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Structural health monitoring in thick-walled FRP structures

• Inspection techniques
  – Non-destructive evaluation (NDE)
  – Structural health monitoring (SHM)
  – Sensor mapping
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Non-destructive evaluation (NDE)

SSC-463

INSPECTION TECHNIQUES FOR MARINE COMPOSITE CONSTRUCTION AND NDE

SHIP STRUCTURE COMMITTEE
2012
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Non-destructive evaluation (NDE)

• Description of potential defects
• Non-destructive evaluation techniques
• Aerospace Damage & Repair Inspection Procedures
• Wind Turbine Blades
• Test panels & Case studies
• Summary & conclusions
Non-destructive evaluation (NDE)

- Description of potential defects
  - Bonded joint failures (adhesive, cohesive, mixed)
  - Air bubbles
  - Blisters
  - Core crushing
  - Core shear failure
  - Crazing
  - Delaminations
Non-destructive evaluation (NDE)

- Description of potential defects
  - Fibre failure
  - Kissing bond
  - Impact damage
  - Matrix cracking
  - Moisture ingress
  - Ply/fibre waviness
  - Resin rich/poor area
Non-destructive evaluation techniques

- Visual inspection
- Tap testing
- Ultrasonic inspection
- X-radiography
- Eddy current
- Thermography
- Moisture meters
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Non-destructive evaluation (NDE)

- Non-destructive evaluation techniques
  - Bond testers
  - Laser shearography
  - Modal methods
  - Structural Integrity and Damage Evaluation Routine (SIDER)
  - Acoustic emission
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Non-destructive evaluation (NDE)

• Aerospace Damage & Repair Inspection Procedures
Non-destructive evaluation (NDE)

- Aerospace Damage & Repair Inspection Procedures

![Comparison of the effectiveness of NDE techniques for honeycomb sandwich structures by Airbus (Bisle 2010)](image-url)
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Non-destructive evaluation (NDE)

- Wind turbine blades
  - Visual
  - Ultrasonics
  - Shearography
  - SHM (FBG)
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Non-destructive evaluation (NDE)

- Test panels & Case studies

<table>
<thead>
<tr>
<th>Defect</th>
<th>Laser Shearography</th>
<th>Ultrasonic Inspection</th>
<th>Infrared Thermography</th>
<th>Digital Tap Hammer</th>
</tr>
</thead>
<tbody>
<tr>
<td>De-lamination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. Size Detected</td>
<td>2 inches</td>
<td>2 inches</td>
<td>3 inches</td>
<td>3 inches</td>
</tr>
<tr>
<td>Max. Depth Detected</td>
<td>1 - 2 plies</td>
<td>1 ply</td>
<td>2 - 3 plies</td>
<td>2 - 3 plies</td>
</tr>
<tr>
<td>Overall Effectiveness</td>
<td>Good exp. for kissing bonds</td>
<td>Can’t detect kissing bonds</td>
<td>Can’t detect kissing bonds</td>
<td>Can’t detect kissing bonds</td>
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<tr>
<td>Water Ingress</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. Size Detected</td>
<td>2 inches</td>
<td>4 inches</td>
<td>2 inches</td>
<td>4 inches</td>
</tr>
<tr>
<td>Max. Depth Detected</td>
<td>Skin core interface</td>
<td>Skin core interface</td>
<td>Skin core interface</td>
<td>Skin core interface</td>
</tr>
<tr>
<td>Overall Effectiveness</td>
<td>Good</td>
<td>Use higher frequency transducer</td>
<td>Very good</td>
<td>Fair</td>
</tr>
<tr>
<td>Impact Damage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. Size Detected</td>
<td>1 inch</td>
<td>2 inches</td>
<td>1 inch</td>
<td>3 inches</td>
</tr>
<tr>
<td>Max. Depth Detected</td>
<td>Skin core interface</td>
<td>1 - 2 plies</td>
<td>Skin core interface</td>
<td>Skin core interface</td>
</tr>
<tr>
<td>Overall Effectiveness</td>
<td>Very good</td>
<td>Good</td>
<td>Good</td>
<td>Only edge delaminations found</td>
</tr>
<tr>
<td>Void</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. Size Detected</td>
<td>2 inches</td>
<td>2 inches</td>
<td>1 inch</td>
<td>Defect not detected</td>
</tr>
<tr>
<td>Max. Depth Detected</td>
<td>½ inch</td>
<td>½ inch</td>
<td>¼ inch</td>
<td></td>
</tr>
<tr>
<td>Overall Effectiveness</td>
<td>Fair with thick laminates</td>
<td>Good for uniform laminates</td>
<td>Very good</td>
<td>Not effective</td>
</tr>
<tr>
<td>System limitations</td>
<td>Requires good reflective surface – not good with matt finish black parts or clear gel coat; not good with thick or highly curved parts</td>
<td>Requires good calibration sample and uniform laminate; small probe area; known good laminate required for baseline data; defect must produce a thermal gradient</td>
<td>Only effective with larger defects</td>
<td></td>
</tr>
<tr>
<td>Equipment cost</td>
<td>$100,000</td>
<td>$40,000</td>
<td>$10,000</td>
<td>$1,500</td>
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</tbody>
</table>
Non-destructive evaluation (NDE): conclusion

- By far the best NDE tool for marine composites is still the human eye. However, visual inspection cannot reveal the extent of damage with certainty.
- The initial assessment of NDE technologies revealed laser shearography, thermography, ultrasonic testing and digital tap hammers to be the most promising for marine composites inspection.
Non-destructive evaluation (NDE): conclusion
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Non-destructive evaluation (NDE)

• Terahertz inspection

- Reflected THz signal. ‘Dark blue’ areas indicate the presence of the defects and ‘yellow areas’ indicate the ‘0’ defect zone. Reflective tape markers used as reference points are clearly visible at coordinates (230,250) and (370,250).
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Structural health monitoring (SHM)

- Acoustic emission
  - See previous report

- Fibre Bragg Gratings
  - See presentation by E-LASS Vigo 2019
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Sensor mapping

Remotely Controlled Aquatic Drones

- Flexible, easy and quick to deploy platform
- High quality sensors and data capturing
- Easy accessibility to difficult and dangerous to reach places
- Observation and inspection of assets as well as their surroundings
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Sensor mapping

https://www.youtube.com/watch?time_continue=113&v=fWz4b2FxgkM&feature=emb_logo

INSPECT ASSETS
We operate where other technologies cannot, either because these technologies are too dangerous, too expensive or simply not practical to use.

MAINTENANCE
We deliver a basis for Predictive Maintenance and Reliability Centred Maintenance. Repeatable measurements and modeling allows for tracking changes over time.

DATA DRIVEN
Robust data processing chain covering acquisition, network communication, storage, processing, integration, visualisation and distribution risk mitigation.
Sensor mapping

Xtend Technology: visual inspection, NDT & sample drilling

Did you know that Xtend Technology already have inspected several bridges both in Norway and Germany. We will soon also include AI function and offer services where we are going from fly and see to fly, see & work. Meaning our Drone will perform NDT and drilling like sampling of concrete test samples and other...
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