SAND2015-2005C

Non-Destructive Inspection of Blades

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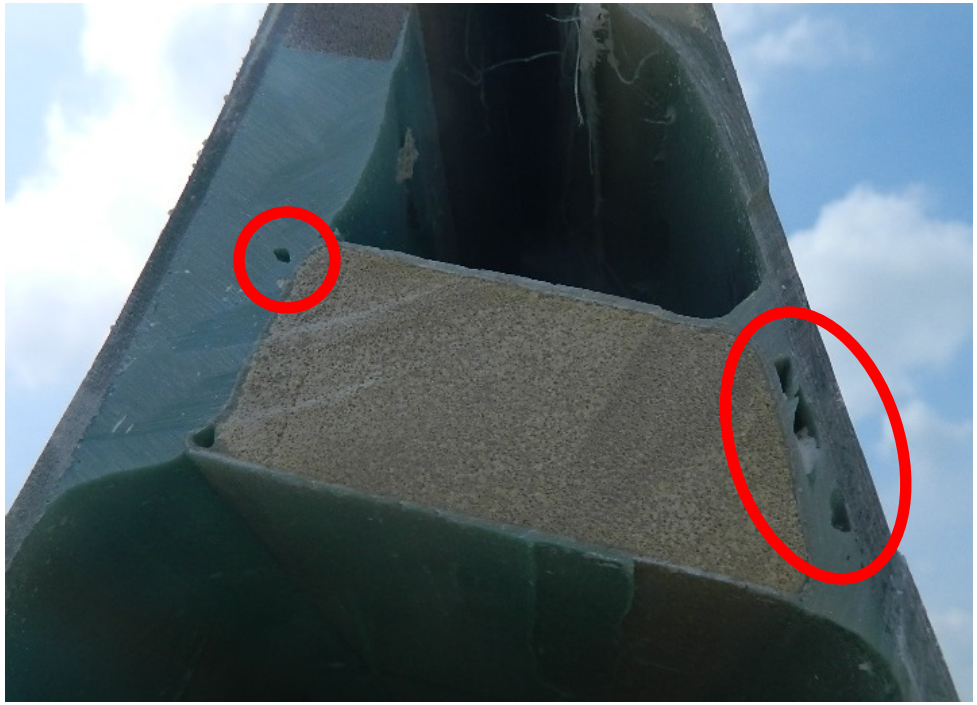
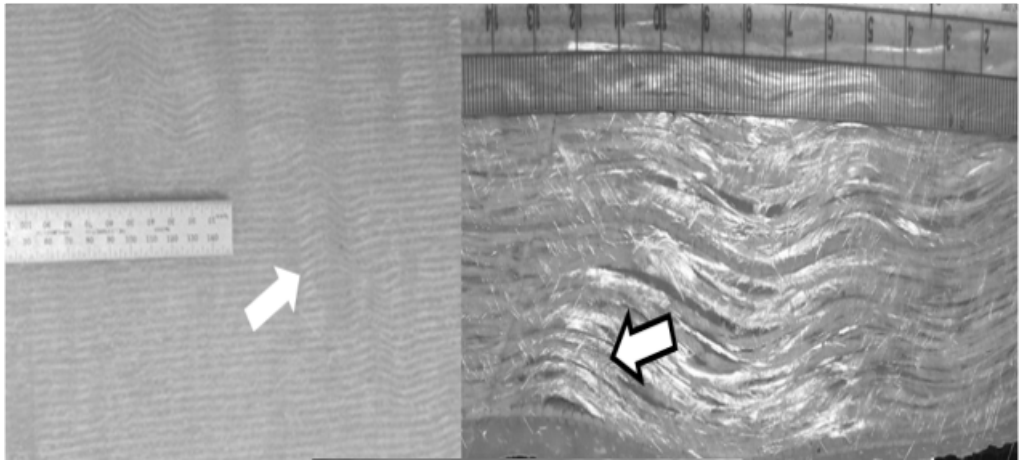
Non-Destructive Inspection

- Nondestructive inspection/testing (NDI/NDT) is a wide group of analysis techniques used in science and industry to *evaluate* the properties of a material, component or system *without* causing *damage*.
- *Different technologies* are used to find *different types* of defects and damage, in *different materials*, in *different settings*.
- Some methods lend themselves to scheduled inspections
- Others are used for more detailed inspections when a problem is suspected.
- Why use NDI? To detect damage that is not visible and/or before it becomes critical

…but, if you really want to know, you can always go the *destructive* route

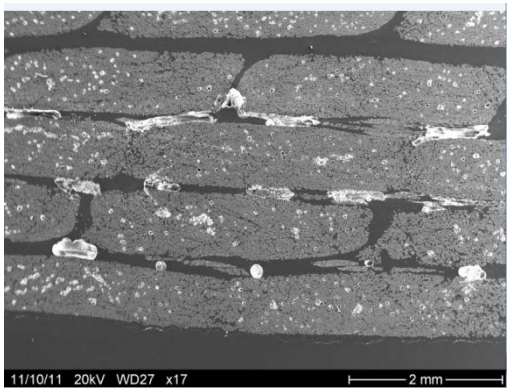


Defects

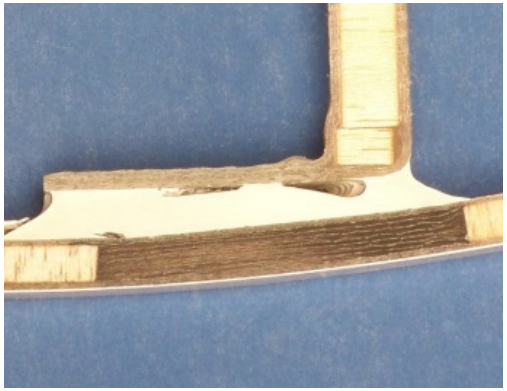


(In-Plane) (Out-of-Plane)

Fiber Waviness



Porosity

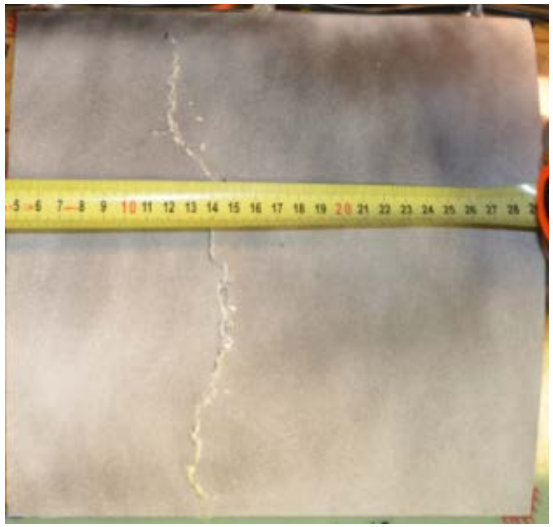


Voids

Damage

Delamination

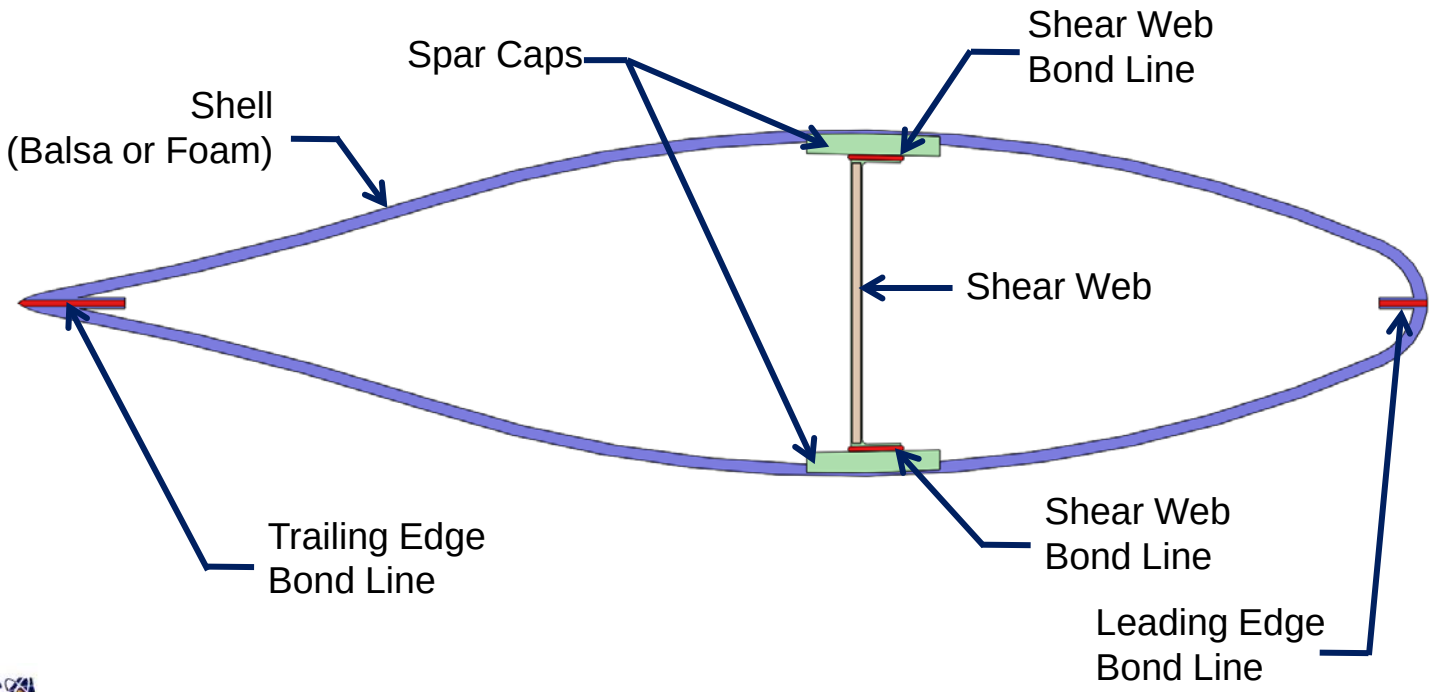
Disbond



Crack

Inspection Areas

- Sparcaps
  - Thick, unidirectional laminates, glass or carbon
- Shell
  - Multi-directional laminates with core material in between
- Bondlines
  - Shear webs and trailing edges, underneath laminate
- Roots
  - Very thick, multi-piece laminates

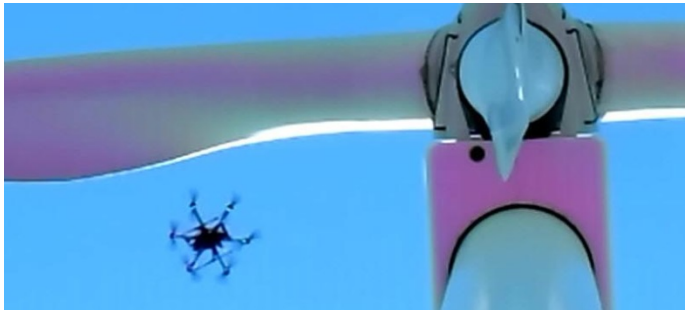


NDI Technologies

- **Pulse-Echo Ultrasonics (UT)**
- **Phased Array UT**
- Laser UT
- UT Spectroscopy
- Oblique Incident UT
- Guided Wave UT
- **Air Coupled UT**
- **Thermography**
- **Shearography**
- Digital Radiography
- Acoustography
- Computed Tomography
- Terahertz Imaging
- Microwave
- Acoustic Emission
- Strain Mapping
- Resonance
- Low Frequency Bond Testing
- **Tap Testing**
- **Visual Inspection**

Visual Inspection

Simple, cheap, and effective at finding larger and surface-visible damage



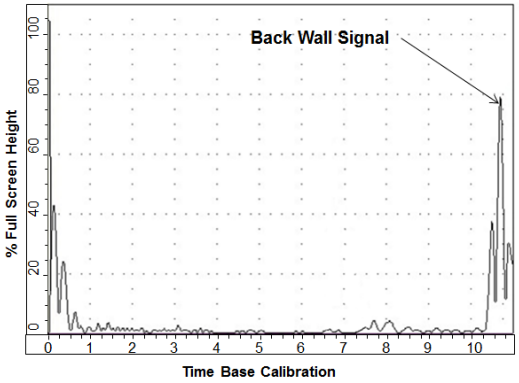
Drone

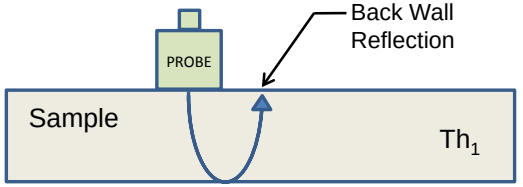
Rope Access

Pulse-Echo Ultrasonics

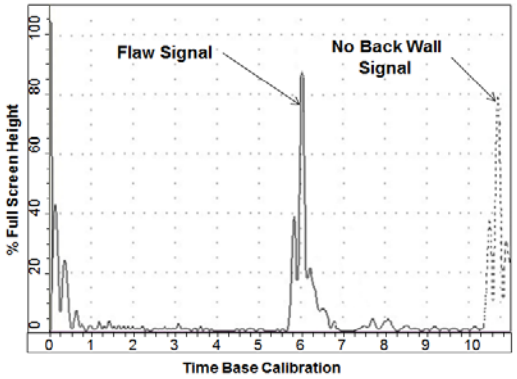
- 1 or 2 transducers that transmit and/or receive high frequency sound waves

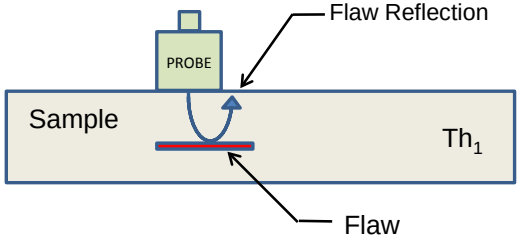
Pulse Echo UT – No Flaws





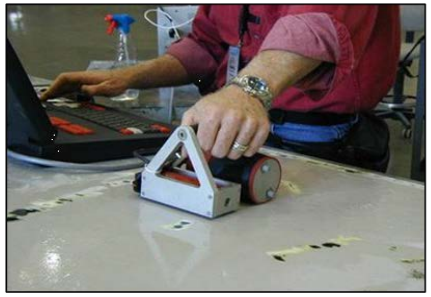
Pulse Echo UT - Shift in Backwall Signal Due to the Presence of a Flaw

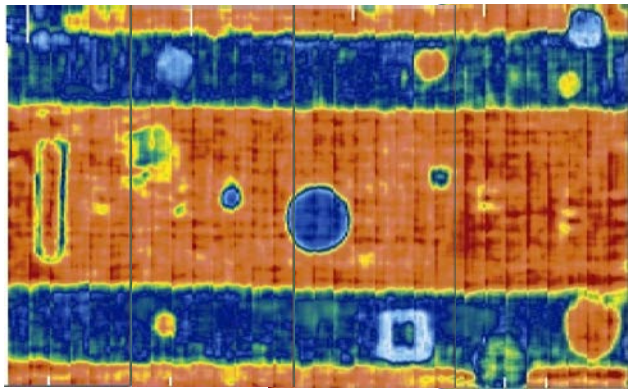




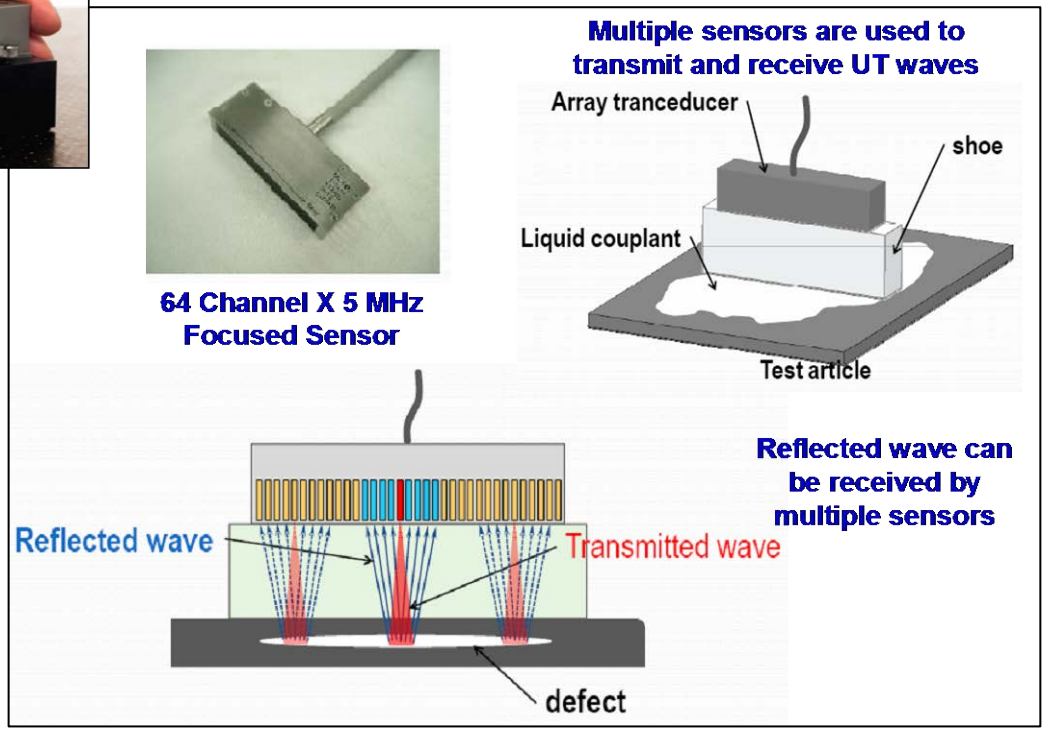
Phased Array Ultrasonics

- Same UT technology but with multiple transmitters and receivers
- Rapid coverage with two-dimensional images





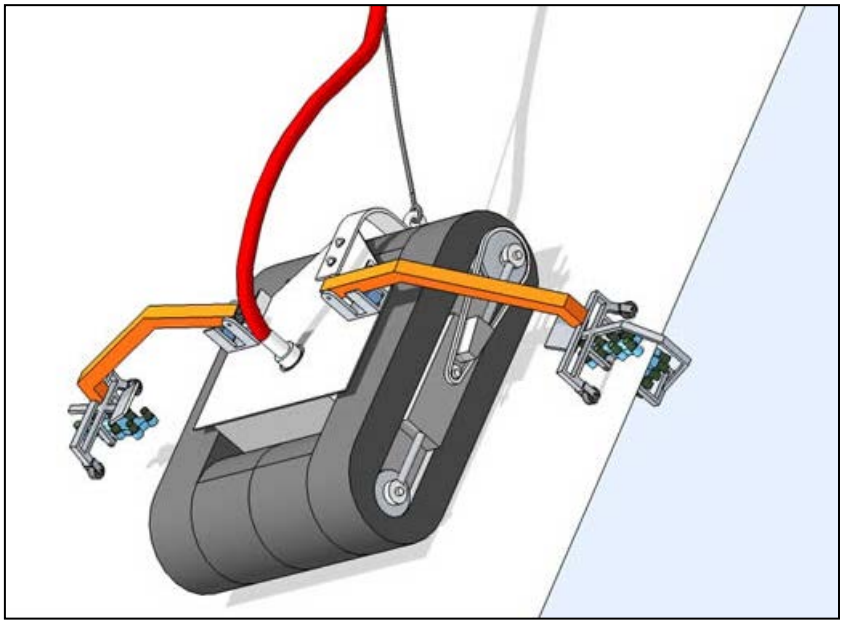
PA-UT Image with Two Bond Lines (dark blue)



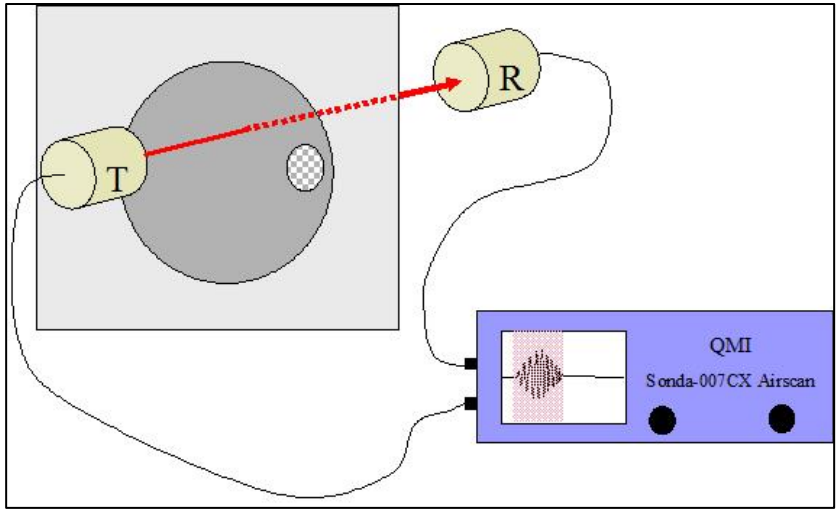
Operation of an Ultrasonic Array

Air-Coupled Ultrasonics

- Does not require liquid couplant
- Requires access to both sides of the structure
- Must fixture the probes such that they are in proper alignment
- Often used for trailing edge inspections



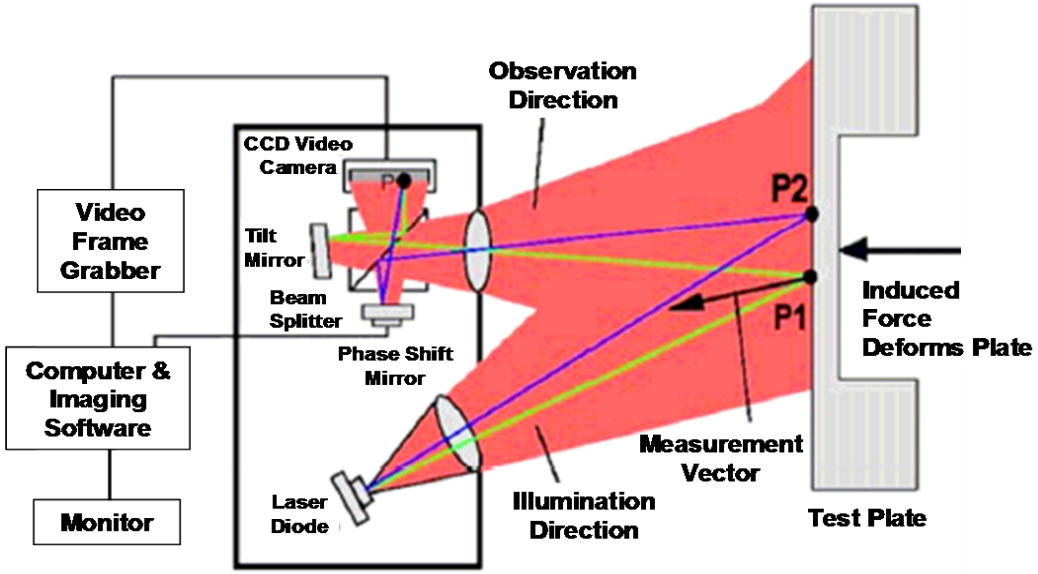
International Climbing Machines



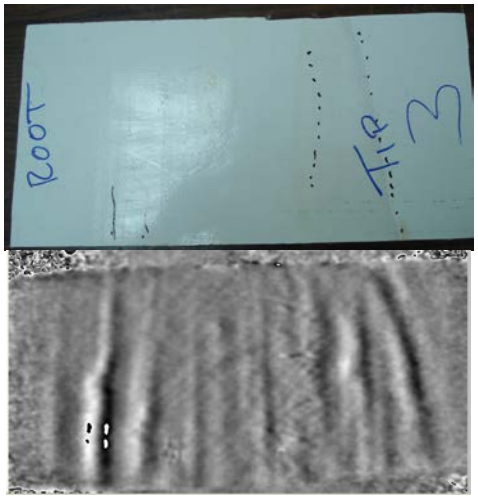
Schematic of Air Coupled Ultrasonic Inspection of Panel in Through-Transmission Mode

Shearography

- Object is illuminated with laser light
- Deformation of surface is created by vacuum, thermal, vibration or mechanical load which induces some deformation of the outer surface.
- Comparison of images captured before and after loading



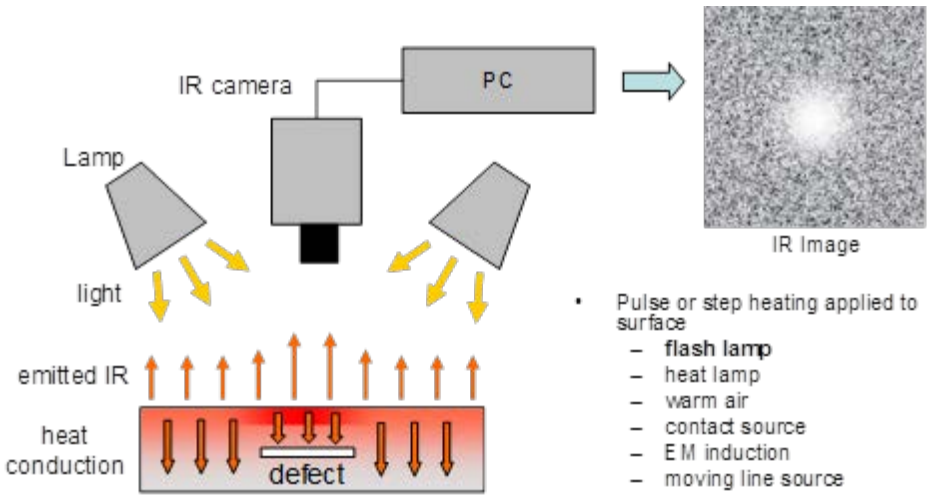
Basic Principal of Shearography

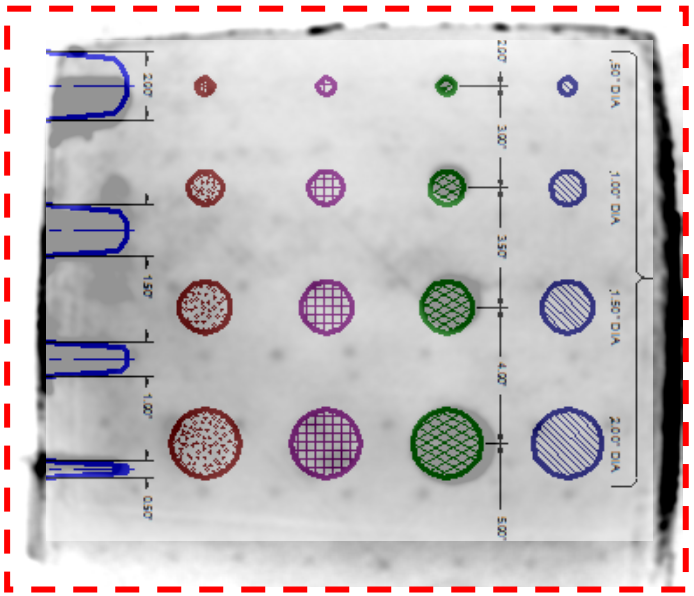


Shearography Image of Wrinkles in a Composite Laminate

Thermography

- Object is actively or passively heated
- IR image is taken before/after
- Can show heat emanating from crack surfaces rubbing together





Sandia Wind Turbine Blade Test Specimen Library

Engineered Test Specimens

Wind Blade Specimens

NNSA National Nuclear Security Administration

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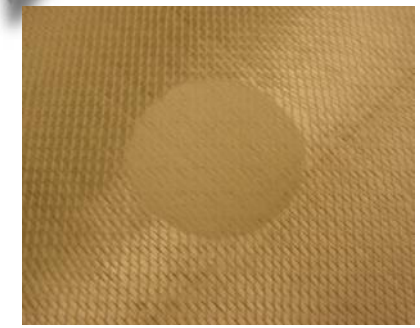
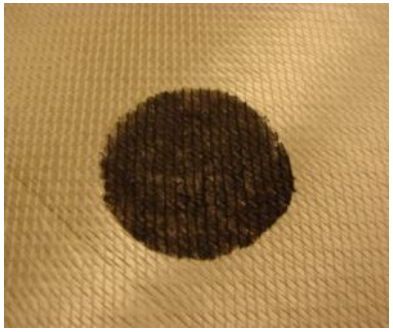
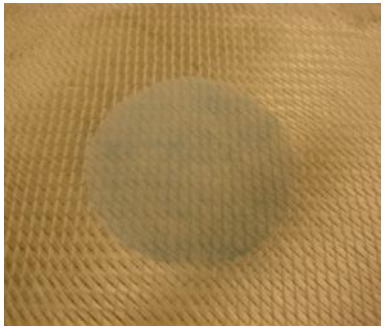
Engineered Flaw Types



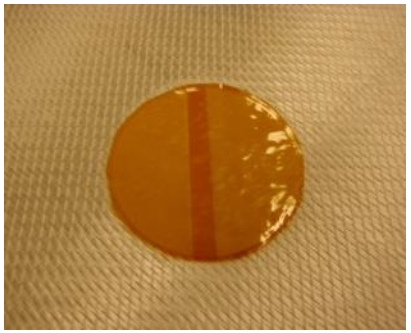
Glass Beads



Grease



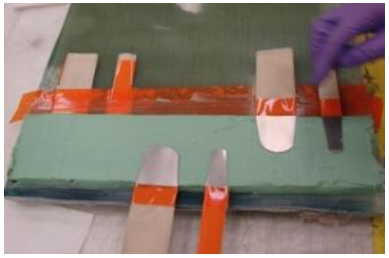
Mold Release



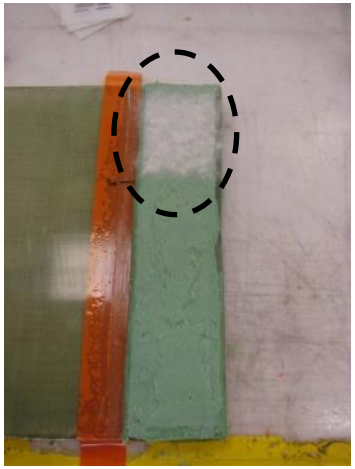
Pillow Insert

Materials inserted into multiple layers

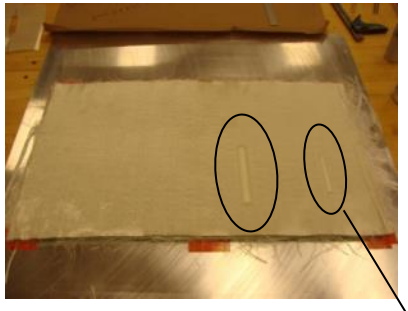
Voids in bond joint



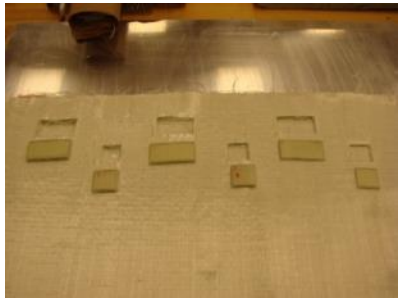
Pull tabs in bond joint



Glass beads In bond joint



Waviness produced by pre-cured resin rods



Dry fabric areas

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Lab Results

Suitable Inspection Areas for Inspecion Techniques						
Method	Spar Cap	Spar Cap to Shear Web Bond Line	Leading & Trailing Edge	Sandwich Structure	Deep Subsurface Flaws	Near Surface Flaws
Shearography	Satisfactory	Poor	Limited	Excellent	Insufficient	Good
Pulse Echo Ultrasonics	Excellent	Excellent	Satisfactory	Insufficient	Excellent	Good
Phased/Linear Array Ultrasonics	Excellent	Excellent	Satisfactory	Insufficient	Excellent	Good
Air Coupled Ultrasonics	Good	Good	Good	Good	Good	Good
Thermography	Limited	Poor	Limited	Excellent	Insufficient	Good

Field Use Considerations

- Ultrasonic: coupling fluid
- Air-coupled Ultrasonic: need access on both sides
- Thermography: heat soak time

Wind Blade Probability of Detection (POD) Experiment

Purpose

- **Generate industry-wide performance curves to quantify:**
  - **how well current inspection techniques are able to reliably find flaws in wind turbine blades (industry baseline)**
  - **the degree of improvements possible through integrating more advanced NDI techniques and procedures.**

Expected 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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Wind Blade POD Experiment

What We Need

- Qualified Inspectors
  - Wind blade manufacturing companies
  - Blade service companies
  - Operators
  - NDI equipment development labs
- 2-2½ days of your time

How Does This Benefit You?

- Training perspective, inspections on representative blade structure
- Inspector will receive feedback on how they performed
  - PoD Value, smallest flaw size detectable with 95% confidence
  - Number of flaws detected
  - Number of flaws missed
  - Number of false calls, if any
  - Flaw sizing
  - Location and type of flaws missed

Wind Blade POD Experiment

If you are interested in participating in this experiment or have other questions, please contact me or my colleagues using the following:

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