NDT Toolbox for Honeycomb Sandwich Structures

a comprehensive approach for maintenance inspections
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Air-Coupled UT

Low-Cost / Advanced Thermography
Paint Thickness Measurement

OMA –
Online Maintenance Assistance
Inspection Tasks

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- ELCH
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- Vacuum Loss

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Remote Support
- OMA – Online Maintenance Assistance
„Big“ Traditional Sandwich Parts

Elevator

Trailing edge

Section through elevator

Rudder

FRONT SPAR ATTACHMENT

TRAILING EDGE
# Comparison of Test Methods

<table>
<thead>
<tr>
<th>Test procedure</th>
<th>Outer skin Bonding</th>
<th>Inner Skin Bonding</th>
<th>Fluid</th>
<th>Estimated Insp. Time</th>
<th>Flaw size</th>
<th>Training</th>
<th>Remarks – Availability - Advantages – Constrains</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIT</strong> (field inspection technology)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tap Test / Woodpecker</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>25 mm 50 mm</td>
<td>No</td>
<td></td>
<td>• High human factor!</td>
</tr>
</tbody>
</table>
| ELCH                    | Yes                | Yes                | No    | 100 mm               | No / No   |          | • Simple, reliable, qualified  
|                         |                    |                    |       |                      | Introducion|          | • Development for improvement: OPTO-ELCH                                                                       |
| BONDMASTER              | no procedure       | no procedure       | No    | 25 mm                | UT II + Special course |          | • Portable, reliable  
|                         |                    |                    |       |                      |            |          | • Competing with UT                                                                                          |
| Ultrasonic              | Yes                | Yes                | No    | 48h                  | 25 mm     | UT II +  | • Procedure available  
|                         |                    |                    |       |                      |            |          | • Equipment common  
|                         |                    |                    |       |                      |            |          | • Not for large areas                                                                                       |
| X-Ray                   | No                 | No                 | No    | 4-8h                 | 1 cell    | RT II    | • Everywhere available  
|                         |                    |                    |       |                      |            |          | • Safety?                                                                                                    |
| Thermography            | No                 | No                 | No    | 4-h                  | 1-3 cells | IRT Level I limited | • Relatively Cheap  
|                         |                    |                    |       |                      |            |          | • Small and highly portable  
|                         |                    |                    |       |                      |            |          | • Easy to use                                                                                               |
| **Close to FIT**        |                    |                    |       |                      |           |          |                                                                                                               |
| OptoELCH                | no                 | no                 | No    | 24h                  | 25mm      | Introduction | • Simple, reliable, compact, cheap  
|                         |                    |                    |       |                      |            |          |                                                                                                               |
| Shearography            | missing threshold  | too expensive      | No    | 16h                  | 25mm      | SH II No course avail. | • Expensive/bulky  
|                         |                    |                    |       |                      |            |          | • No quantitative deformation indication  
|                         |                    |                    |       |                      |            |          | • Missing inspector certification scheme                                                                         |

- **Applicability Verified**
- **In Development**
- **With Adaptaion Possible**
- **Potential**
- **Not Applicable**
Current Set of General Procedures in Airbus NTM

The old procedures

• 51-10-03 Tap Test on sandwich
• 51-10-06 UT, CFRP- accidental damage (to be updated soon with content of 55-30-01)
• 51-10-09 Visual Inspection on CFRP
• 51-10-10 X-Ray for sandwich / water ingress
• 51-10-19 Woodpecker for sandwich

The new procedures

• 51-10-24 UT on sandwich (mostly parallel surfaces)
• 51-10-25 IRT on sandwich (vertically mounted structures)
• 51-10-26 ELCH on sandwich (mostly parallel surfaces)
• 51-10-27 Endoscope on sandwich
• 51-10-28 Vacuum Loss on sandwich
General Procedures

Inspection Tasks

Other Methods

Developments

Remote Support

Taptest
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Ultrasound
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Bondmaster And Similar Equipment
Shearography
Air-Coupled UT
Low-Cost / Advanced Thermography
Paint Thickness Measurement
OMA – Online Maintenance Assistance
Tap Test

Manual Tap Test
Extremely simple NDT instrument
pocket size, ultra low cost
available everywhere

Mitsui Woodpecker
Simple NDT instrument
pocket size, low cost
simple use

- For outer skin debonding top skin should be not too thick
- For core damages but only sandwich of less than 15..20 mm core thickness
- For rear skin debonding also core < 15..20 mm
- Average POD - not too far from other methods

Of limited use: e.g. rudder structure cannot be inspected for rear skin debonding.

General NTM Procedure: Taptest: NTM 51-10-03, Woodpecker NTM 51-10-19
X-Ray Inspection

Use: To detect fluid in honeycomb cells

- Needs special safety precautions
- Bulky equipment, limited portability
- Access to the inside of boxes (e.g. rudder) is limited - placing film inside box not everywhere possible.

**Consequence:**
Resolution loss as X-rays have to pass both rudder shells

Considered as 2nd or last step for evaluation of indications

General NTM Procedure: X-ray: NTM 51-10-10
X-Ray: Placing Film and Tube

Options to perform X-Ray-Inspection on a closed box like the rudder

With access through hand hole

Without access through hand hole

General NTM Procedure: X-ray: NTM 51-10-10
ELCH-Check (Elasticity Laminate CHecker)

General NTM Procedure: ELCH: NTM 51-10-26

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ELCH – POD Exercise

<table>
<thead>
<tr>
<th>Location of Debonding</th>
<th>Type of Honeycomb</th>
<th>Detectable Damage Size in mm Detection Probability &gt; 95 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge Area</td>
<td>4.8/40/32 kg</td>
<td>Test grid 50 mm x 50 mm: R = 90</td>
</tr>
<tr>
<td></td>
<td>6.4/40/24 kg</td>
<td>Test grid 100 mm x 100 mm: R = 70 (Pd = 90 %)</td>
</tr>
<tr>
<td></td>
<td>6.4/30/24 kg</td>
<td></td>
</tr>
<tr>
<td>Centre Area</td>
<td>4.8/40/32 kg</td>
<td>Test grid 50 mm x 50 mm: D = 105 (Pd = 80 %)</td>
</tr>
<tr>
<td></td>
<td>6.4/40/24 kg</td>
<td>Test grid 100 mm x 100 mm: D = 120 (Pd = 90 %)</td>
</tr>
<tr>
<td></td>
<td>6.4/30/24 kg</td>
<td>D = 90</td>
</tr>
</tbody>
</table>

General NTM Procedure: ELCH: NTM 51-10-26

Qualification ELCH MBB-BT 100;
Example: POD edge area

Typical qualification sample
Type A - delamination between plies of outer CFRP skin, parallel to surface
Type B - disbonding between the outer skin and the honeycomb core
Type C - cracked honeycomb core parallel to the inspection surface
Type D - crushed honeycomb core in parallel area
Type E - disbonding between inner skin and honeycomb core
Type F - fluid ingress in honeycomb core
Ultrasonic for Fluid Detection

General NTM Procedure: Ultrasonic - NTM 51-10-24
## Ultrasonic – POD Exercise

### POD versus defect length, Z-Profile

All Configurations

<table>
<thead>
<tr>
<th>Aera</th>
<th>Honeycomb Configuration</th>
<th>Detectable Damage a90/95</th>
<th>False Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z-Profile</td>
<td>A+B+C+D+E</td>
<td>42.5mm x 30mm</td>
<td>1 %</td>
</tr>
<tr>
<td>Area outside of the Z-profile</td>
<td>A</td>
<td>D = 85.7mm</td>
<td>0.9 %</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>D = 40.8mm</td>
<td>0.8 %</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>D = 51.9mm</td>
<td>0.2 %</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>D = 42.8mm</td>
<td>1.5 %</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>D = 48.9mm</td>
<td>0.3 %</td>
</tr>
<tr>
<td></td>
<td>A+B+C</td>
<td>D = 44.8mm</td>
<td>0.8 %</td>
</tr>
<tr>
<td></td>
<td>D+E</td>
<td>D = 44.2mm</td>
<td>0.7 %</td>
</tr>
<tr>
<td></td>
<td>A+B+C+D+E</td>
<td>D = 42.4mm</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

A = 3,2/39/48Kg; B = 4,8/40/32Kg; C = 6,4/40/24Kg; D = 4,8/30/32Kg; E = 6,4/30/24Kg

### POD versus defect diameter, out of the edges, configuration C

**Z-Profile Area**

- Defect size a [mm]: POD (confidence level) ⊗ ± 90°V
Ultrasonic Array Inspection for Sandwich a next step
“Microinvasive“ or Key-Hole Inspections

General NTM Procedure: NTM 51-10-27 NTM 51-10-28
Thermography (Vertical Structures)

Fluid detection in honeycomb with simple thermography equipment “consumer“-thermo camera & handheld-“Hot-Air-Fan“

For hot regions on earth: Cooling by evaporation of sprayed water

General NTM Procedure: NTM 51-10-25
Thermography (Vertical Structures)

Optimal inspection conditions:

Conditions preferred:
- Vertical position of shells.
- Fluid has always contact to outer skins

Problem:
- Capillarity of cells
- Water does not move even if cells are tilted

poor inspection conditions:
Thermography – POD Exercise

**40mm high honeycomb core**

2ml fluid detected with
\[ \varepsilon \geq 95\%, \text{ POD } = 90.5\%, \, 1.9\% \text{ false calls} \]

- 3.2mm cell width: \( a_{90/95} = 5.6 \text{ cells} \)
- 4.8mm cell width: \( a_{90/95} = 2.5 \text{ cells} \)
- 6.4mm cell width: \( a_{90/95} = 1.4 \text{ cells} \)

**30mm high honeycombs:**

6ml fluid detected with
\[ \varepsilon \geq 95\%, \text{ POD } = 90\%, \, 1.9\% \text{ false calls} \]

- 4.8mm cell width: \( a_{90/95} = 10 \text{ cells} \)
- 6.4mm cell width: \( a_{90/95} = 5.6 \text{ cells} \)

**Boundary condition:** CFRP-Skin < 1.5 mm

Method is optimized for quick & handheld inspection, heat duration is limited

This limits allowed thickness of skin

With better controlled and longer upheating phase this limitation can be shifted.
Thermography (Horizontal Structures)

Heating Blankets

Alternatives

Oven

Fridge
Other Methods

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General Procedures

Other Methods

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Shearography
Air-Coupled UT

Low-Cost / Advanced Thermography
Paint Thickness Measurement

OMA – Online Maintenance Assistance
Inspection with Bondmaster (Resonance Testing)

Type A - delamination between plies of outer CFRP skin, parallel to surface

Type B - disbonding between the outer skin and the honeycomb core

Type C - cracked honeycomb core parallel to the inspection surface

Type D - crushed honeycomb core in parallel area

Type E - disbonding between inner skin and honeycomb core

Type F - fluid ingress in honeycomb core

Remark: Capabilities for sandwich inspection limited compared to Ultrasonic (NTM 51-10-24); this is an additional equipment and UT-equipment is standard Bondmaster is currently not included in the set of “General Procedures“.
Mobile Shearography

Shearography lacks a lot of necessary features for an InService Inspection method:
Expensive bulky equipment, own training scheme, lack of world wide EN4179/NAS 410 training, and:
Lack of simple threshold for defect definition !!!
Missing evaluation software to quantify deformation!
Way out: OptoELCH™ (Patent Pending)
Air Coupled Ultrasonic Scanning System

Air-coupled UT for shop inspection of sandwich shells – backup for investigations

Low frequencies (75…500KHz)
Burst excitation to avoid standing waves
Developments

**Inspection Tasks**

- Taptest
- ELCH
- Ultrasound
- Thermography
- X-Ray
- Boroscope
- Vacuum Loss

**General Procedures**

**Other Methods**

- Bondmaster And Similar Equipment
- Shearography
- Air-Coupled UT

**Developments**

- Low-Cost / Advanced Thermography
- Paint Thickness Measurement

**Remote Support**

- OMA – Online Maintenance Assistance
The new system consist of:

- high performance bolometer & integrated controller to drive the thermal loading units (lamp / flash),
- Additional lamps in master / slave configuration.
- Power supply in lamps integrated.
- Controlled by ruggedized Touch-PC or Pad-Computer (like Asus Eee Pad EP121)
Paint Thickness Measurement on CFRP

FOGALE Paint Scope

Other methods like UT checked, but did not showed the necessary reliability.

Currently the Microwave approach seems to be the most favorable.

FITM FSC1

FSC1 (from FITM/ Germany) uses microwave reflection measurement.

Special probe makes measurement independent from anisotropic permittivity $\varepsilon_r$ of CFRP substrate.

Paint Scope from FOGALE/ France with capacitive probe using the low conductivity of CFRP.
Remote Support

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Other Methods
- Low-Cost / Advanced Thermography
- Paint Thickness Measurement

Developments

Remote Support

OMA – Online Maintenance Assistance
Online Maintenance Assistant Concept

Figure 7 – Remote adjustment of a complex NDT equipment
Online Maintenance Assistance Systems

Onsight2000R

Mobile Remote Assistance (Visual Service Support-VSS)

Frontline Communicator

ATA NDT Forum 2010 Albuquerque: NDT Toolbox for Honeycomb Sandwich Structures

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Abstract:
Recent in-service occurrences triggered Airbus to improve the toolbox for in-service inspection methods to inspect honeycomb sandwich structures. The introduction of scheduled health checks for some sandwich structures (control surfaces), which require large area inspections, made Airbus developing a set of - as we call it - general procedures, which can be easily called up to perform those inspections. The NTM has now included this toolbox of procedures in the Chapter 51 establishing a general NDT approach, to reduce development time for specific procedures, and to give the customer support the capability for a fast response in case unscheduled NDT is necessary to determine the location and size of possible damages. For the customer it brings the advantage, to have those proven NDT procedures available having clearly described capabilities and application ranges.

This presentation shall give some background, how those procedures where developed, which was the idea of the selection of the tooling, what is the range of application and capability, which scenarios do they cover, which training must an inspector have etc. Also some outlook will be given to developments, which shall make those procedures even faster, easier, better.

One of the meanwhile famous tools and procedures is the ELCH, we will give here some basics about the idea behind, the range of application and its position in between the other methods of the toolbox.

Another development is the ultrasonic procedure to cover rear side debonding even in thick sandwich structures and thick skin material. Also the physics behind and the capabilities of detection shall be touched.

There are some special cases of weak bonding, which cannot be covered with traditional NDT. Here a special leak detection method was developed. It is not really NDT as it makes some drilling of holes necessary - somehow a “micro invasive method”, only used if really no other real NDT can help.

Fluid ingress is a popular domain for thermographic inspection. Nevertheless thermography can detect more. In the past advanced thermography was reputed to be very expensive – we will show some new approaches to overcome this.

Finally we will report some details about our verification / qualification method to determine the precise capabilities and limits of those general procedures in the toolbox. An extensive POD exercise was done, that gives a clear view about the capabilities of or general procedures. This will be rounded up with some considerations about other methods, which have currently not been selected for our tool box.

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