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Review of Progress in Quantitative Nondestructive Evaluation

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

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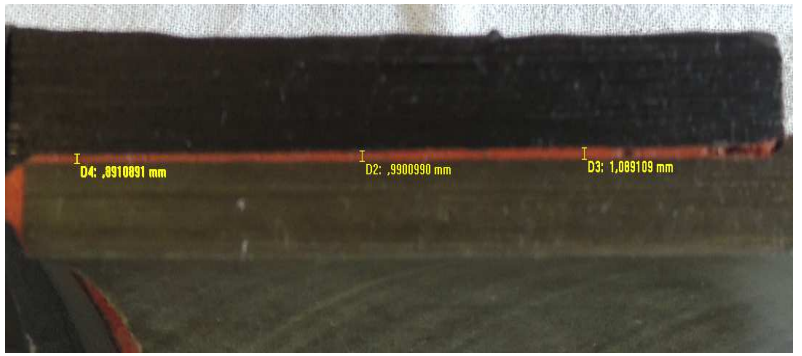
METHODOLOGY
Studied Samples

- 16” diameter GFRP pipeline joint: epoxy + glass fiber
- Through wall thickness: aprox. 20mm
- Adhesive layer thickness: aprox. 1mm



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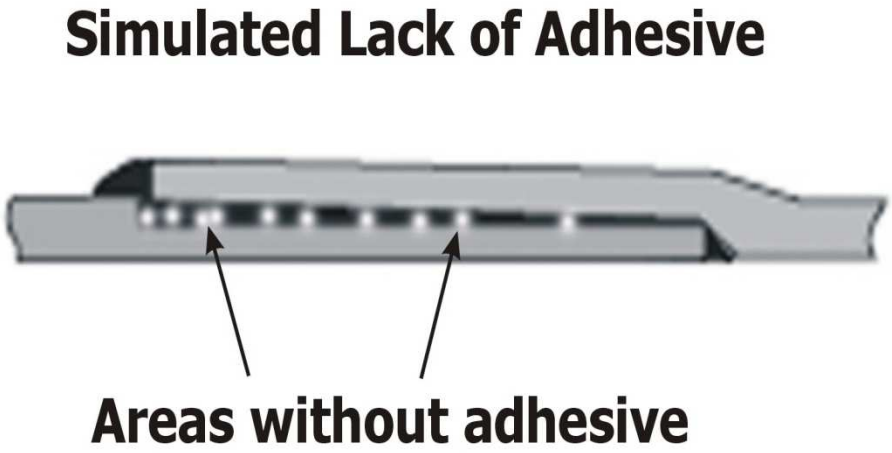
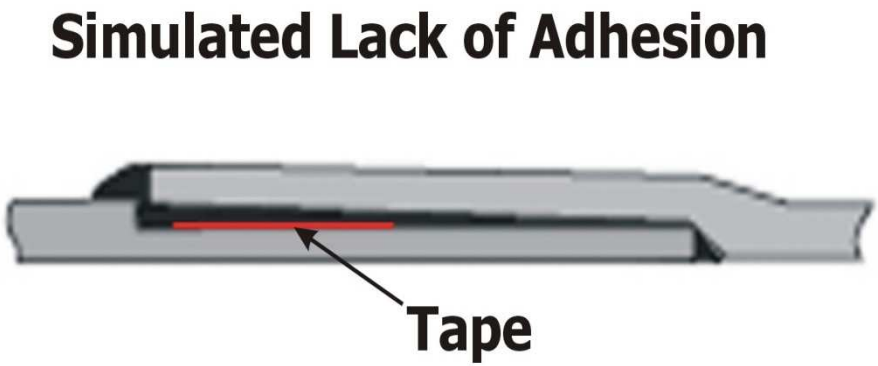
METHODOLOGY
Studied Defects

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.



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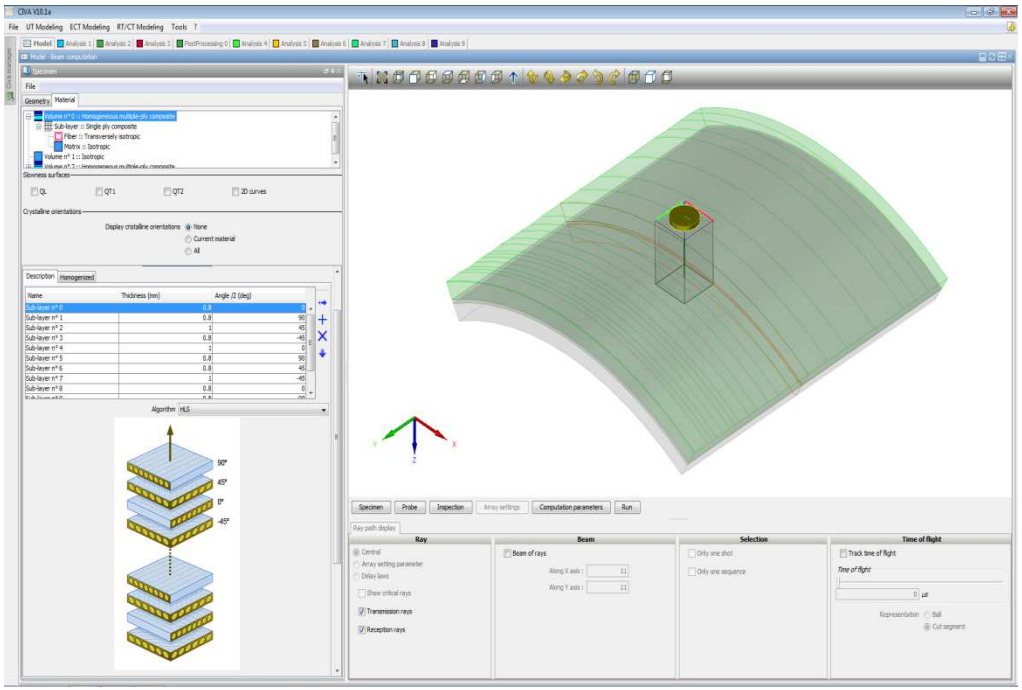
METHODOLOGY
Simulations

Ultrasonic Module of CIVA© 11 beta version.

Simulation of GFRP structure and commercially available transducers.



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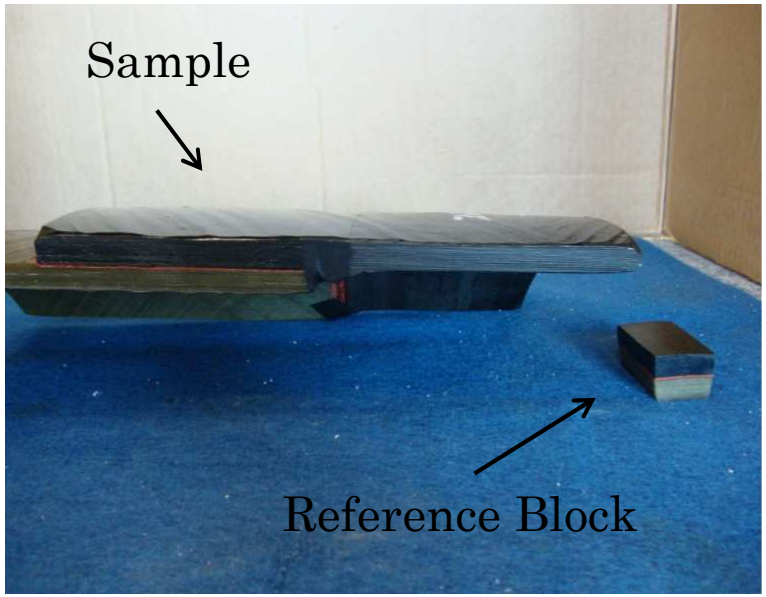
METHODOLOGY
Reference Block

Aim: validate the inspection

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



Sample and its reference block

METHODOLOGY
Transducers & Equipment

- Contact transducers:
  - 1.6MHz, 2.25MHz, 5MHz.
- Ultrasonic Equipment: GE USIP 40
- Manual Scanning

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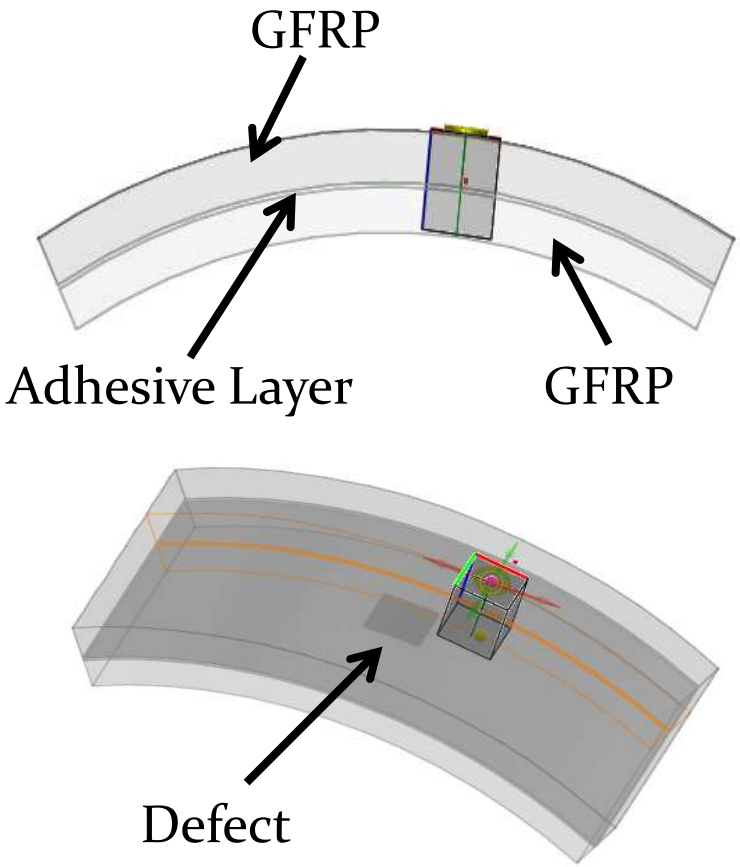
RESULTS
Simulations

1.6 and 2.25MHz Transducers

Scanning step: 9mm

Computation of surface, interface and backwall echos



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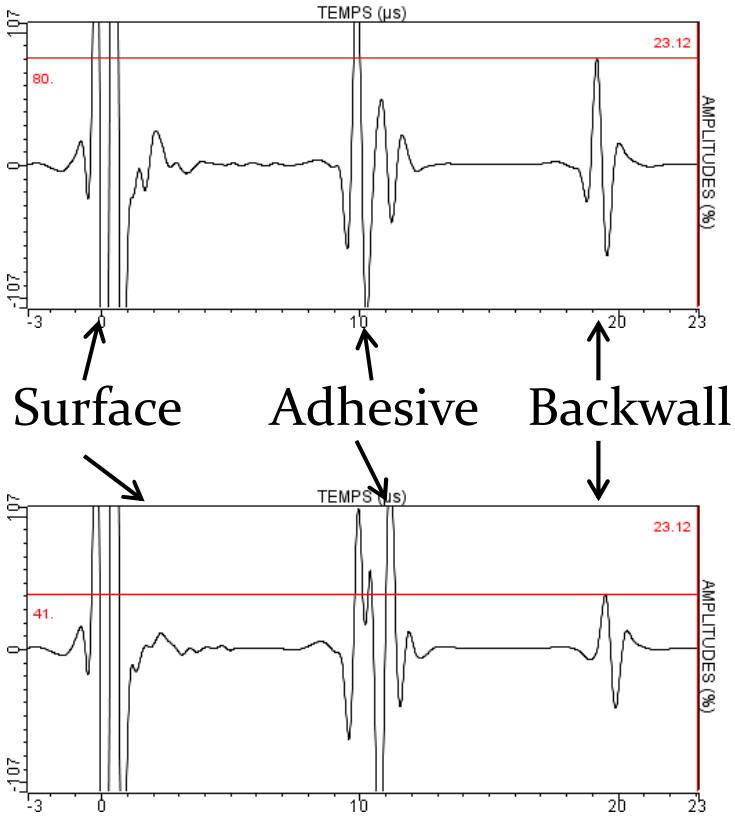
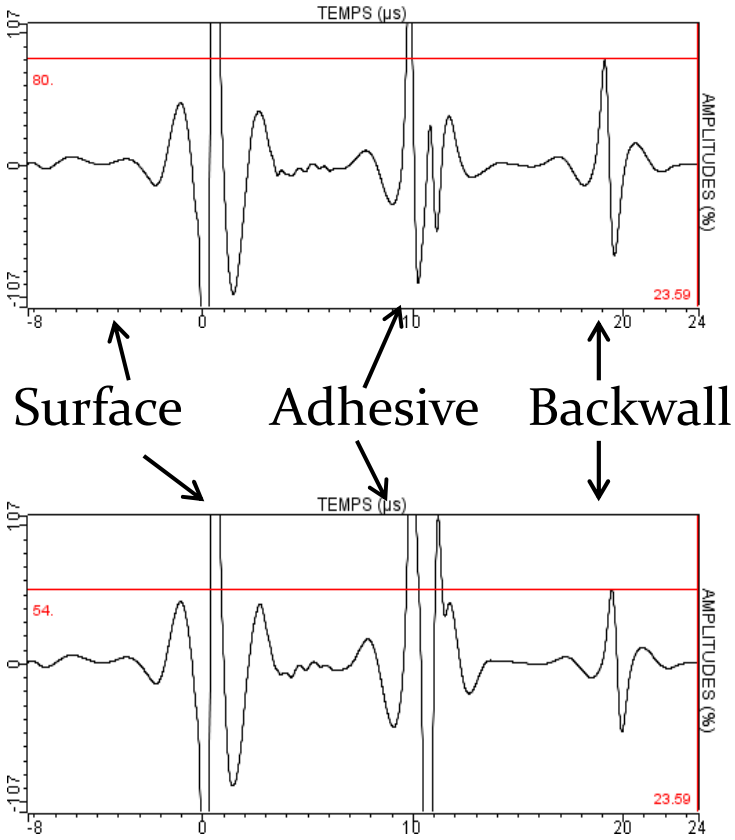
RESULTS

Simulations: Lack of Adhesion

1.6 MHz – Non Defective Area



2.25 MHz – Non Defective Area



1.6MHz – Defective Area

2.25 MHz – Defective Area

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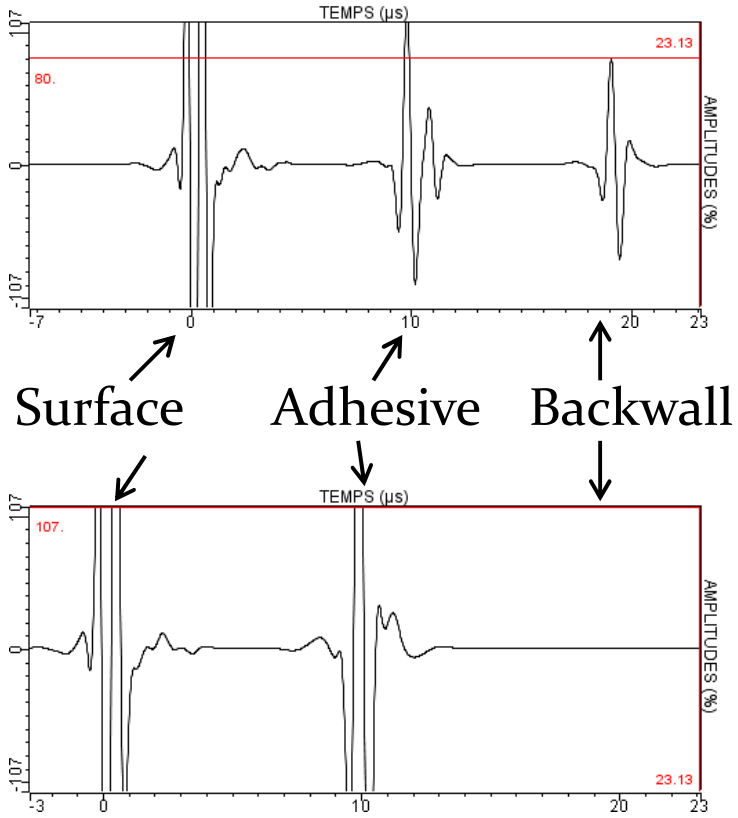
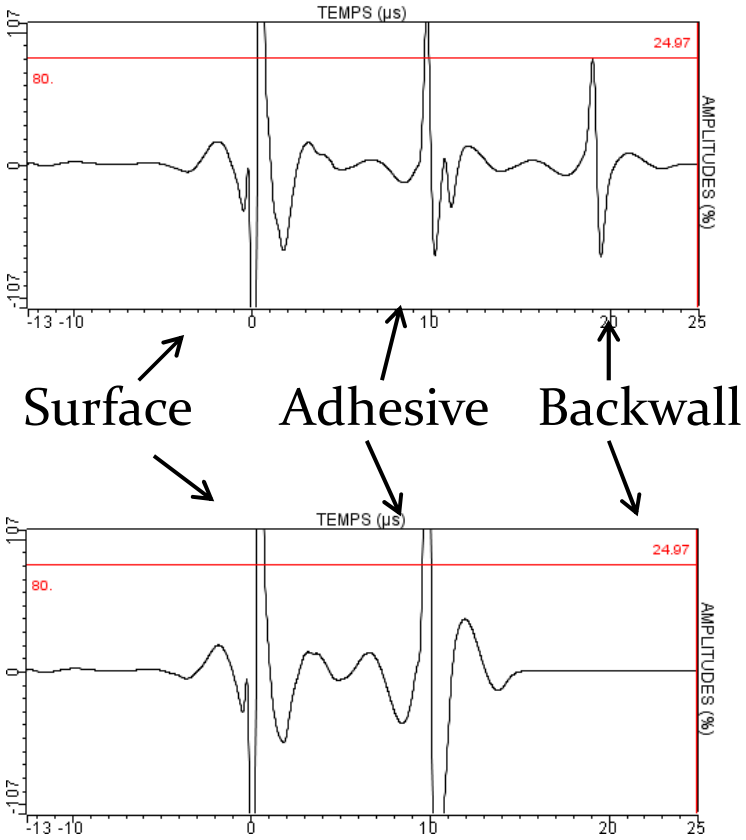
RESULTS

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

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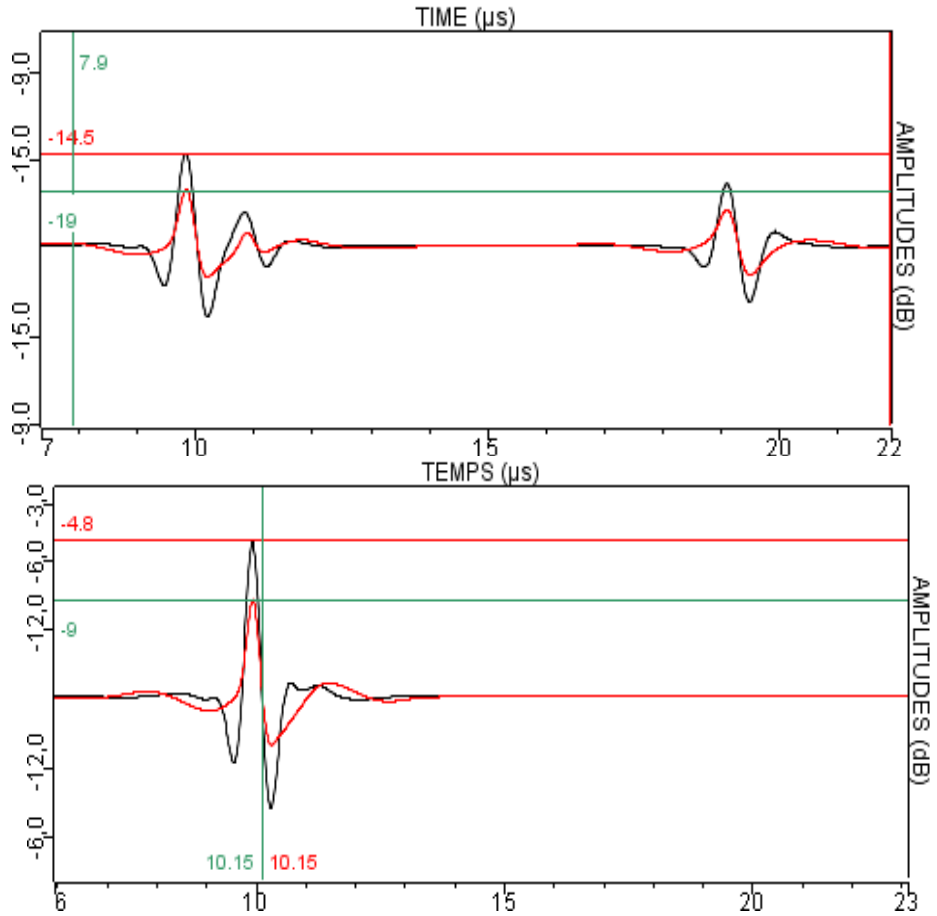
RESULTS
Simulations: 1.6 x 2.25MHz

1.6MHz

2.25MHz



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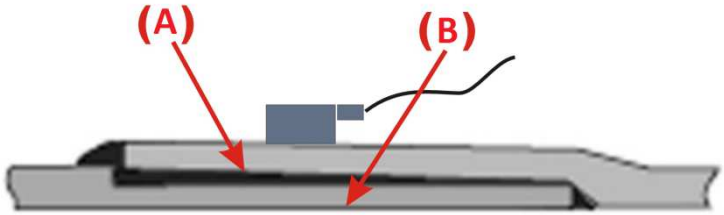
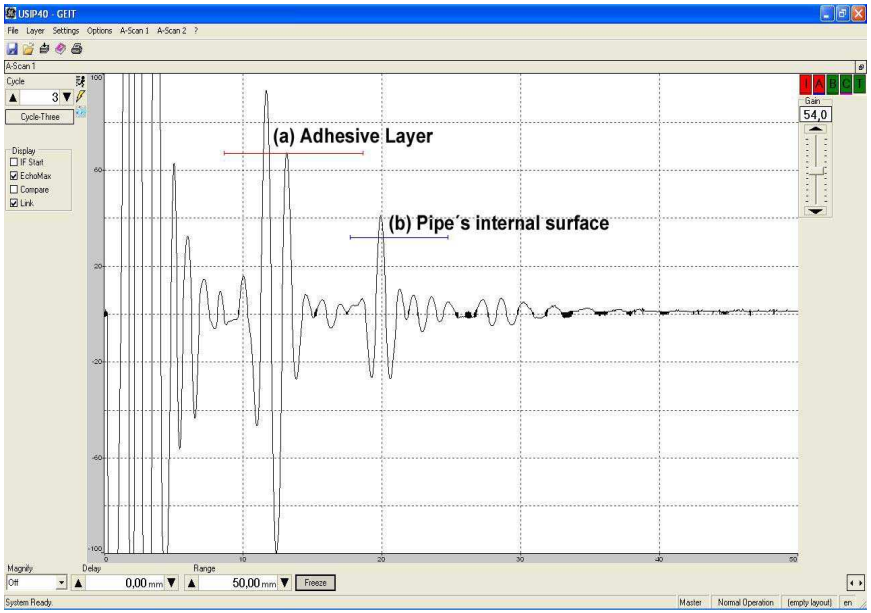
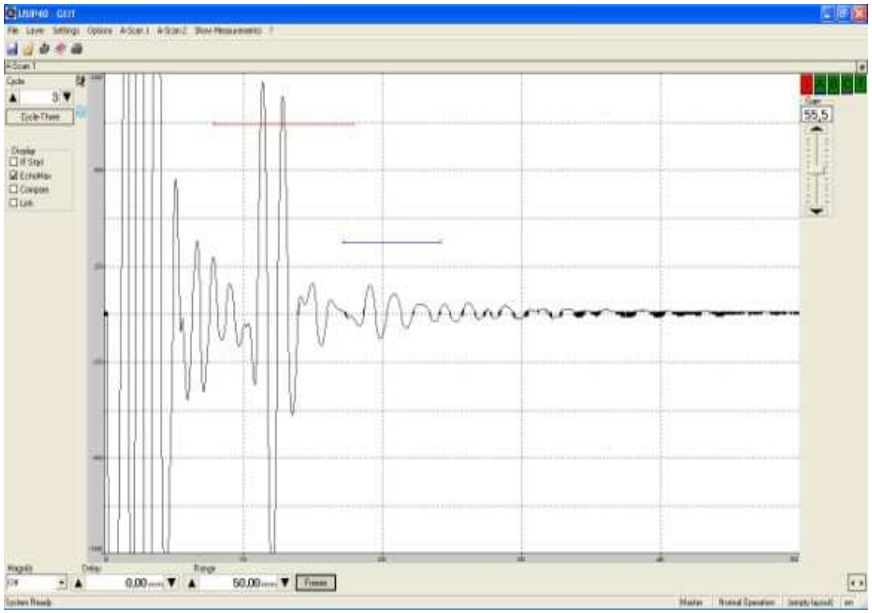
RESULTS
Experimental A-Scans







Non defective areas

Defective areas

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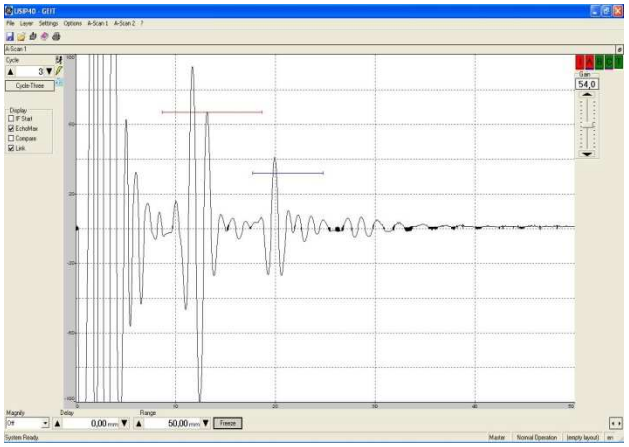
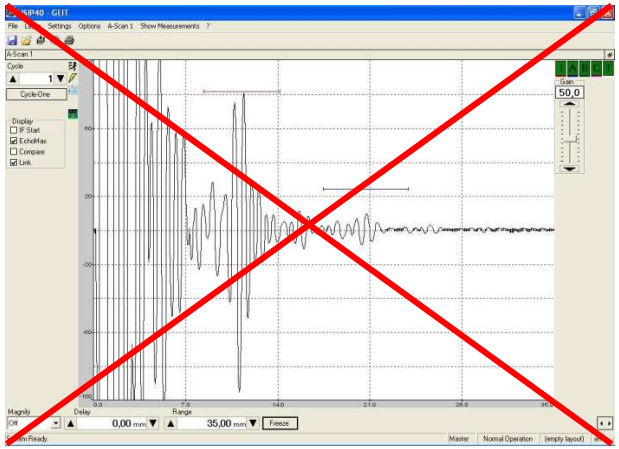
RESULTS
Frequency Behavior

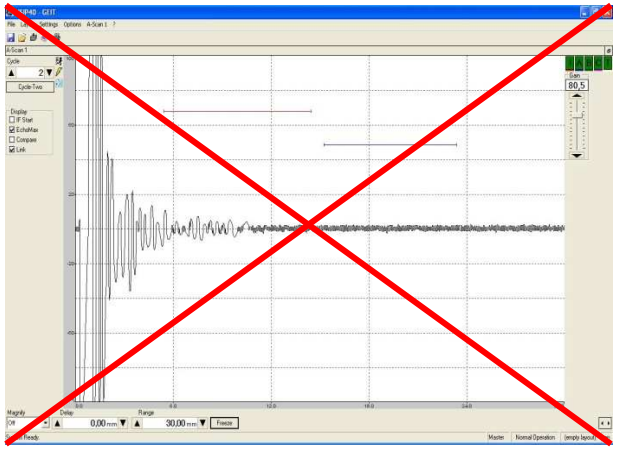
- Signals taken from the reference block
- 2.25MHz: the lowest frequency that returned good signals
- Used transducer: Imasonic IM 1626, 1.6MHz



1 MHz



2.25 MHz



5 MHz

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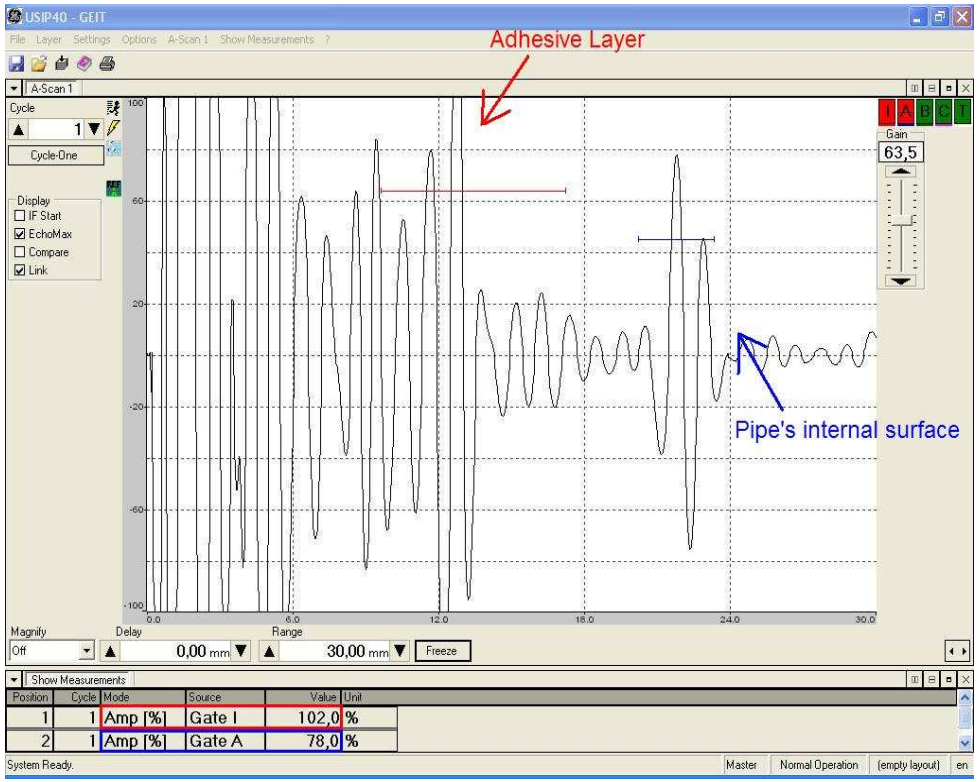
RESULTS
Calibration

Take a signal from the reference block, adjust the gain to elevate the second signal (pipe's internal surface) to 80% of the display.



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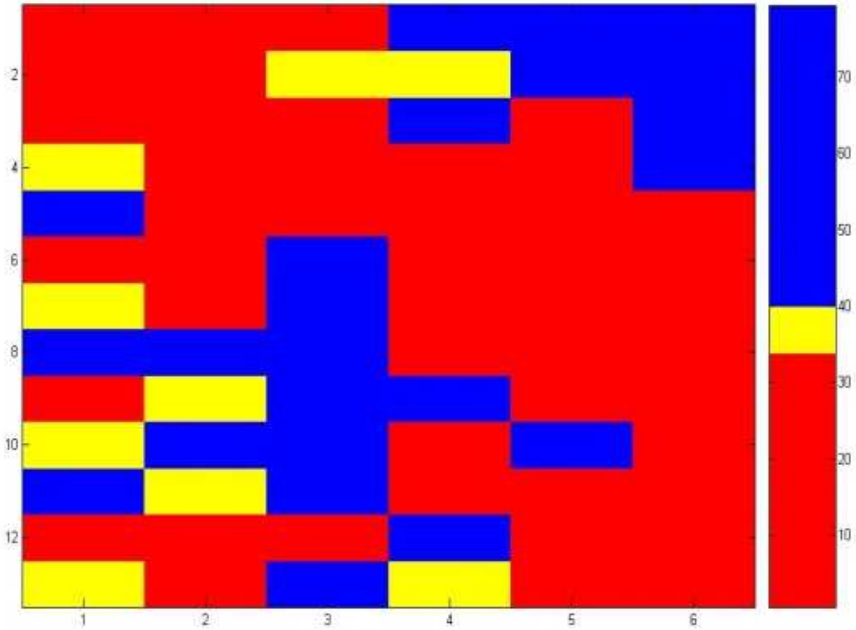
RESULTS
Acceptance Criteria

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

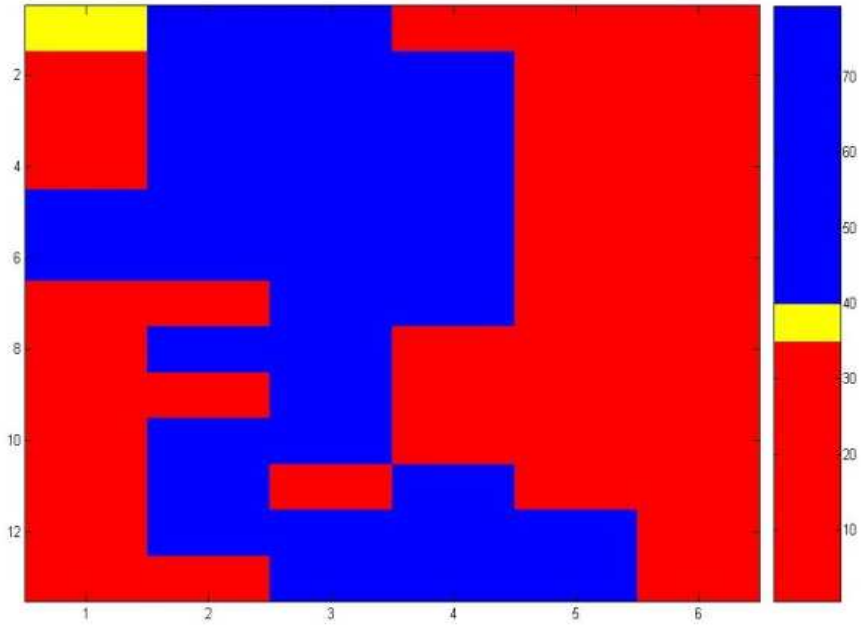
- Amplitudes below 35% - Defective Areas
- Amplitudes between 35% and 40% - Transition areas
- Amplitudes above 40% - Non-defective areas

RESULTS
C-Scans

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



Lack of Adhesion on 4-2



Lack of Adhesion on 4-3

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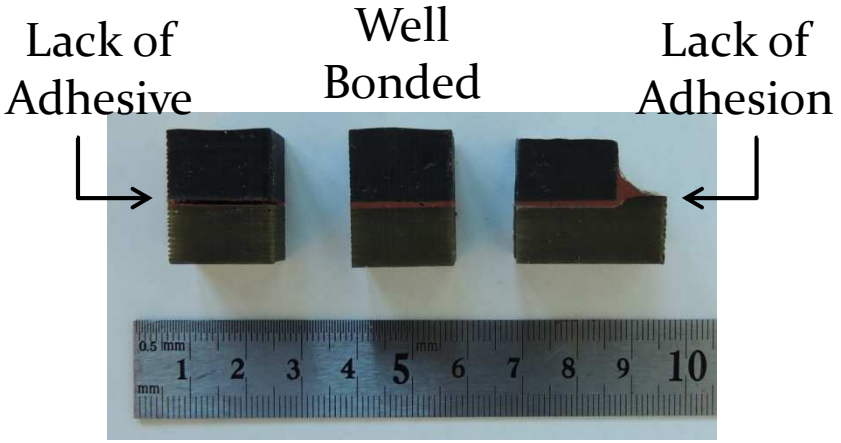
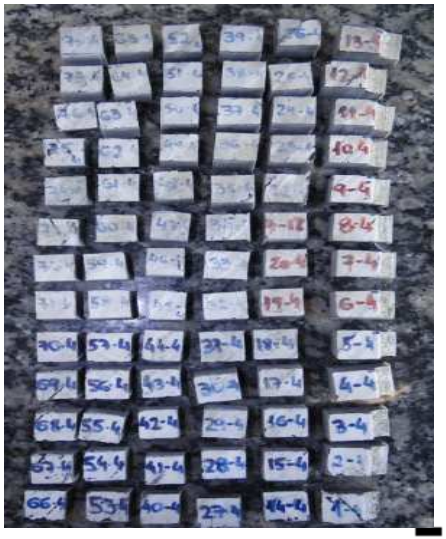
RESULTS
Cutting of the Joints

Selected Samples:

- Lack of Adhesion 4-2 and 4-3
- Lack of Adhesive 8-2 and 8-3

Method of evaluation:
Visual inspection





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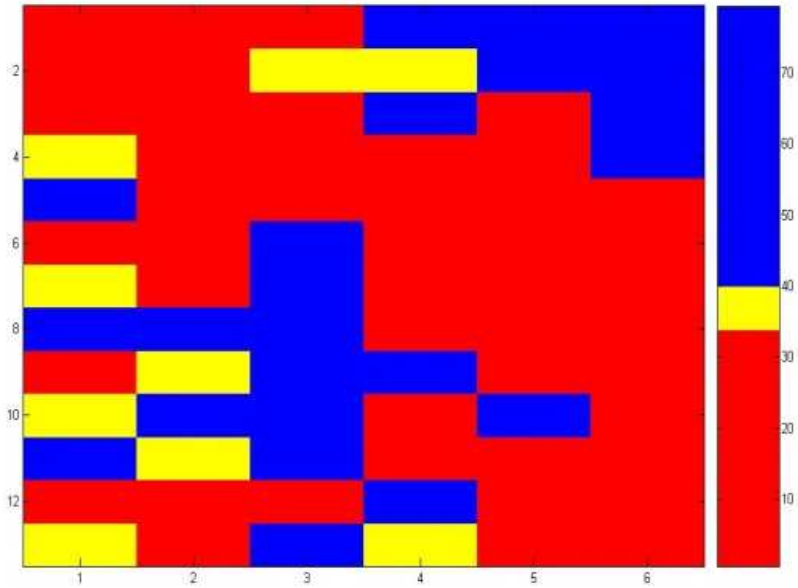
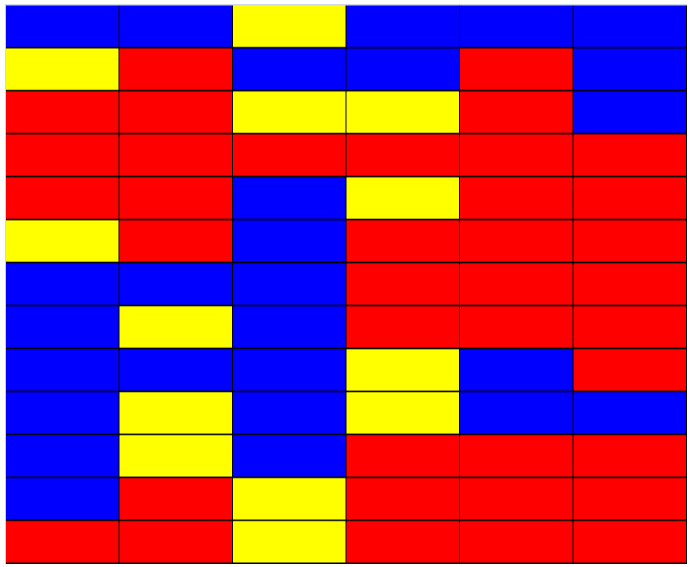
RESULTS
Comparison

Lack of Adhesive 8-2



US C-scan



Real Map

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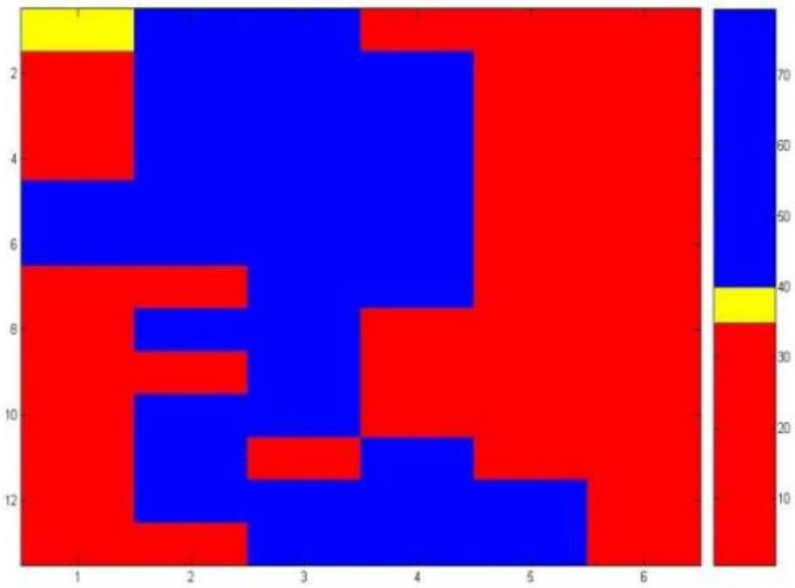
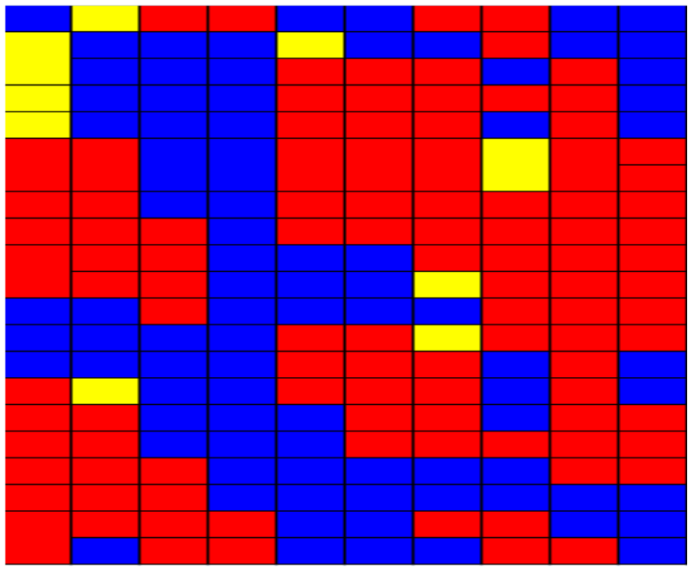
RESULTS
Comparison

Lack of Adhesive 8-3



US C-scan



Real Map

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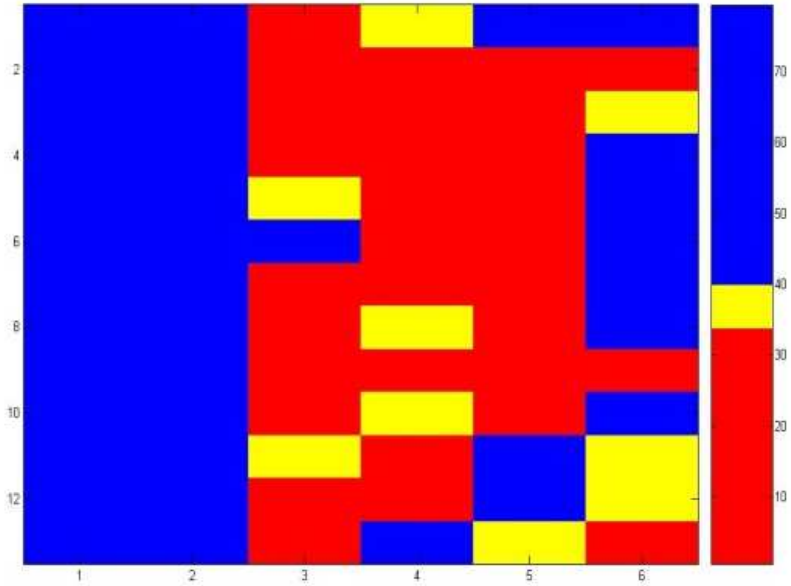
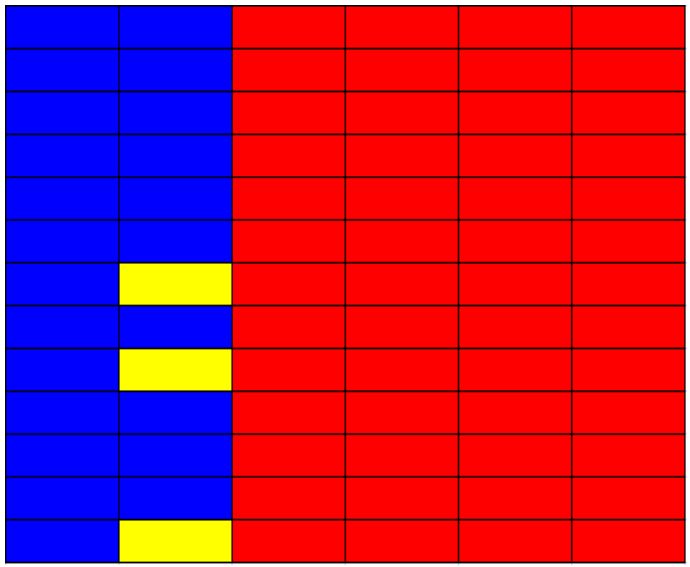
RESULTS
Comparison

Lack of Adhesion 4-2



US C-scan



Real Map

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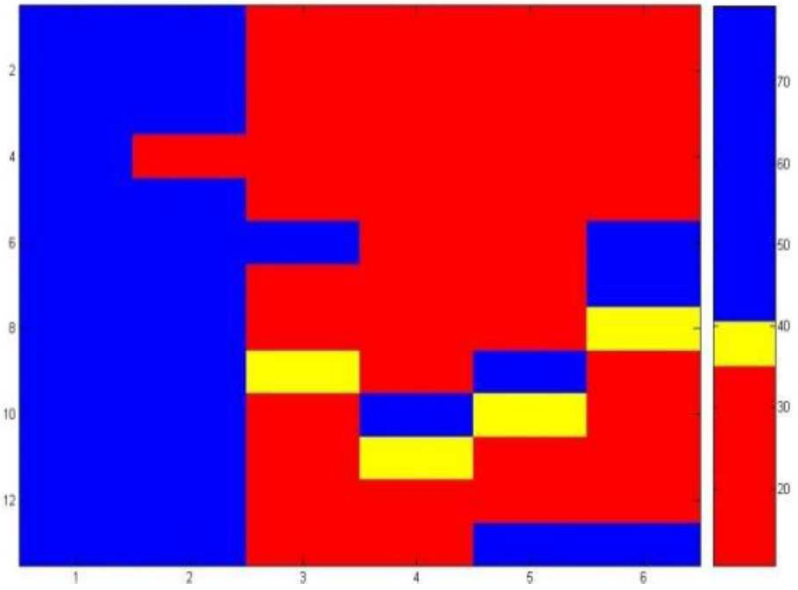
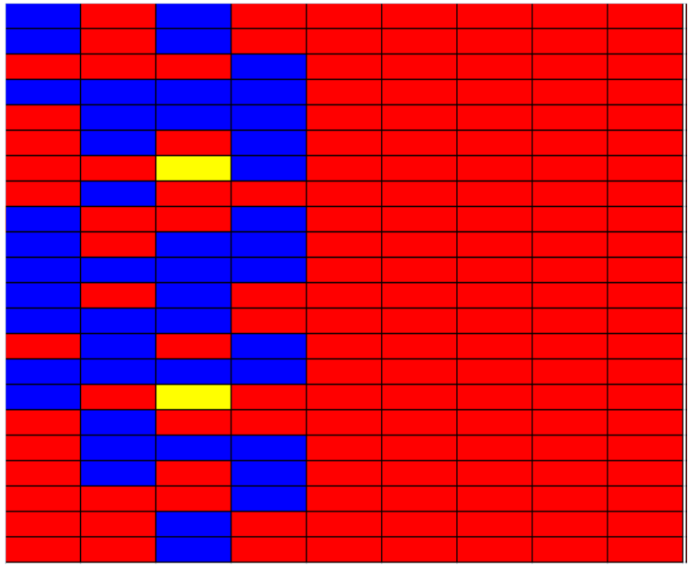
RESULTS
Comparison

Lack of Adhesion 4-3



US C-scan



Real Map

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RESULTS

Evaluation: US x Visual

Sample	Accuracy (%)
Lack of Adhesion 4-2	70
Lack of Adhesion 4-3	74
Lack of Adhesive 8-2	69
Lack of Adhesive 8-3	65

Accuracy: based on the comparison between C-scan and real maps.

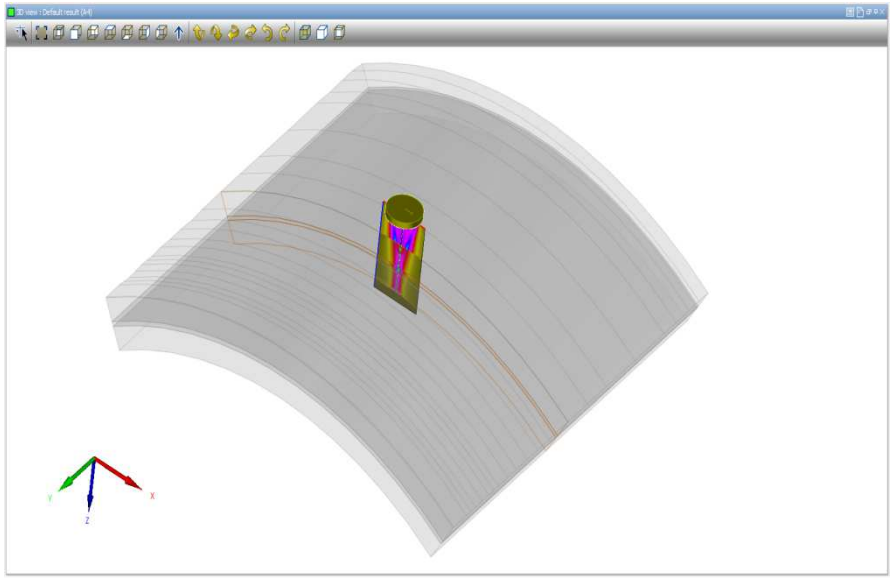
RESULTS
Evaluation: US x Visual

- 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



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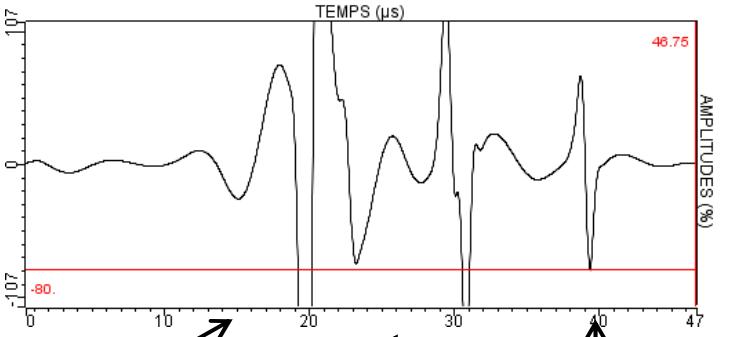
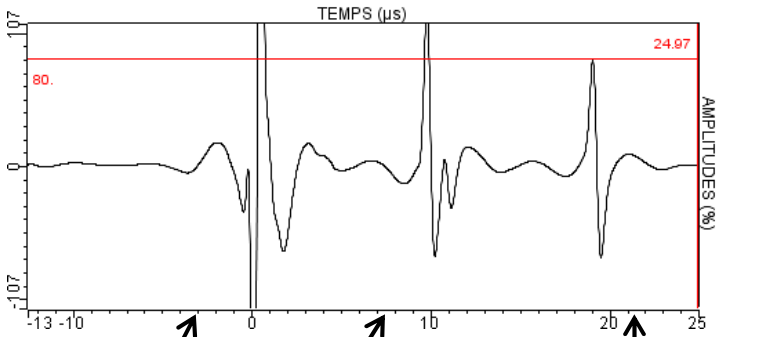
RESULTS
Focused Transducer Simulations

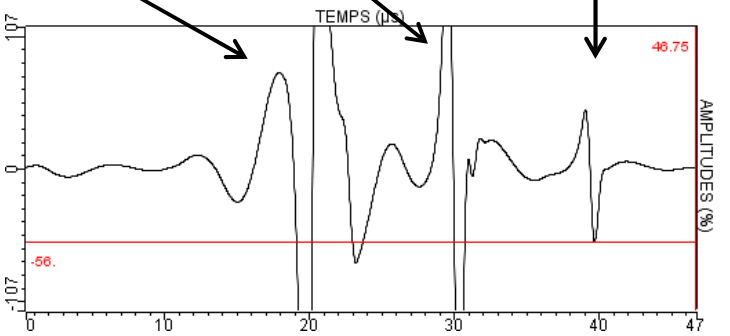
Lack of Adhesion | **Lack of Adhesive**

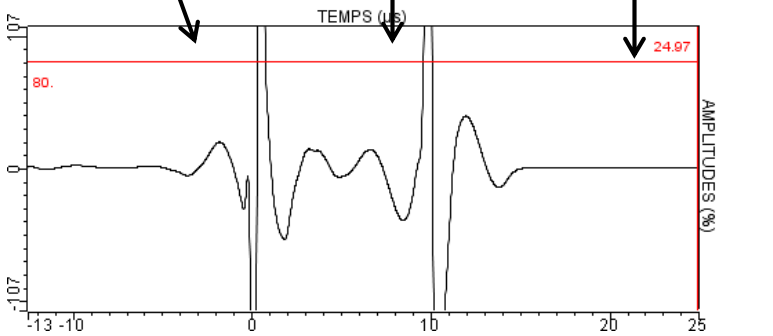
Well Bonded





Defective





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CONCLUSIONS

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

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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

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FUTURE WORK

Inspections with focused transducers

Automatization of the proposed methodology

Evaluation of more sofisticated techniques

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Thank you!

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