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Eprints ID: 10125

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Munoz Cuartas, Victor and Perrin, Marianne and Pastor, Marie-Laetitia and Welemane, Hélène and Cantarel, Arthur and Karama, Moussa

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Application of non destructive testing to the detection defects in composite structures used in the aeronautic industry

Victor Munoz, Marianne Perrin, Marie-Laetitia Pastor, Hélène Welemane, Arthur Cantarel and Moussa Karama
PRESENTATION OUTLINE

1. Introduction
2. Objectives
3. Materials and experimental setup
4. Results
5. Analysis and conclusions
INTRODUCTION

Increasing of composite in aeronautics industry

Reduction of weight and simplification of assembly

Applying of different mechanical and thermal loads

Internal stress

Maintenance

Why NDT field is being developed

Using NDT

How?
INTRODUCTION

Different NDT methods:

- Liquid penetrant inspection
- Magnetic control inspection
- Eddy currents control
- Radiographic testing
- Shearography
- Ultrasonic test
- Infrared thermography

These controls must be easy to implement and effective.

Experimental protocols must be developed with the aim of applying these techniques on the spot.
OBJECTIVES

- The aim of this research is to compare these 2 different NDT techniques:
  - **Ultrasonic test**
    - The most widespread technique. It is certified by the aeronautic industry.
  - **Infrared thermography**
    - Technique in process of certification by the aeronautic industry.

- Accuracy and detectability (of defects) for both techniques were studied.
MATERIAL AND EXPERIMENTAL SETUP

Specimens:

1. Carbon/epoxy laminated composite

- Damages are simulated with flat bottomed holes (discontinuity inside the continuous medium)
- Specimen divided in 2 sections
  - 4 mm wide section
  - 8 mm wide section

15 Defects ranging from 2 mm to 10 mm diameter
MATERIAL AND EXPERIMENTAL SETUP

Specimens:

2. Carbon/glass/epoxy skin with foam-core sandwich composite

18 defects ranging from 3 mm to 6 mm diameter.

Placed in both sides of the skin section

Damages are simulated with Teflon inserts inside the skin.
MATERIAL AND EXPERIMENTAL SETUP

Ultrasonic test (US):

- Equipment used
  - Omniscan
  - Coding system
  - 5 MHz multi-elements transducer of 64 elements
  - Gel coat

- Configuration:
  Reflection mode, monitoring in contact
MATERIAL AND EXPERIMENTAL SETUP

Ultrasonic test (US):

- Measurements are made using the -6 dB method:
  - It consists in measuring where the backwall echo decreases of 50%
MATERIAL AND EXPERIMENTAL SETUP

Infrared thermography (IRT):

- Equipment used
  - IR camera (thermal resolution: 20 mK)
  - 1000 W halogen lamp as a heat source
  - Software ALTAIR for the treatment of the film

- Configurations:
  - Reflection mode
  - Transmission mode
  - Pulsed heating
MATERIAL AND EXPERIMENTAL SETUP

Lock-in infrared thermography (IRT):

- Equipment used:
  - IR camera (thermal resolution: 20 mK)
  - 1000 W halogen lamp as a heat source
  - Software ALTAIR LI for the treatment of the film
  - Signal generator (0.1 Hz frequency and 4 V amplitude)

- Configuration:

```
<table>
<thead>
<tr>
<th>IR Camera</th>
<th>Computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal generator</td>
<td>Signal amplifier</td>
</tr>
</tbody>
</table>
```

Sinusoidal signal
Infrared thermography (IRT):

- It does not exist any rule for IRT measurements. In this work, the size of defects is measured with a visual criterion in the IRT mapping.
RESULTS

Ultrasonic test (US) – Specimen A:

- **Accuracy**: No results were obtained for specimen B because the foam-core properties prevent wave propagation and the skin is very thin, then the input peak is mistaken for defects.
- **Detectability**: 14 of the 15 defects were detected (93%).

Measured size of defects was 1 mm larger or smaller than the real size.
RESULTS

Infrared thermography (IRT) – Specimen A:

**Accuracy**

In the case of lock-in thermography (at 0.1 Hz frequency and 4 V amplitude), 8 of the 15 defects were detected (two more than classical IRT). But no measurement was done because of the small temperature contrast.

**Detectability**

6 of the 15 defects were detected (40%).

Measured size of defects was 1 or 2 mm larger than the real size.

Images taken from the film at 5 seconds (a) and 10 seconds after having switched on the halogen lamp.
RESULTS

Infrared thermography (IRT) – Specimen B:

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Detectability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured size of defects was 2 mm larger than the real size. Lock-in IRT leads to similar results as classical IRT for this specimen</td>
<td>18 of the 18 defects were detected (100%). Lock-in IRT leads to similar results as classical IRT</td>
</tr>
</tbody>
</table>

Lock-in IRT on specimen B
## ANALYSIS AND CONCLUSIONS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>US</th>
<th>IRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size accuracy</td>
<td>1 mm (larger)</td>
<td>1 and 2 mm (larger)</td>
</tr>
<tr>
<td>Minimal diameter detection</td>
<td>2 mm from 1 mm deep</td>
<td>2 mm from 0 mm deep</td>
</tr>
<tr>
<td>Depth limit detection</td>
<td>No depth limit</td>
<td>2,8 mm for a 6 mm diameter defect for this nature of specimen (specimen A)</td>
</tr>
<tr>
<td>Detectability in the laminated composite</td>
<td>14/15. Non detected a 2 mm defect at 1 mm deep</td>
<td>8/15. Non detected defects beyond 5,2 mm deep and 3 mm diameter</td>
</tr>
<tr>
<td>Detectability in foam-core sandwich composites</td>
<td>Input peak and defect peak mistaken. In addition, foam-core properties prevent wave propagation: No defect detected</td>
<td>18/18 by analyzing both sides of the sample</td>
</tr>
<tr>
<td>Time for getting results</td>
<td>About 10 min</td>
<td>Instantly</td>
</tr>
<tr>
<td>General limitation</td>
<td>Detection of defects close to the inspection surface and the backwall</td>
<td>Important specimen thickness. There is no information about the depth of defects</td>
</tr>
</tbody>
</table>
• Both methods have the same accuracy regarding the defects diameter

• In the case of foam-core sandwich composites, IRT is more adequate because heat propagates easily through the foam

• In the case of laminated composites, US is more adequate because ultrasounds waves have no limit in depth, which is not the case for IRT.

• In US, defects located near the contact surface (less than 1 mm) are hardly distinguished from the signal input peak

• IRT does not give information about the depth of defects. Only a 2D mapping (of the analysed surface) is obtained

• It is noted that both techniques could be complementary. Firstly, IRT could give the information about the presence of defects and their position; then an US test would give the information about their size, nature and depth

• Future works will be done with the aim of developing experimental protocols for controlling complex aeronautical structures. Damage evolution will also be studied with NDT in dynamic and static test
THANK YOU

ICNcT Conference 2013
The 16th International Conference of Nonconventional Technologies