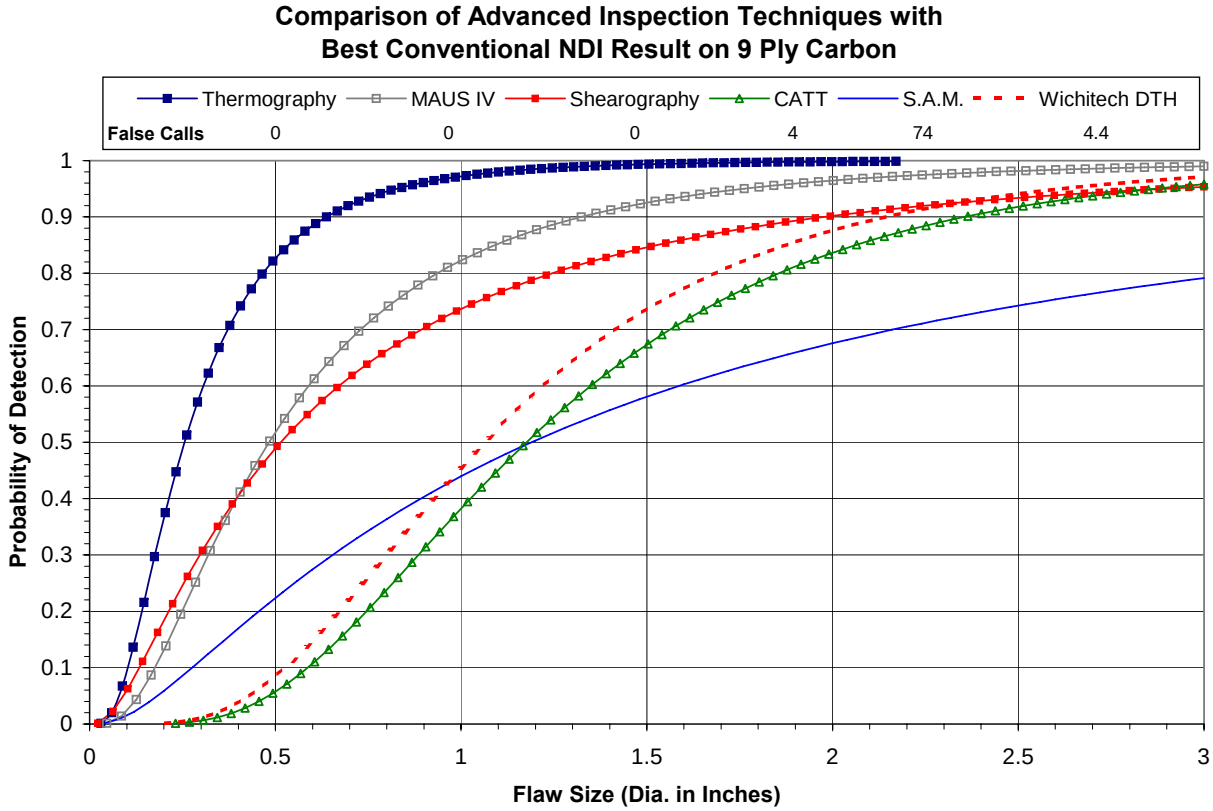
Performance of Multiple Devices for A Single Type of Test Specimen



Results - evaluate performance attributes

1) accuracy & sensitivity (hits, misses, false calls, sizing)
2) versatility, portability, complexity, inspection time (human factors)
3) produce guideline documents to improve inspections
4) introduce advanced NDI where warranted

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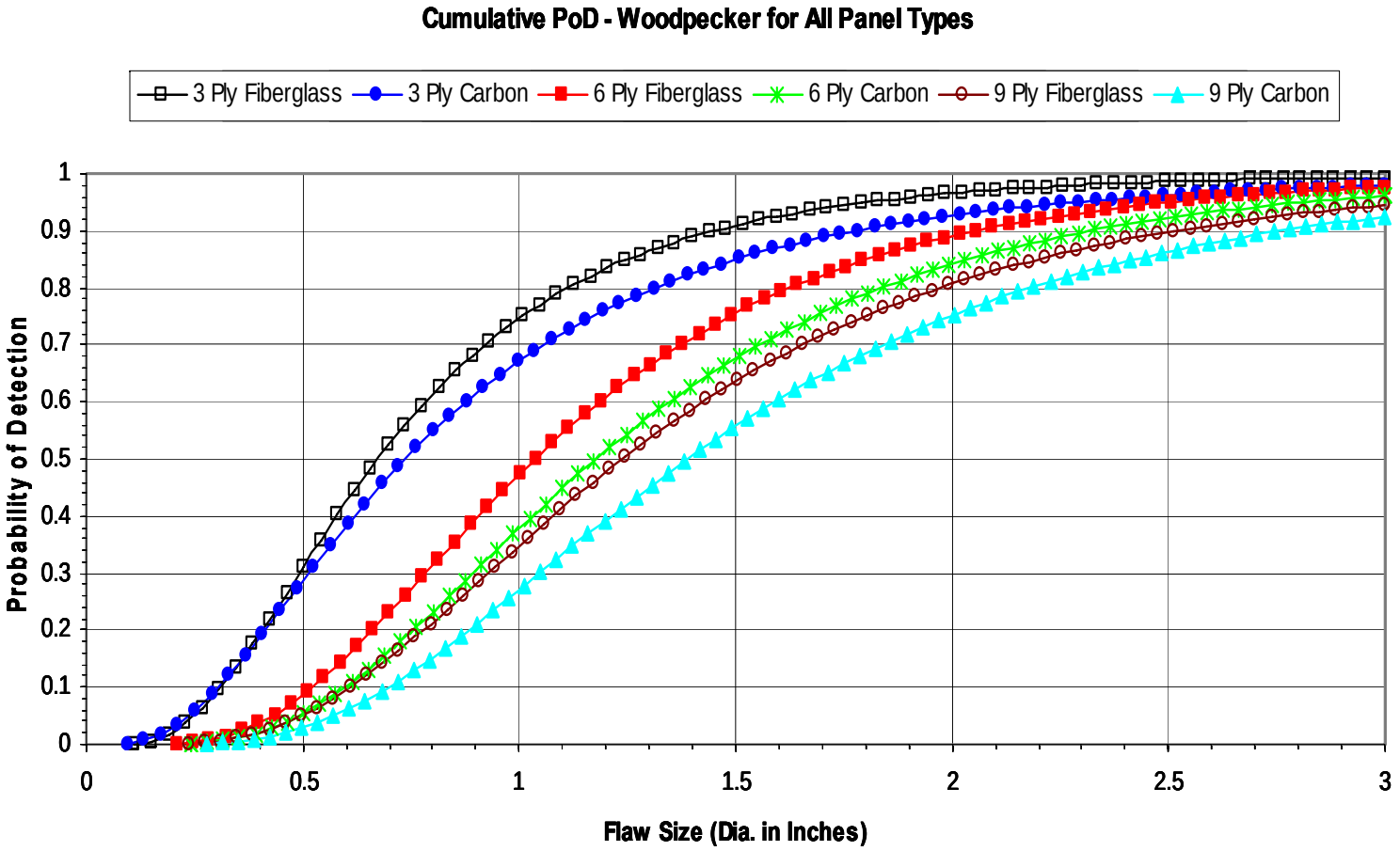
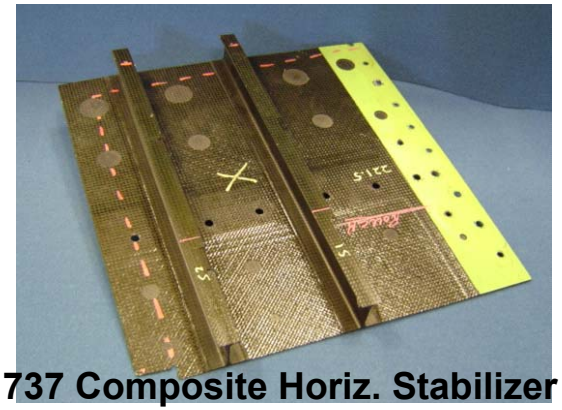
Performance of Single Device (Woodpecker) Over Range of Test Specimen Types



An Experiment to Assess Flaw Detection Performance in Composite Laminate Structures

Purpose

- Determine in-service flaw detection capabilities: 1) conventional NDT methods vs. 2) improvements through use of advanced NDT.
- Optimize laminate inspection procedures.
- Compare results from hand-held devices with results from scanning systems (focus on A-scan vs. C-scan and human factors issues in large area coverage).
- Provide additional information on laminate inspections for the "Composite Repair NDT/NDI Handbook" (ARP 5089).



737 Composite Horiz. Stabilizer

A380 Section 19

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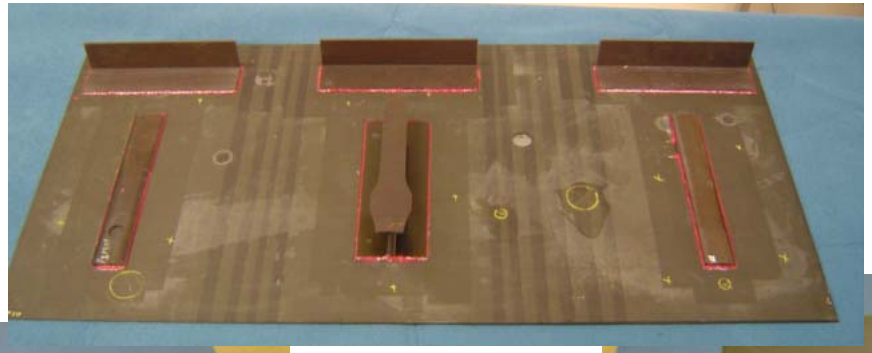
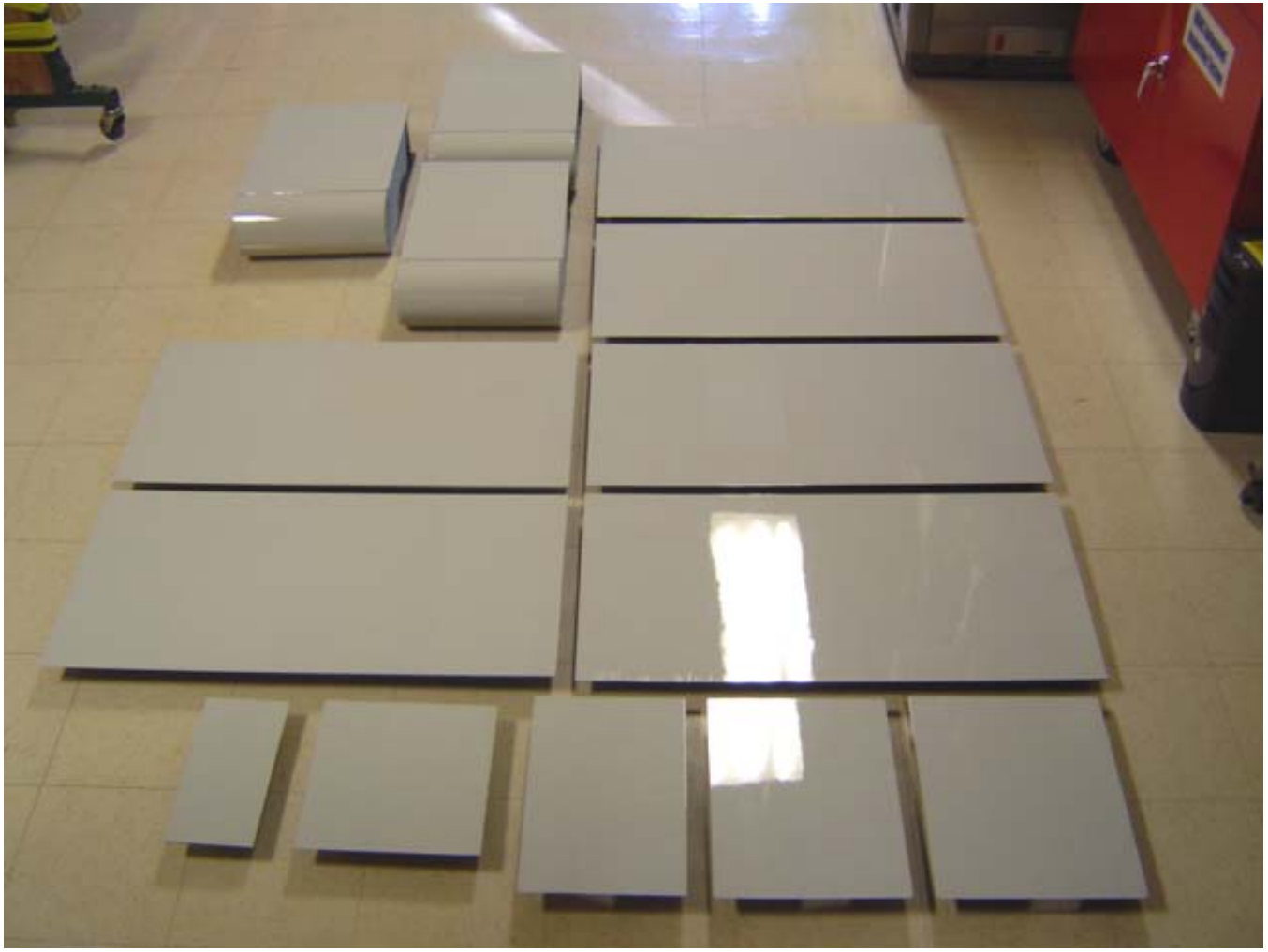
Thick Laminate With Complex & Simple Taper



Specimen Set - Flaw Detection in Solid Laminate Composites



Thickness Range: 12 – 64 plies

Simple Tapers

Complex tapers

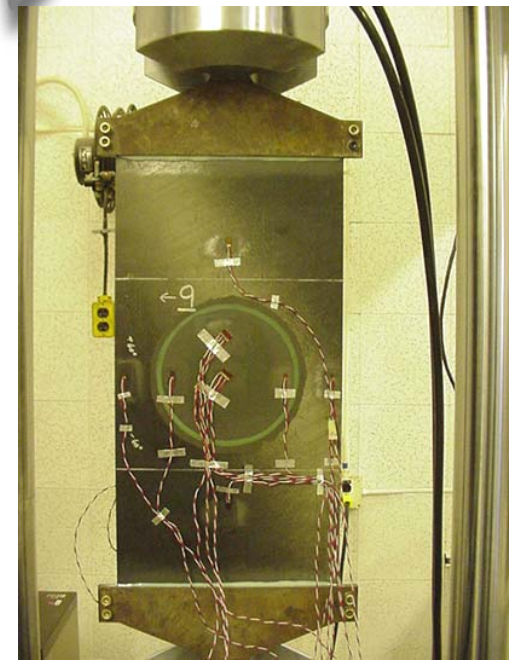
Substructure Flaws

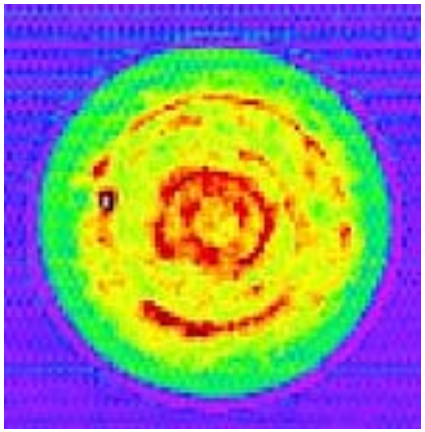
Curved Surfaces

Array of flaw types

NDI Ref. Stds.

Composite NDI & Laminate Repair Systems – Compare Mechanical & NDI Performance



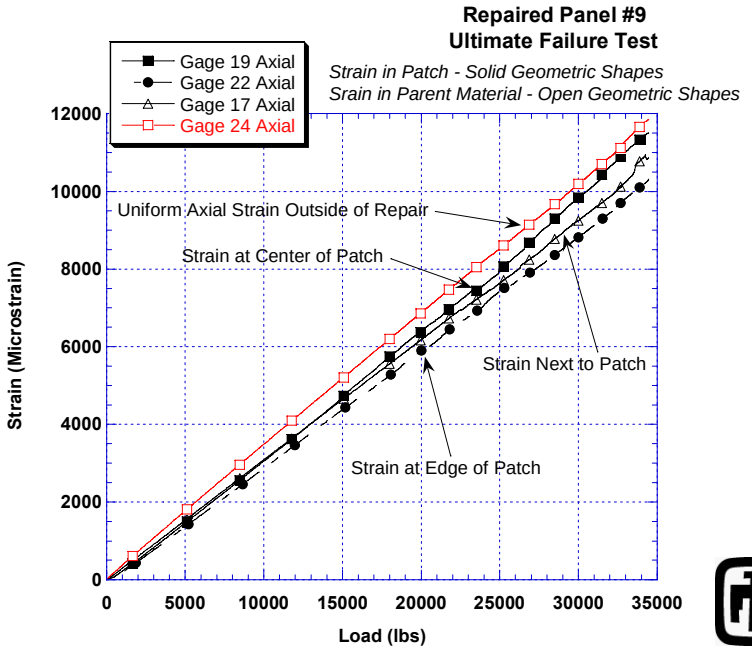


Ultrasonic C-Scan

Strain field & repair efficiency assessment vs. NDI findings

Uniaxial carbon graphite; plies plus one repair

Comprehensive evaluation of composite repair and associated NDI technology to ensure proper mesh between structural integrity & flaw detection



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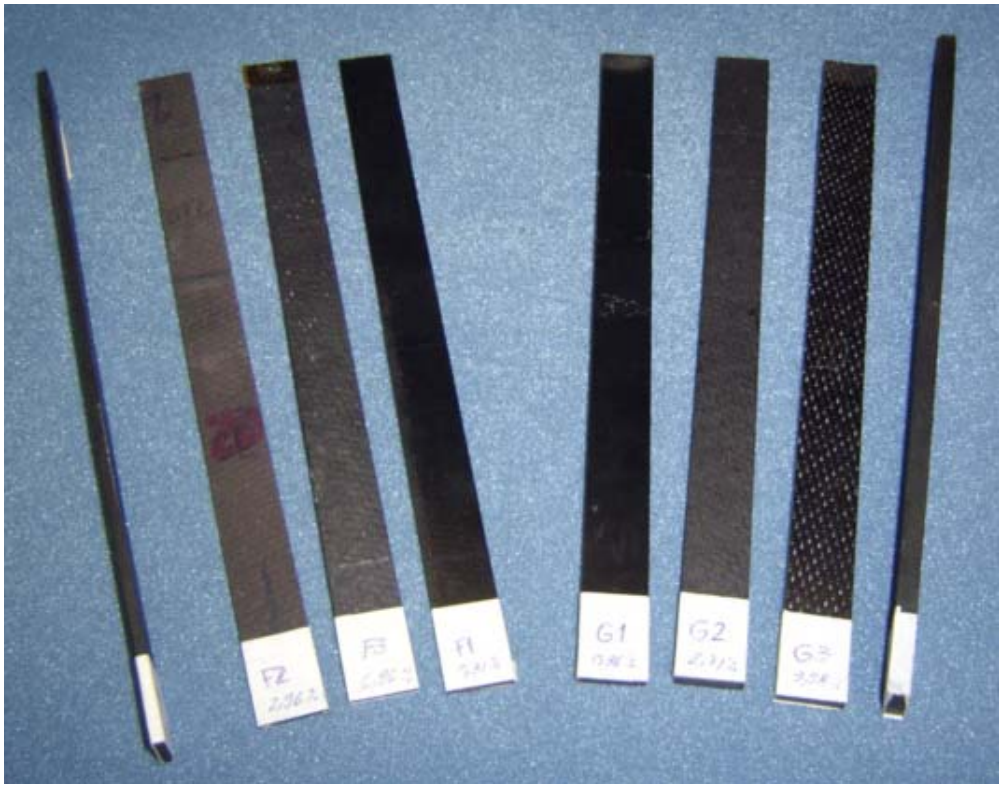
Use of NDI to Quantify Porosity Levels & Assess Mechanical Properties vs. Porosity

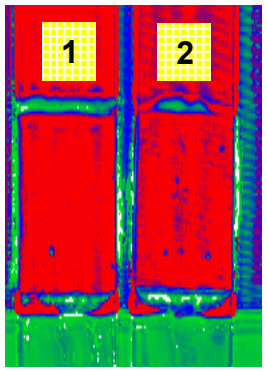


Carbon Weave

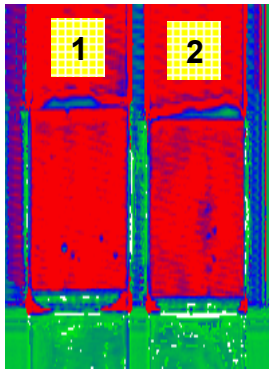
- Intercompare mechanical tests, NDI & acid etch methods to assess porosity, strength and fatigue life
- Use of NDI tests to calculate mechanical properties
- Use of advanced NDI to improve quantification of porosity (stratified porosity that may exist in a repair)

Characterize Bonded Joints:
Quantify Adhesive Strength

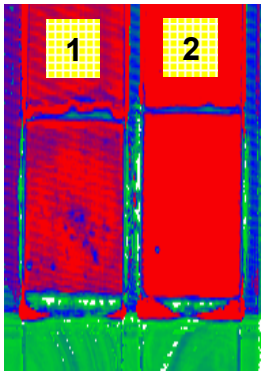
TTU of Weak Bond Specimens Show Trends



Pristine - Best

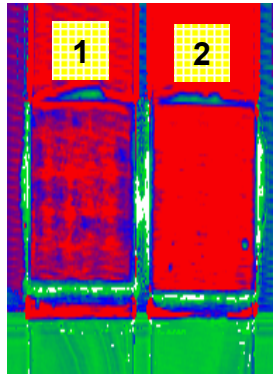


70% MR Dilution

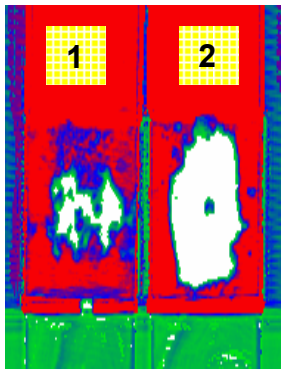


30% MR Dilution

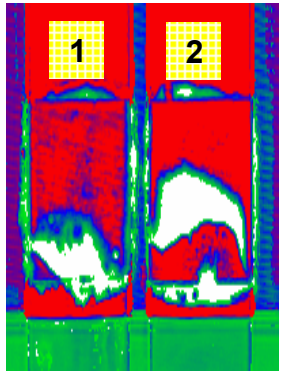
33% MR Screen



66% MR Screen



Room Temp.



100 MR

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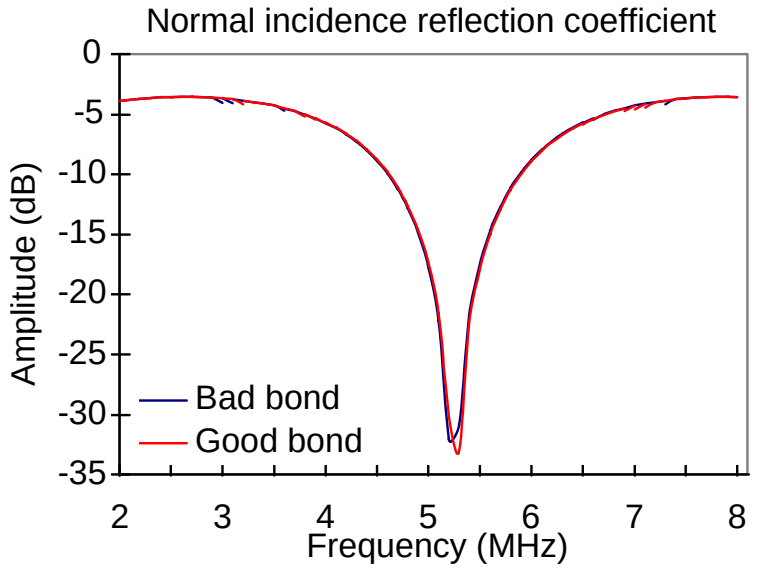
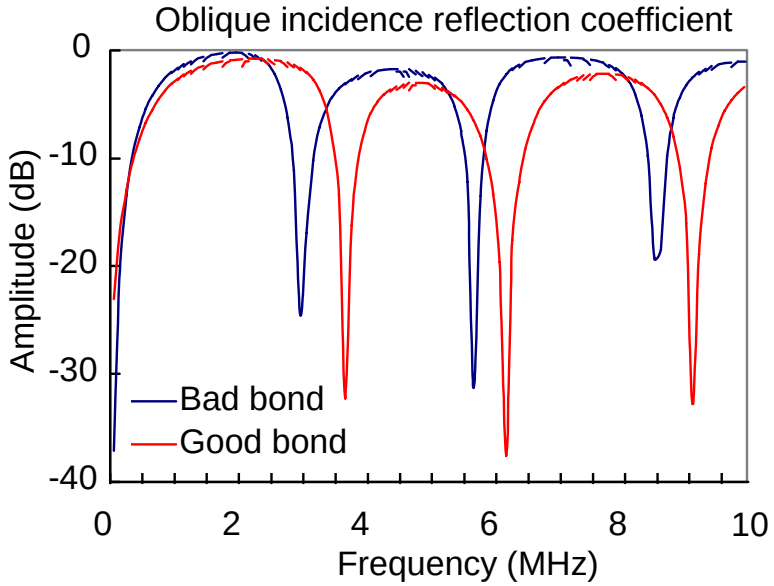
Angle Beam Ultrasonic Spectroscopy (ABUS)

- **Compare received and transmitted waveforms in frequency domain; study frequency/amplitude shifts & change in damping in FRF**
- **Oblique wave (broadband UT beam) introduces shear stress in the bond line**
- **Difference between longitudinal wave and shear wave interrogation**



Negligible Affects on Normal Wave (?)



Frequency and Amplitude Shifts Differentiate Bonds

Future Direction of *CACRC Damage Assessment & Quality Inspection Task Group*

- **Detection of Barely Visible Impact Damage (BVID); determining extent of composite damage → driven by visual detection**
- **Enhanced visual inspection**
- **Inspection of scarfed composite repairs; in-process QA**
- **Inspection of fastened repairs to composite structure (in-process QA; no current post-repair NDI requirement)**
- **NDI vs. Damage Tolerance vs. Residual Strength – assess structural integrity (focus on particular materials?)**
- **NDI of adhesive bonds ("kissing" disbonds; weak bonds)**
- **Ascertaining deterioration of material properties due to environmental exposure (temp., moisture, chemicals, stress)**

Future Direction of *CACRC Damage Assessment & Quality Inspection Task Group*

- Detection of fluid ingress
- Quantification of porosity (ref. stds. are critical)
- Detection of matrix micro cracking hidden beneath painted surfaces
- Rapid, large area inspection methods (improve POD; decrease false calls)
- Methods to inspect highly attenuative materials (weaves, thick structures, multi-layered structures) – proprietary issues?
- Utilization of SHM techniques
- Evaluating NDI performance - assessing conventional NDI in light of advanced NDI methods

Future Direction of
CACRC Damage Assessment & Quality Inspection Task Group

- **Optimization of NDI procedures; improved documentation and guidance**
- **Training – knowledge of hardware & procedures; use of "qualification standards"; industry standardization**
- **Ramp NDI – qualified personnel; equipment availability**
- **Implement a database – trends assessment**

CACRC Inspection Task Group Update and Overview

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