Bond Testing Technology

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Introduction

- Adhesive-bonded and composite components and structures have become an important part of aircraft manufacturing over the last 35 years.
- Quality and reliable is extremely important to the integrity of composite structures throughout their service life.
- The wide range of materials and configurations used in composite structures and the need for nondestructive evaluation of bonds has resulted in many different types of testing equipment and methods being used.
Introduction

• As there are many different NDT methods used on composites, we will look at Bond Testing using Sonic-Acoustic inspection method.

• This technology has been quite successful for over the last 40 years. However, no single inspection method has been found adequate for the wide variety of materials and construction method used today in composite structures.
Bond Testing History

• Perhaps the earliest form of bond testing is the coin tap method.

• Coin tap was followed by the tap hammer method.

• Mechanical taps were replaced by early electronic instruments.
Overview of Composites and Bond Types
Overview of Composite

We can see the increased percentage of composite materials in the commercial aircraft industry over the last thirty-five years.
Overview of Composites

What are Composites:

Composites are made up of two or more materials with distinct properties and combined into a heterogeneous mixture. The mixture benefits from mechanical properties not found within the individual properties. Composites can involve ceramics, wood and/or polymers.

Composites are made up of non-metallic components consisting of Fiberglass, Boron, Aramid (nylon), Kevlar or Graphite (Carbon).
Overview of Composites

Material for Composite Structures

- Different material types can be used for the skin:
  - Aluminum
  - Fiberglass
  - Graphite (Carbon)
  - Hybrid
  - Kevlar (DuPont™)

- The core that is used in composite component structures comes in different material type and densities:
  - Aluminum
  - Fiberglass
  - Nomex
  - Rohacell
Overview of Composites

Defects found in Composite Structures

• Generally four types of flaws in composite materials:
  – Disbond
  – Core Damage
  – Delamination
  – Porosity

• These flaws can occur due to the following:
  – Impact damage
  – Lighting Strike (heat damage)
  – Manufacures Defect
Understanding Bond Testing Technology
Three generally accepted modes of Inspection

- There are three test modes and five inspection methods available with the BondMaster 1000e+.

- The optimum method would be selected using a test standard that represents both bond and disbond conditions based on the construction of the component.
BondMaster Overview

The BondMaster is a unique instrument for bond testing (BT) that can be used to test a
array of bonded and composite materials used in a variety structures. There are
similarities and differences when comparing this flaw detector with Ultrasonic flaw
detectors. As in ultrasonic flaw detectors, the BondMaster uses sound waves however,
unlike ultrasonic testing (UT) it does not use reflected ultrasound energy. In UT, sound is
coupled into a material and then echoes are detected to determine if flaws are present or
material thickness.

BMT B1000e+
BondMaster Overview

- Bond testing Pitch-Catch & MIA, uses changes in plate-waves / flexural and compression waves that result from a good bond compared to areas that are not bonded well, or where there may be a disbond or delamination within a structure.

- Bond testing Resonance, does not use sound propagation velocity or reflected sound, but only changes in phase and amplitude of the propagating / standing wave measured within a component.
Resonance Mode

- Resonance method is very similar to an ultrasonic A-scan pulse echo inspection with couplant included, it is based on changes in phase and amplitude in probe resonance.

- Resonance method uses special a narrow bandwidth contact Sonic probes. The test is based on the change in the impedance of the resonant- Q - acoustically coupled to a material.

- The impedance change in the crystal are analyzed to detect changes within the part being tested.
Resonance Mode: typical application

- Resonance is generally used for detecting skin-to-skin disbonds such as aluminum lap joints. This mode also works well for inter-ply delamination in composite structures. In many cases the depth of delamination's can be estimated using the signal-phase rotation.

250KHz resonance probe used on an aircraft lap splice joint to detect corrosion between the lap splice skins
Mechanical Impedance Analysis operates without couplant and is usually spring loaded, it is based on measuring the stiffness and mass of the material under test.

When the transmit and receive elements are nulled, they vibrate together at the same phase and amplitude. When the probe is placed on a structure, the receiving element is affected by the sample stiffness, which varies from bonded to disbonded conditions. This change is monitored as a comparison between the transmit and receive phase and amplitude signals. The next figure shows a difference in phase.

Transmit and receive elements are nulled and in phase.

Transmit and receive elements are in contact with a test part and are 180 degrees out of phase.
MIA Mode: typical application

- MIA probes have a point-contact area suitable for use on irregular or curved surfaces. The MIA method works well to detect disbonds and crushed core conditions.

S-MP-5 probe being used on a rear wing end plate from a Formula 1 race car, the construction is carbon fiber skins with Rohacell foam core and Nomex core. This inspection is used to detect near surface skin to core disbonds.
Pitch-Catch Test Mode

- The pitch-catch mode is very easy in terms of calibration and requires no couplant.
- One element transmits (pitches) a burst of acoustic energy into the test part and a separate element receives (catches) the plate-waves / flexural propagated across the test piece as shown.
- The plate-waves / flexural motion are propagated into the test piece. Disbonds and delamination's change the stiffness of the part. The return signals are detected and a phase-amplitude display is used to show the effect of good and bad bonds on the sound path.

Cross-sectional view of a typical pitch-catch probe.
Pitch-Catch Mode

Impulse & RF Method

- The pitch-catch Impulse and RF methods utilize a repeated burst of a single frequency. The frequency is selected to provide the maximum plate / flexural motion within the component under test.

- A variable time gate is used to select the received pulse that has the greatest change in amplitude when the probe is scanned from a bonded area to a disbonded area.

- The user positions a time gate at the optimum point to monitor the response of the receive signal most affected by disbonds. This optimizes the data displayed by the flying dot on the RUN display.
Pitch-Catch Mode

**Swept Method**

- For the pitch-catch swept method, one element sweeps through multiple frequencies defined by the operator. The swept frequency (5KHz – 100KHz) provides a circular display.

- The swept signals are monitored and processed by the second element. The return signals are detected and a phase vs. amplitude display is used to show the effects of good bond compared to the disbond areas along the plate wave path.

Bond | Disbond | No contact
Pitch-Catch Test Mode

RF Method: typical application

S-PC-P14 pitch catch probe used on a carbon fiber skin / Nomex cored structure to detect near-side and far side skin to core disbonds.
Overview of Pitch-Catch
BondMaster Pitch-Catch Observation

TTU C-scan image

- Pitch-Catch is of the most commonly used test method for skin to core disbonds.

- Test standard CFRP honeycomb sandwich. ARP 5606 CHRS-2-6, also listed in some NTM procedures.
BondMaster Pitch-Catch Observation

CHRS-2-6 Fiberglass core, test results at 14Khz looking at nearside disbonds.
BondMaster Pitch-Catch Observation

CHRS-2-6 Nomex core, results at 14Khz Testing looking at nearside disbonds
BondMaster Pitch-Catch Observation

CHRS-2-6 Fiberglass core; at 22KHz, best results for near and far side disbond.
BondMaster Pitch-Catch Observation

CHRS-2-6 Fiberglass core good results at 22KHz Testing looking at far side disbond
OmniScan BondTesting

Olympus NDT now offers a “new” OmniScan BondTesting software update to the OmniScan MX. This new software update enables customers to use the OmniScan with the Eddy Current ECA/ECT Module and BondMaster probes to create C-Scanning images while testing in Pitch-Catch method.
What is required to do OmniScan BondTesting?

- OmniScan MX and ECA/ECT Module
- MXB Software
- BondMaster probe adapter for OmniScan
- Standard BondMaster probe and cable
- Appropriate yokes and probe holder
- YX Scanner
OmniScan in BondTesting Mode

• OmniScan Impedance plane representation is equivalent to BondMaster RF impedance plane (phase angle inversion). Superior phase repeatability.
• Up to 8 simultaneous frequencies
• C-scan generated from the vertical amplitude of the impedance plane (vertical strip chart)
• Tested with probe S-PC-P13L pitch-catch probe
Tests standards (honeycomb sandwich)

CHRS-1-3, CHRS-1-6, CHRS-1-9 and CHRS-1-12 samples: composite, 306 mm x 280 mm. 3 to 12 plies, 1 in thick honeycomb
Observations

Defect detection in function of frequency

CHRS-1-6 at 8 kHz (only disbond is detected)

CHRS-1-6 at 20 kHz (disbond, delamination and potting detected)
Observations

Defect detection in function of frequency

CHRS-1-6 far-side at 18 kHz (disbond)

CHRS-1-6 at 14 kHz, very poor disbond detection
Observations

Variation of defect shape in function of frequency and position of the probe at frequency smaller than 20 KHz.
Observations

Variation of defect shape in function of frequency and position of the probe at frequency higher than 20 KHz
Observations

Variation of defect shape in function of frequency and position of the probe
Conclusions

• The use of a single instrument offering multiple inspection methods allows inspection of a wide variety of composite materials and configurations.

• The Pitch-catch, MIA, and Resonance methods, as discussed, each have particular advantages in terms of application solutions. These methods are defined in aircraft NDT manuals.

• Portable BondTester C-scan imaging device can improve detectability, reliability

• C-scan imaging will be very helpful in damage assessment and repair requirements.
Thank you