STEEL TO COMPOSITES
STRUCTURAL BONDING
MEASUREMENT
IN LIGHTWEIGHT MARINE
TRANSPORT APPLICATIONS

E LASS VIGO 2019
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AGENDA

- (Hybrid) Bonding overview
- Qualify Project
- SHM approach
- Strain FE SIMULATION
- Reliability Analysis
- Com&Sens
**WHY BONDING?**

- Assembly of a wide variety of substrates
  - Metal/metal, metal/composite, metal/glass...
- **Cold solution**
  - No thermal deformation, no thermal affection
  - Intervention at late construction stage
- **Cost effective** joining technic
- **Easy, simple**
  - Be careful, can be dangerous
  
  - Surface preparation
  - Environmental conditions
  - External aggression
  - Design
- **Efficient: Strong resistance**
- **Reduction** of weight, noise and vibration & components

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**QUALIFY LIGHTWEIGHT**

**Interreg 2 Seas Mers Zeeën**
ADHESIVES IN INDUSTRY

Bonded patch repair
ADHESIVES IN MARINE
QUESTIONS

• Will this joint be reliable after twenty years of exposure to the harsh marine environment?

• Is it strong and tough enough?

• How can the properties of an adhesive joint be optimized?

• What types of adhesive joint designs are best to withstand specific loading and service conditions?

• Can we accurately model the response of an adhesive joint?
QUALIFY PROJECT

ENABLING QUALIFICATION OF HYBRID STRUCTURES FOR LIGHTWEIGHT AND SAFE MARITIME TRANSPORT

Enabling Qualification of Hybrid Structures for Lightweight and Safe Maritime Transport.

QUALIFY will deliver the knowhow and guidelines for the uptake of hybrid marine structures (metal/composite).
OBJECTIVES

• Evaluate the **long term** structural **performance** of the adhesively bonded joint under representative environmental conditions

• Develop a **certification procedure** for adhesively bonded hybrid joints representative for marine structures

• Develop a **reliable inspection** and **maintenance protocol** for adhesively bonded hybrid joints
Establishing a **structural health management** methodology for **in-situ monitoring** of adhesively bonded bi-material joints to enable decision making protocols aiming to shift the current schedule based maintenance scheme to a **condition based maintenance paradigm**.
SHM APPROACH

• Test approach via FEM simulation
  • Effect of debonding on different levels (glue/steel, composite/steel interface or within the glue)
    → Use strain transfer from boat to superstructure and vice versa
  • Minimum Size of detectable debond/crack

SHM approach 2 steps (2 different techniques)
  • Integrity monitoring on sea → detecting hot spots and size of defect
  • Harbour inspection → detailed size of defect
MONITORING TECHNIQUES

OFFLINE TECHNIQUES

- Ultrasonic
- Thermography
- CT scan
- DIC

Crack damage in a composite
MONITORING TECHNIQUES

ONLINE TECHNIQUES

Fibre Optics
- Distributed
  - Input light
  - Back reflections
- Grating-based
  - FBG1
  - FBG2
  - FBG3

Accelerometer

AE

Can be based on optical fibres
2 load cases analyzed at fore end of superstructure

Length of disconnection:
- 0 mm
- 600 mm
- 900 mm
- 1200 mm
- 1500 mm
SIMULATIONS DONE ON CFRP AND STEEL
ANALYSIS ON STEEL

About 100 mm
  • Clear change in strain values

About 300 mm
  • No change in strain values

Case A+

Case A−

Longi strain along the measurement
  About below joint 100 mm

Increase of size

Increase of length

Longi strain along the measurement
  About below joint 300 mm
ANALYSIS ON COMPOSITES

- At two heights:
  - About 100 mm
    - Clear change in strain values
    - + and -300µε
  - About 300 mm
    - Small change in strain values
    - + and -100µε

Case A+

Case A−
FBG SENSING POINTS POSITION

Distance in between sensors

150 mm?

30 cm?

Redundancy of sensor lines

Connection from both sides possible
CONCLUSIONS

- Further Finite element simulations are needed
- Possibility to detect defects/disbonds by looking at the strains on the composite side
- If we have every 30 cm a sensor a potential defect of 15 cm can be detected
- Necessity to know the loading condition, wave direction to do active classification of loading conditions

<table>
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<th>Wind speed (m/s)</th>
<th>rpm</th>
<th>Pitch angle (deg)</th>
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<tr>
<td></td>
<td>Min.</td>
<td>Max.</td>
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<tr>
<td>1:Pitch : &gt;80</td>
<td>n/A</td>
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<tr>
<td>2:Pitch : ±80</td>
<td>0</td>
<td>20</td>
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<tr>
<td>3:Pitch : ±20</td>
<td>n/A</td>
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<tr>
<td>4:RPM : &lt;10</td>
<td>n/A</td>
<td>n/A</td>
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<tr>
<td>5:RPM : ±10</td>
<td>n/A</td>
<td>n/A</td>
</tr>
<tr>
<td>6:RPM : &lt;16</td>
<td>n/A</td>
<td>n/A</td>
</tr>
<tr>
<td>7:RPM: ±16</td>
<td>n/A</td>
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<tr>
<td>8:Curt-Out</td>
<td>20</td>
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Example Different loading conditions for a wind turbine (Courtesy 24Sea)
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FBG SENSORS IMPLEMENTATION

• ONLINE/OFFLINE

• APPLICABILITY:
  • Glue fibres on boat-hull, superstructure (accessibility to structure needed, from outside)
  • Multiple fibres can be used with multiple sensors,
  • Measurement frequency high enough to detect dynamic effects

• REPAIRABILITY:
  • Only when not embedded in the bonded joint
  • Renew/repair sensor is possible
FEASIBILITY OF INSTALLATION

Flat sensor strip
Protection of environment
Switch to round GFRP rod

Stand alone read-out unit
- Measurement
- 4G
• Unprotected steel samples with optical & electrical strain gages
• Optical sensors and glue have survived the salt spray
  • Spectrum can still be read completely
• Corrosion got between strain sensor and steel, so most likely no longer measuring strain (As expected, to be verified)
• Corrosion prevention required for sensors glued steel

• CFRP samples with same sensors now in salt spray chamber at TUD
  • Much better results expected since no corrosion under adhesive
FRONT RUNNER IN FIBER OPTIC SENSING

JUNE 2019
SERVICES & ADDING VALUE BY SENSING

STRUCTURAL MONITORING

DEVELOPMENT PARTNER

ENGINEERING > PRODUCTION > INSTALLATION > COMMISSIONING > DATA MANAGEMENT
SENSEING FLOW

TECHNOLOGY IMPLEMENTATION

SENSOR SYSTEM INSTALLATION

ENGINEERING

PRODUCTION & INSTALLATION

OPERATION & COMMISSIONING

WE DELIVER SMART STRUCTURES DATA

DATA ACQUISITION & MANAGEMENT

DATA ANALYSIS & INTERPRETATION

DATA REPORTS

DATA OUTPUT
ASSET MANAGEMENT

- **Increase production uptime**: Collect real data of structural integrity
- **Shift to predictive maintenance**: Avoid blind spots between periodic inspections
- **Reduce TCO**: Use data for diagnostics and statistics
- **Predict LIFETIME**: Automate alerts of critical faults
Design Validation

In Situ loads measurements
  Get real insight of loading conditions

Real load monitoring
  Reliable & accurate

Avoid trial & errors
  Design fit for purpose

Validate your Finite Elements
  System wide stress, strain & temperature
Cure & flow analysis

Composites process control

Strain mapping

Reliable & Accurate measurements

Sensor Network

Multiplexing of sensing points

Non Intrusive

In-situ embedded strain, temperature sensing

CURE & FLOW ANALYSIS

PROCESS CONTROL
COMPOSITES REINFORCED FIBER OPTIC SENSORS

- Flat type (composite tape, ~5mm width)
- Round type (composite rod, ~0.5mm – 2mm diam)

Customized sensor configuration
- Variable lengths (~1m – 100m or more)
- Variable amount of sensing points (~max 20/line)
- Custom predefined sensor locations (min 1cm spacing)
DESIGNED FOR HARSH ENVIRONMENTS

EMBEDDED OR SURFACE MOUNTED COMPOSITES BASED SENSORS

- Fast installation time
- Variable & unlimited in length
- Geometric freedom (round, square, L-shape)

- Extensive multiplexed sensor network
- Chemical resistant (sea water, oil, ...)
- Reproducible UV glueing
Fiber optic edge connection solution for embedded optical fibres in composite materials
non-intrusive connection featuring low optical-loss and fiber strain relief with standard FO pigtail.

Patent EP16180924.9