Crack Detection in Aluminium 2024-T3 Plates and in an Airbus A320 Slat-Track using Electrical Crack Gauges

Materials Performance and Non-Destructive Testing
Department of Metallurgy and Materials Engineering
Katholieke Universiteit Leuven (K.U.Leuven)

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Katholieke Universiteit Leuven

- Founded in 1425
- The oldest and largest University in the Low countries (Belgium, Netherlands, Luxembourg, parts of Northern France & Western Germany)
- Department of Metallurgy and Materials Engineering founded in 1930
- Located in Leuven, Flanders, Belgium
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Introduction

• **Structural Health Monitoring** (SHM) on aircraft materials still in an experimental phase

• **Fatigue Cracks** are a major concern for aircraft maintenance

• **Permanent Crack Gauges** are of major interest in European research projects such as AISHA II (Aircraft Integrated Structural Health Assessment) and CHOSeN (Cooperative Hybrid Objects Sensors Networks)

• **The target** of this research is an integrated SHM system with crack gauges for reliable crack detection

source: Holger Speckmann, Airbus
Is SHM on aircrafts important?

- **Very Important** due to possible structural damages

source: http://www.facstaff.bucknell.edu

source: http://www.flightglobal.com

source: http://online.wsj.com
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Material and Methods

Parts tested

• Airbus A320 Slat-Track
• Aluminium 2024-T3 plate (300x80x1) mm
What is a Slat-Track?

Slat-Track extends the slats:

• They reconfigure the air stream
• They prevent stalling at high angles
• Producer: ASCO Industries

Reference: S Vanlanduit et al., 'Damage Assessment of Structures VI', Trans Tech Publications Ltd, pp. 549-556, Zurich-Uetikon 2005

Source: www.michaelseattle.blogspot.com
Electrical Crack Gauges

Conductive stripes made of conducting epoxy:

• Electrically conductive component
• Fast thermally curing
• Embedded (Coating)
Why Aluminium 2024-T3?

Aluminium 2024-T3 is widely used in aerospace applications:

- Light material
- High strength-to-weight ratios
- High ultimate and yield strength
- Very good behaviour in fatigue
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Al 2024-T3 plate – Initial durability test

First test without hole:
- 6 Electrical crack gauges
- 135000 cycles at 15Hz
- Stable behaviour – stability fatigue test
Al 2024-T3 plate – Creation of a hole

Fatigue test setup for Al 2024-T3 plates:

- 6 parallel embedded electrical crack gauges
- Initial hole with 3,5mm diameter for crack initiation
Al 2024-T3 plate – Test with hole & crack

Test with hole:

- Crack initiates from hole
- Crack propagation perpendicular to load direction
Test with hole:

- 6 Electrical crack gauges
- Interruption of conducting material - Sudden increase in resistances
AI 2024-T3 plate – Test with hole & crack

Test with hole:

• Investigation on conductivity regain
• Gauges near the hole → No conductivity (plasticity)
• Gauges away from the hole → Initial regain of conductivity

<table>
<thead>
<tr>
<th>Gauge</th>
<th>Resistance Before Test (Ohm)</th>
<th>Resistance After End of Test (Ohm)</th>
<th>Conductivity regained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,626</td>
<td>5,993 then Out of range (→ ∞)</td>
<td>Yes at 6 kN</td>
</tr>
<tr>
<td>2</td>
<td>3,452</td>
<td>Out of range (→ ∞)</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>3,227</td>
<td>Out of range (→ ∞)</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>3,173</td>
<td>Out of range (→ ∞)</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>3,115</td>
<td>Out of range (→ ∞)</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>3,259</td>
<td>5,149 then Out of range (→ ∞)</td>
<td>Yes at 0 kN</td>
</tr>
</tbody>
</table>

Results:
Most of crack gauges did not regain conductivity after fatigue cyclic load
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Airbus A320 Slat-Track Setup

Setup Information:
• Embedded electrical conductive crack gauge
• Gauge tested with **pre-existing** crack
• 3-point bending test is responsible for open-close crack behaviour
• **Target** → Monitor crack gauge performance in “closed crack” condition
Airbus A320 Slat-Track 3-point Bending Test

5 cycles bending test:
- Load applied and released 5 times
- Interruption and regain of conductivity

<table>
<thead>
<tr>
<th>Load</th>
<th>Compressive extension (mm)</th>
<th>Compressive load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0.09</td>
<td>0.014</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.54</td>
<td>2.049</td>
</tr>
</tbody>
</table>

Resistance Measurements & Load vs Time

- Resistance
- Load

Load 0.6kN
 Interruption and regain of conductivity

Load 2kN
Load 0 - 2kN
Load 0 kN
Resistance behaviour:
- Blue points show resistance values after each bending
- Resistance values were slightly higher after each cycle
- After many cycles possibility of complete interruption of conductivity
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The “Closed Crack” problem

- Fatigue is responsible for cracks
- Cracks are more frequently closed when the plane is not on operation
- Regain of conductivity is an issue in closed cracks

Option:
- Small box with electric fuse inside
- Conductivity lost for first time → Relatively high current through fuse
- Fuse is burned → Light indicator
- Light off → Crack over critical size, part need to be replaced
Example of Final Implemented SHM system

- SHM of Slat-Tracks
- Flexible system
- Simple data acquisition system
- On-line or off-line monitoring
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Further Investigation

**Ongoing research** at MTM, KU Leuven on electrical crack gauges as sensors for SHM
- Appropriate materials selection
- Material behavior on aerospace applications
- Adaptability & reliability
- Durability tests in real conditions

**Main target** for the implementation of a SHM based on electrical crack gauges:
- Creation of sensors that will not regain conductivity when broken
- In that way, critical cracks can instantly and reliably be monitored
Further Investigation

**Ongoing research:** Apply crack gauges on an Airbus A380 Slat-Track

Courtesy of www.airliners.net
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Summary

Characteristics of the Electrical Crack Gauges:
- Interruption of the electrical conductivity due to the crack growth can be easily monitored
- Ability to detect closed cracks when they reach a critical size
- Can follow complex lines and cover medium to large areas of aircraft components
- Crack gauges need to be at hot spots, area screening more difficult requiring e.g. ultrasonic Lamb waves, Lamb waves more difficult to interpret

Key points:
- They give an added value to SHM with crack monitoring
- Offer options to reduce/focus the scheduled maintenance of an aircraft
- Possibility of saving high costs for unnecessary service
- Increase safety for a more secure world air fleet
Acknowledgements

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Project:
• Aircraft Integrated Structural Health Assessment (AISHA II)

• Academische Stichting Leuven

• Ing. Johan Vanhulst for technical support
Are There Any ?’s

Why does God allow suffering in the world?
Why isn’t Christianity more inclusive?
Where did evil come from?
What if there is no God?

Thank you for your attention!

Dankie vir u aandag!