Ultrasonic Inspection of Adhesive Joints of Composite Pipelines

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MOTIVATION

The crescent use of composite materials on many sectors of the industry and, specially, on the oil industry;

Inexistence and necessity of a methodology of non-destructive inspections capable to assure the integrity and reliability of joints used on pipelines conducting fluids.
OBJECTIVE

Evaluate the application of the ultrasonic technique at the detection of defects as lack of adhesive and lack of adhesion, commonly found in adhesive joints of GFRP pipelines applied at onshore and offshore facilities.
ULTRASOUND IN GFRP

- Anisotropy and attenuation: inherent characteristics
- Most studied defects: porosity, delaminations, matrix/reinforcement disbonding, fatigue damages
- Developments focused on aerospace applications: Thin Structures
METHODOLOGY

Studied Samples

• 16” diameter GFRP pipeline joint: epoxy + glass fiber

• Through wall thickness: aprox. 20mm

• Adhesive layer thickness: aprox. 1mm
**METHODOLOGY**

**Studied Defects**

**Lack of Adhesive**: Areas with absence of the adhesive layer.

**Lack of Adhesion**: Foreign body that prevents the direct contact between the adhesive layer and the pipe’s surface.
METHODOLOGY
Simulations

Ultrasonic Module of CIVA© 11 beta version.

Simulation of GFRP structure and commercially available transducers.
METHODOLOGY
Reference Block

Aim: validate the inspection

This block has the same cross section as the inspected samples.
METHODOLOGY

Transducers & Equipment

- Contact transducers:
  - 1.6MHz, 2.25MHz, 5MHz.

- Ultrasonic Equipment: GE USIP 40

- Manual Scanning
RESULTS
Simulations

1.6 and 2.25 MHz Transducers

Scanning step: 9 mm

Computation of surface, interface and backwall echos

GFRP Adhesive Layer GFRP

Defect
RESULTS
Simulations: Lack of Adhesion

1.6 MHz – Non Defective Area
1.6 MHz – Defective Area
Surface Adhesive Backwall

2.25 MHz – Non Defective Area
2.25 MHz – Defective Area
Surface Adhesive Backwall
RESULTS
Simulations: Lack of Adhesive

1.6 MHz – Non Defective Area

2.25 MHz – Non Defective Area

1.6 MHz – Defective Area

2.25 MHz – Defective Area
RESULTS
Simulations: 1.6 x 2.25MHz

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1.6MHz

2.25MHz
RESULTS

Experimental A-Scans

Non defective areas

Defective areas
RESULTS
Frequency Behavior

- Signals taken from the reference block
- 2.25MHz: the lowest frequency that returned good signals
- Used transducer: Imasonic IM 1626, 1.6MHz
Take a signal from the reference block, adjust the gain to elevate the second signal (pipe’s internal surface) to 80% of the display.
RESULTS
Acceptance Criteria

Acquired data: amplitude values (in % of the display) of the pipe’s internal surface echo.

- Amplitudes below 35% - Defective Areas
- Amplitudes between 35% and 40% - Transition areas
- Amplitudes above 40% - Non-defective areas
RESULTS

C-Scans

Blue: well bonded areas
Yellow: Transition areas
Red: defective areas

Lack of Adhesion 8-2

Lack of Adhesion 8-3
RESULTS

Cutting of the Joints

Selected Samples:
- Lack of Adhesion 4-2 and 4-3
- Lack of Adhesive 8-2 and 8-3

Method of evaluation:
Visual inspection
RESULTS
Comparison

Lack of Adhesive 8-2
RESULTS
Comparison

Lack of Adhesive 8-3

US C-scan | Real Map
RESULTS
Comparison

Lack of Adhesion 4-2

US C-scan

Real Map
RESULTS
Comparison

Lack of Adhesion 4-3

US C-scan

Real Map
## RESULTS

**Evaluation: US x Visual**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Adhesion 4-2</td>
<td>70</td>
</tr>
<tr>
<td>Lack of Adhesion 4-3</td>
<td>74</td>
</tr>
<tr>
<td>Lack of Adhesive 8-2</td>
<td>69</td>
</tr>
<tr>
<td>Lack of Adhesive 8-3</td>
<td>65</td>
</tr>
</tbody>
</table>

Accuracy: based on the comparison between C-scan and real maps.
RESULTS
Evaluation: US x Visual

• Limitations of the proposed methodology:
  
  – Lack of Adhesion: US was not able to detect some areas with the presence of a foreign body (adhesive tape).
  
  – Lack of Adhesive: US was not able to precisely dimension some defective areas. Defective areas not entirely covered by the US beam can be mistaken for non-defective areas.
RESULTS

Improvement of Accuracy & Resolution

- Focused Transducers: concentration of the energy at a focal spot

- CIVA simulation of a 1MHz commercially available transducer
RESULTS
Focused Transducer Simulations

Lack of Adhesion
Well Bonded
Surface  
Adhesive  
Backwall

Defective

Lack of Adhesive
Surface  
Adhesive  
Backwall
The pulse-echo technique is suitable to detect lack of adhesion and lack of adhesive defects in the studied material.

CIVA 11 was able to predict the ultrasonic response in the studied GFRP structure.

CIVA 11 was able to predict the frequency behavior in the studied GFRP structure.
CONCLUSIONS

Best transducer frequency: aprox. 1MHz

Visual inspection after cutting the samples confirmed the global results former obtained with US inspection.

Focused transducers may improve sensibility and resolution
FUTURE WORK

- Inspections with focused transducers
- Automatization of the proposed methodology
- Evaluation of more sophisticated techniques
Thank you!

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