Microwave Coating Thickness Inspection for Aerospace Composite Structures

Airlines for America NDT Forum

September 22-25, 2014

Presented by: Jesse McDaniel
# Systems and Materials Research Corporation (SMRC)

**Background**

- Small business founded in 1998
- Based in Austin, Texas

**Microwave Theory**

- Heavy R&D/product development concentration
  - Outsourced manufacturing
  - Licensing
  - Strategic Partnering

**MNDE Toolkit**

- Three key manufacturing technologies developed for military aerospace platforms
  - Intelligent Sealant Application System (ISAS™)
  - QwikSeal® pre-sealed aircraft fasteners
  - Microwave Nondestructive Evaluation (MNDE) Toolkit™

---

QwikSeal® is a registered trademark of SMRC
ISAS™ and MNDE Toolkit™ are trademarks of SMRC
Industry Need

- Use of composite materials has expanded rapidly in aerospace and other industries
- Many of the traditional NDI methods must be reevaluated for accuracy and some have proven to no longer function as intended
- Aerospace manufacturers and maintainers are currently seeking replacement technologies for accurate coating thickness measurement over composite structures

Background
- 80,000 – 90,000 metric tonnes per year expected by 2015
- Aerospace segment comprises 10-20% of global market

**Global Carbon Fiber Market**
Coating Thickness Inspection

- Nondestructive inspection (NDI) technologies used to monitor coating thickness to detect:
  - undercoated substrates, can lead to early substrate failure
  - overcoated substrates, which contribute to aircraft weight
  - effect the efficacy of lightning strike protection mechanisms, especially expanded copper foil (ecf) mesh

Figure 1 – Example of a composite coating matrix from a cross-sectional micrograph of coating over an aerospace composite panel with expanded copper foil.
Microwave Non-Destructive Evaluation

- Simple microwave and electronic components
- Well-founded, innovative calibration software
- Highly accurate coating thickness measurements
- Ability to see surface characteristics through coatings
- Robust software-defined functionality
- Ideal technology for composite coating thickness measurement

Using this foundation we can build standalone and custom integrated solutions using our MNDE technologies.
**MNDE Toolkit™**

- **Software-defined, multi-function portable NDE system**
  - Coating thickness
  - Hidden fastener detection
  - Corrosion under specialty coatings

*Hardware built and tested at Lockheed, Northrop, and JAX. Hardening required before fleet-ready. Many enhancements under discussion.*
The MNDE Toolkit Remote Probe can be adapted to provide wireless x/y scanning capabilities in a handheld, easy-to-use system. Coating thickness accuracies are approximately ± 1% for composite and metallic substrates. Imaging capabilities can provide corrosion and flaw detection as well as identification of sub-surface elements such as fasteners for repair.
BladeChek™

- Designed to measure erosion coating thickness on highly curved surfaces
- Proprietary laser pitch/catch system measures only when microwave is normal to surface

Self-contained coating measurement solution for high radius of curvature and flat applications. Calibration requires computer. Commercially available.
Test Case – Aerospace CFRP

- Provided sample panel sets from aerospace manufacturer
- SMRC performed calibration, sampling and analysis of capabilities over samples
- Improvements made to microwave system to increase accuracy to customer desired 15 micron accuracy

The Remote Probe detects the “peaks and valleys” of the ecf and carbon fiber with rotation of the tool, causing changes in the signal and prediction capability.
Test Case – Aerospace CFRP

Further experiments yielded increased accuracy from improvements to Remote Probe

- Antennae changes to reduce surface irregularity effects
- Selective standoff and calibration
- Signal conditioning using increased gain

Changes to microwave configuration resulted in accuracy improvement to +/- 15 microns

<table>
<thead>
<tr>
<th>Sample Set</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Number of Samples</th>
<th>Specification for 95% Confidence Interval</th>
<th>Predicted Yield for +/- 15 microns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-1 Initial</td>
<td>121</td>
<td>113</td>
<td>1250</td>
<td>161</td>
<td>11.16</td>
</tr>
<tr>
<td>Nor-2 Initial</td>
<td>4</td>
<td>86</td>
<td>4500</td>
<td>121</td>
<td>32.66</td>
</tr>
<tr>
<td>Nor-1 Slot Antenna</td>
<td>-3</td>
<td>23</td>
<td>3500</td>
<td>64</td>
<td>63.18</td>
</tr>
<tr>
<td>Nor-2 Slot Antenna</td>
<td>14</td>
<td>29</td>
<td>3000</td>
<td>24</td>
<td>75.7</td>
</tr>
<tr>
<td>Nor-1 Adjusted Standoff</td>
<td>-7</td>
<td>31</td>
<td>3000</td>
<td>85</td>
<td>31.29</td>
</tr>
<tr>
<td>Nor-2 Adjusted Standoff</td>
<td>-6</td>
<td>24</td>
<td>9000</td>
<td>61</td>
<td>60.87</td>
</tr>
<tr>
<td>Nor-1 with Gain and Adjust Standoff</td>
<td>-9</td>
<td>17</td>
<td>3500</td>
<td>23</td>
<td>49.03</td>
</tr>
<tr>
<td>Nor-2 with Gain</td>
<td>6</td>
<td>23</td>
<td>4500</td>
<td>53</td>
<td>56.71</td>
</tr>
<tr>
<td>Nor-2 with Gain and Adjust Standoff</td>
<td>-4</td>
<td>4</td>
<td>3000</td>
<td>4</td>
<td>100</td>
</tr>
</tbody>
</table>
### Other Aerospace Samples

<table>
<thead>
<tr>
<th>Background</th>
<th>Substrate Composition</th>
<th>Microwave Theory</th>
<th>MNDE Toolkit</th>
<th>Analysis</th>
<th>Summary</th>
</tr>
</thead>
</table>

- Measured vs actual comparison using cross-section/optical measurement
- Range of coatings from 2-14 mils thick on CFRP with ECF
- MNDE Toolkit shows accurate, precise, and repeatable results
- Down-selected as best tool for coating thickness for large-scale platform repair

![Graph showing measured vs actual comparison](image-url)
## Future Work

<table>
<thead>
<tr>
<th>Background</th>
<th>Substrate Composition</th>
<th>Microwave Theory</th>
<th>MNDE Toolkit</th>
<th>Analysis</th>
<th>Summary</th>
</tr>
</thead>
</table>

- Currently the MNDE Toolkit Remote Probe is a software-defined system
  - Requires tether to computer
  - Provides extra capabilities such as fastener and corrosion detection
- SMRC will bring a single, self-contained unit to the marketplace in the next generation Remote Probe
  - No computer tether required
  - Provides coating thickness measurements only
- R&D focused on eliminating rotational uncertainty over expanded copper foil composite substrates

![MNDE Toolkit Remote Probe](image)
Commercial Status
MNDE Toolkit

Summary

• Current system is commercially available for purchase with a production lead time
• Interested in licensing technology dependent upon customer commitments and market size
• Incorporation of feature/requirements above and beyond the current system will be evaluated based on customer commitments/requirements
Discussion

Thank you for your attention!

Contact Information:
Systems and Materials Research Corporation
11525 Stonehollow Drive, A120, Austin, TX 78758
Office: (512) 535-7791 • Fax: (512) 206-4966
www.systemsandmaterials.com

Malcolm D. Prouty, Ph.D.
President
Cell: (512) 968-4750
malcolmprouty@systemsandmaterials.com

Jesse McDaniel
Senior Research Engineer
Cell: (512) 736-1219
jessemcdaniel@systemsandmaterials.com