Imaging Bond Testing

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Worldwide Excellence in Ultrasonics

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Introduction

- Use of composites and adhesively-bonded structures has increased in the aerospace, automotive and marine industries for strength and weight saving.

- The integrity of the bonds is critical for the performance of the structure and existing technologies are not suitable for most inspections.

- Conventional inspection techniques can be of limited use because of the multiple glue lines and attenuative materials inherent in the lay-up.

- Bond Testing has different modes of operation to successfully inspect a wide range of materials and combinations used in multi-layered bonded structures and modern composites.
Typical Material Combinations

• Bonded Structures
  – Aluminum to Aluminum
  – Carbon to Carbon

• Monolithic Composite
  – Carbon
  – Graphite
  – Glass

• Sandwich Construction
  – Aluminum skins
  – Carbon skins
  – Glass fiber skins
  – Nomex, Rohacell core
  – Various honeycombs
Detectable Flaws

- Bonded Structures
  - Disbonds, unbonds, foreign objects

- Monolithic Composites
  - Delaminations, impact damage, foreign objects, porosity

- Sandwich Construction
  - Disbonds, unbonds, impact damage, crushed-core, foreign objects, porosity, delaminations, far-side defects

- Repair validation
Pitch-Catch Mode

- Probe consists of a transmitter and receiver element on separate tips
- Transmitter ‘pitches’ a burst of acoustic energy that propagates into the test part. Receiver ‘catches’ the sound.

- Bonded condition- Sound waves propagate across the skin, with significant attenuation into the core
- Disbonded condition- Little attenuation into the core giving higher amplitude at receiver

Easy calibration and no couplant is required, fast, high penetration

Frequency Range = 10kHz-40kHz
Mechanical Impedance (MIA) Mode

- Probe consists of driver and receiver elements coupled in series with a single probe tip.
- The loading of receiver element, in the tip, is related to the stiffness of the test part.
- When the system is ‘nullled’, the driver and receiver elements vibrate together with the same phase and amplitude.
- As the receiving element moves to a disbonded area, which is weaker, the phase and amplitude of the signals change.

➢ No couplant, accurately locates defects, works on stiff, irregular & curved surfaces.

Frequency Range 4kHz-30kHz
Resonance Mode

• Probe consists of an ultrasonic contact probe driven at its resonance frequency

• The instrument automatically selects the resonance frequency of the probe in air by sweeping over the frequency range and locating the phase null.

• On contact with the test part, the material damping reduces the amplitude of the signal and changes the resonant frequency. This reference condition can be nulled out. A disbond changes the acoustic impedance of the material, changing the phase and amplitude. The phase is related to depth of the defect in multi-layered structures.

• Higher frequency probes are used for better resolution and thinner parts. Thicker parts require lower frequency probes

➢ Requires couplant, best for laminates, high penetration, can determine layer that defect resides in.

Frequency Range 18kHz-370kHz
Traditional Bond Testing

- Single point measurement
- Hard to understand
- Not always possible to distinguish between signal and noise
- Inspector can miss defects easily
- Can be slow
- No digital archive

Bondoscope 3100

RF mode

Impedance plane

Gating
Why does the bond testing market need imaging?

- Easy to understand
- Increased probability of detection
- 100% coverage, no mistakes
- Automatic or manual scans
- Digital Archiving of results
- Faster and more reliable

Pitch-Catch  MIA  Resonance
What is the BondHub?

- Integrated PC and scanner motor driver
- Dedicated imaging and analysis software
- Reads phase and amplitude output from Bondascope (or equivalent device)
- Defines scan area, speed, resolution
- Plots C-scan image, with live gating/filters
- Full analysis software, 3D rendering, export
New inspections now possible

- Marine Glass Fiber/ foam core
- 3/16” skin, chopped mat, 0/90° and 45° lay-up
- UT cannot penetrate, Resonance and P/C failed
- MIa measures an out-of-plane stiffness

Amplitude showing skin-core disbonds

Impedance plane scatter plot

Panel courtesy of Arcadia Aerospace
Cracks and voids in adhesive bond line

- Bonded carbon laminates
- Resonance inspection of adhesive glue line- showing cracks and voids in the adhesive through the carbon skin.
- Vertical cracks represent a few pixel shift, not possible to detect manually

X-component- impedance plane

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Increased Probability of detection

- Carbon skin/honeycomb sandwich panel
- Near and far-side defects skin-core disbonds
- Cannot see all defects in x,y or amplitude
- 110kHz resonance mode, phase display

Panel courtesy of R-CON NDT
Composite Reference Standard

- Aerospace Composite laminate Reference Standard
- 30 ply with brass foil, Armalon, release ply F, poly backing material, pressure sensitive tape inserts at different depths. (BAC5578 Inserts)
- 2 plies from near surface to 2 plies from far surface
- 110kHz resonance mode (compromise)

Phase display

Impedance plane scatter plot with adjusted null

Panel courtesy of Arcadia Aerospace
Composite Step block

- Resonance inspection of carbon laminate step block with inserts.
- Thickness range: 0.014” – 0.070”
- Both the change of thickness and defects affect phase and amplitude

Phase display

Panel courtesy of R-CON NDT
Carbon skin/ Aluminum honeycomb

- Satellite panel - a carbon skin, aluminum honeycomb
- Dry coupled MIA mode
- Crushed core, disbonds, far-side defects and more

Amplitude display
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Pitch-Catch</th>
<th>Mechanical Impedance (MIA)</th>
<th>Resonance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Couplant required for testing</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Surface geometry</td>
<td>Flat or curved to &gt;1” radius</td>
<td>Flat or curved to &lt;1” radius</td>
<td>Flat or slightly curved</td>
</tr>
<tr>
<td>Typical minimum detectable flaw size</td>
<td>&gt;0.5” (12.7mm)</td>
<td>&gt;0.25” (6.4mm)</td>
<td>&gt;0.25” (6.4mm)</td>
</tr>
<tr>
<td>Flaw Depth determination in multi-layered bonding</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Far-side flaws or core damage on sandwich constructions</td>
<td>Best</td>
<td>Poor</td>
<td>Fair</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Applications</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Metal to metal bonded skins (Disbonds)</td>
<td>Fair</td>
<td>Good</td>
<td>Best</td>
</tr>
<tr>
<td>Multi-layer carbon laminate (Delaminations, voids, porosity)</td>
<td>Fair</td>
<td>Poor</td>
<td>Best</td>
</tr>
<tr>
<td>Metal skin to metal honeycomb (Disbonds, crushed core)</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Carbon skin to metal or Nomex™ honeycomb (Disbonds, delaminations, crushed core)</td>
<td>Best</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Carbon skin to foam core (Disbonds, delaminations)</td>
<td>Best</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Multi-core sandwich structures (Inter-core disbonds, core damage)</td>
<td>Best</td>
<td>Poor</td>
<td>Fair</td>
</tr>
<tr>
<td>Bonded Stiffeners (Disbonds)</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Glass fiber skin to foam or wood core (Disbonds, delaminations)</td>
<td>Best</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Perforated metal skin to honeycomb core, used for acoustic liners (Disbonds)</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Carbon-Carbon, used for heat shields (Delaminations)</td>
<td>Best</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Carbon or Glass reinforced pipes or pressure vessels (Disbonds, delaminations)</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Carbon Overwrapped Pressure Vessels (COPV) (Disbonds, delaminations)</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
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<tr>
<td>Composite Repair Validation (Disbonds, delaminations)</td>
<td>Best</td>
<td>Poor</td>
<td>Good</td>
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</table>
Conclusions

• Increased use of multi-layered bonded structures and composites leading to demand for alternate testing method- Conventional ultrasonics has limited capability through multiple bondlines, composites with porosity and sandwich structures.

• Ultrasonic bond testing runs at a lower frequency with a range of operational modes, 2 of which are dry-coupled, that are customized for different material combinations, defect types and constructions.

• **Imaging bond testing** provides a powerful enhancement to conventional bond testing with C-scan imaging and analysis software providing:
  – a digital archive of results
  – an increased probability of detection
  – A new solution to previously ‘non-inspectable’ parts
  – 100% coverage with a faster and more reliable scan