ICCM 23
INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS
BELFAST 2023
30 JULY – 4 AUGUST

INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS
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QUALITY INSPECTION OF THERMOSET LATTICE STRUCTURES WITH PATCHES FOR AIRFRAFT RIB APPLICATIONS

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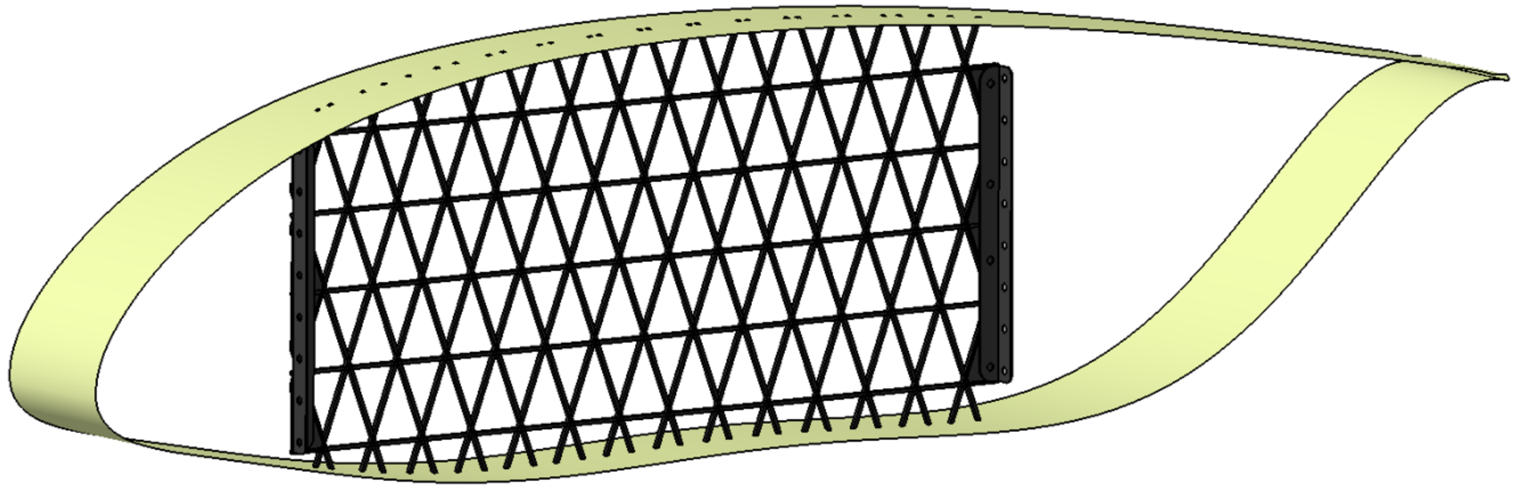
CONTENT

Motivation: Improving composite lattice structures for aircraft applications

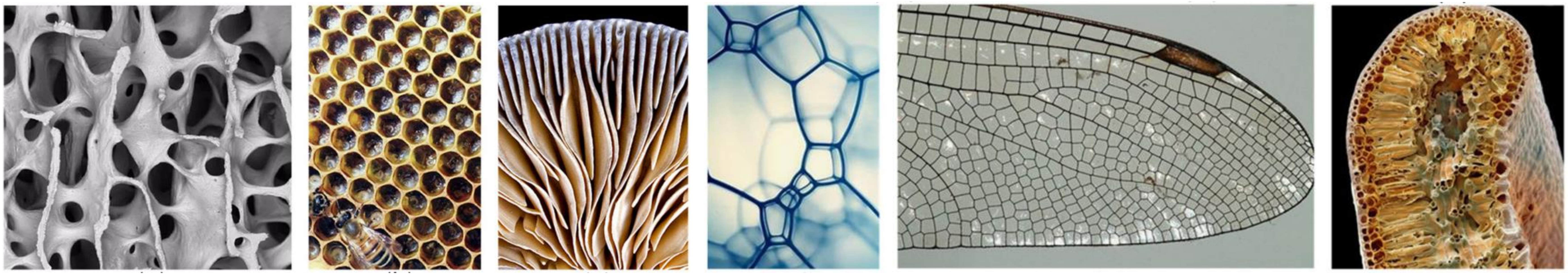
Objective: Quality inspection of composite lattice structures for aircraft ribs

- ❖ Introduction
- ❖ Composite Lattice Structures
- ❖ Aircraft Rib Design
- ❖ Ultrasonic C-Scan Method
- ❖ Quality Inspection with C-Scan
- ❖ Conclusion



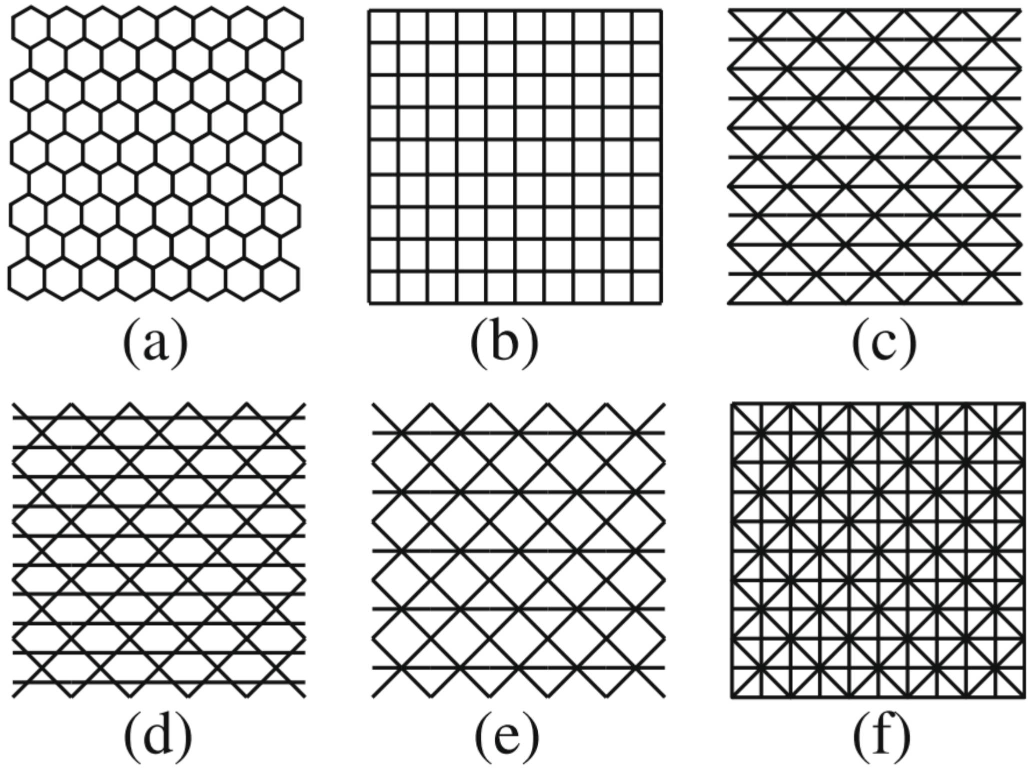
INTRODUCTION

- Composite lattice structures can be described as structural architecture that is made up of continuous fibre-reinforced materials as stiffeners.
- These structures have significantly higher inherent damage tolerance in contrast to their alternatives such as honeycomb sandwich composite structures. Structural efficiency can be seen also a big advantage for grid-stiffened structures.
- However, the behaviour of grid-stiffened structures is not still well-known. Even if there are lots of numerical and analytical models, there is still lack of information under different loading conditions.
- The complexity of grid patterns causes longer manufacturing process time. Moreover, tooling requirement of grid-stiffened structures is a serious disadvantage.

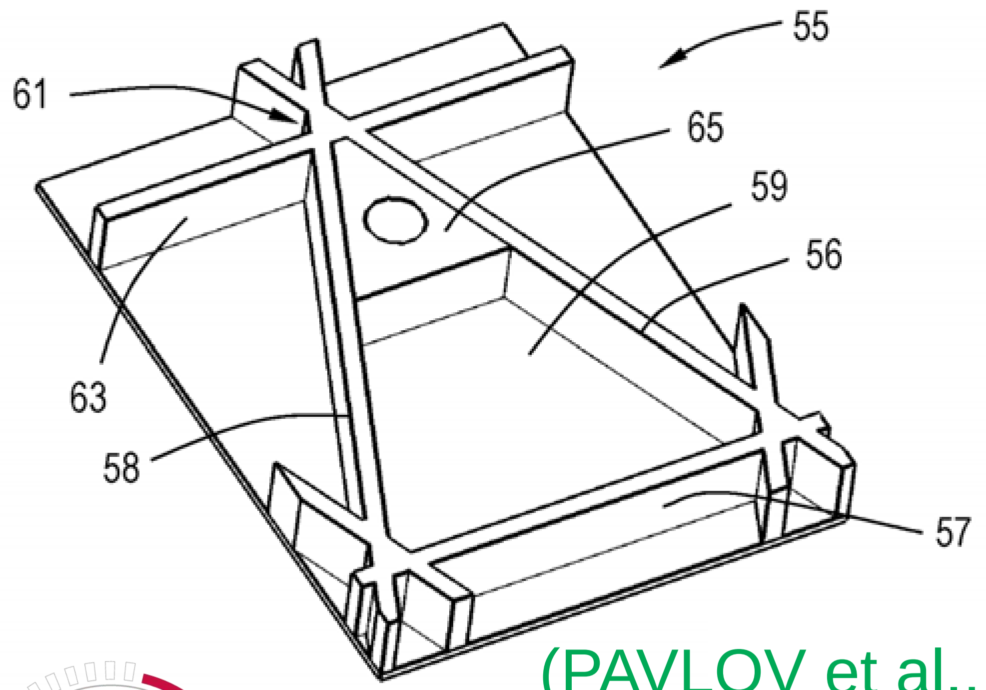


(Nazir et al., 2019)

COMPOSITE LATTICE STRUCTURES



(Fan et al., 2009)



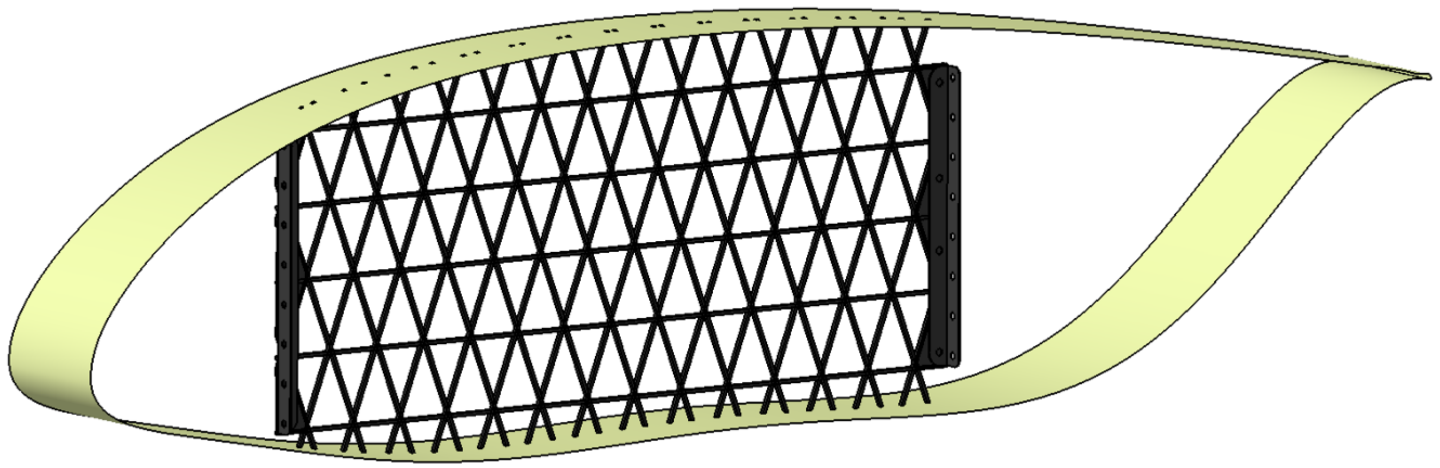
(PAVLOV et al., 2017)

(Pavlov et al.)

AIRCRAFT RIB DESIGN

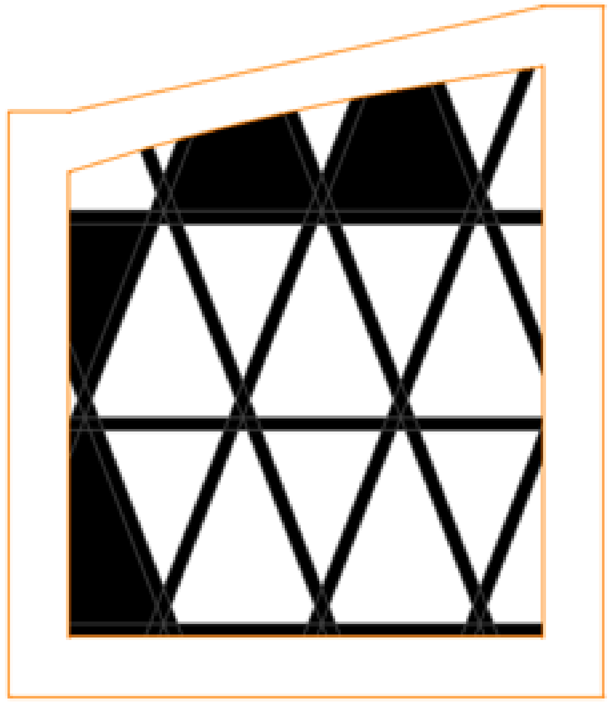
- Commercial aircraft rib design is still typically an aluminium structure that involves multiple components & processes including machining, forming, cutting, bonding and fastening to create an end product.
- This is highly intensive and involves a lot of material wastage to achieve the final design.

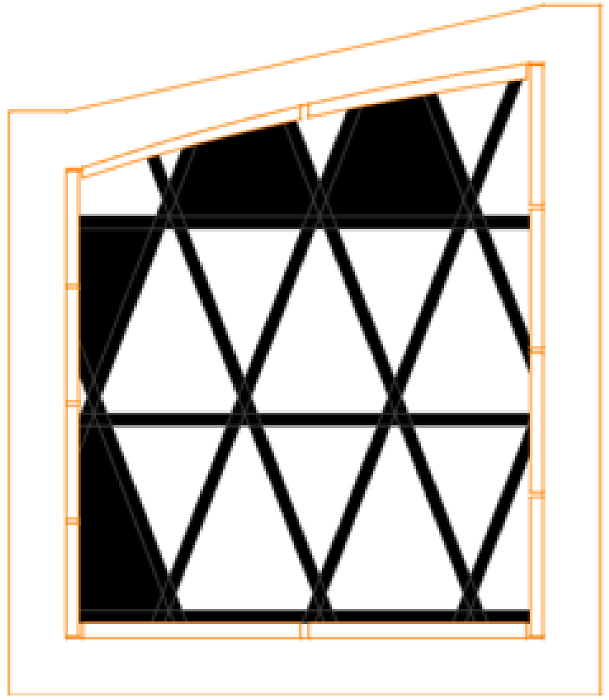
- A typical metallic aircraft rib includes:
  - Cut-outs in upper & lower profiles for stringers on the wing skins
  - Holes in the web to reduce weight & provide access
  - Integrated vertical stiffeners to provide structural integrity
- Implementing ATG Europe's CFRP lattice technology for aircraft ribs would provide multiple benefits including:
  - Ability to tailor the structural architecture to optimise the design
  - Significant weight savings due to efficient architecture and light weight materials
  - Open lattice structure facilitates access for assembly, maintenance, wiring, piping, etc.
  - One-shot manufacturing process
  - Associated cost reductions due to all these points

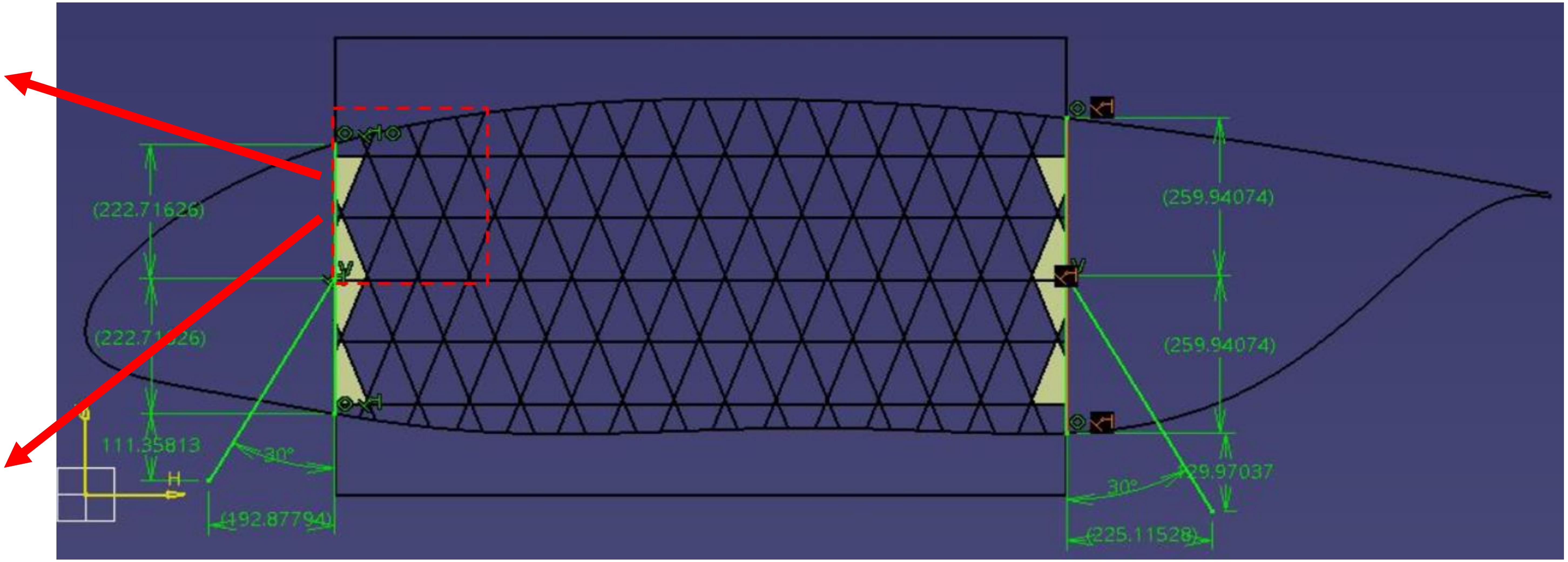


AIRCRAFT RIB DESIGN

❖ Curved section was studied in this work.





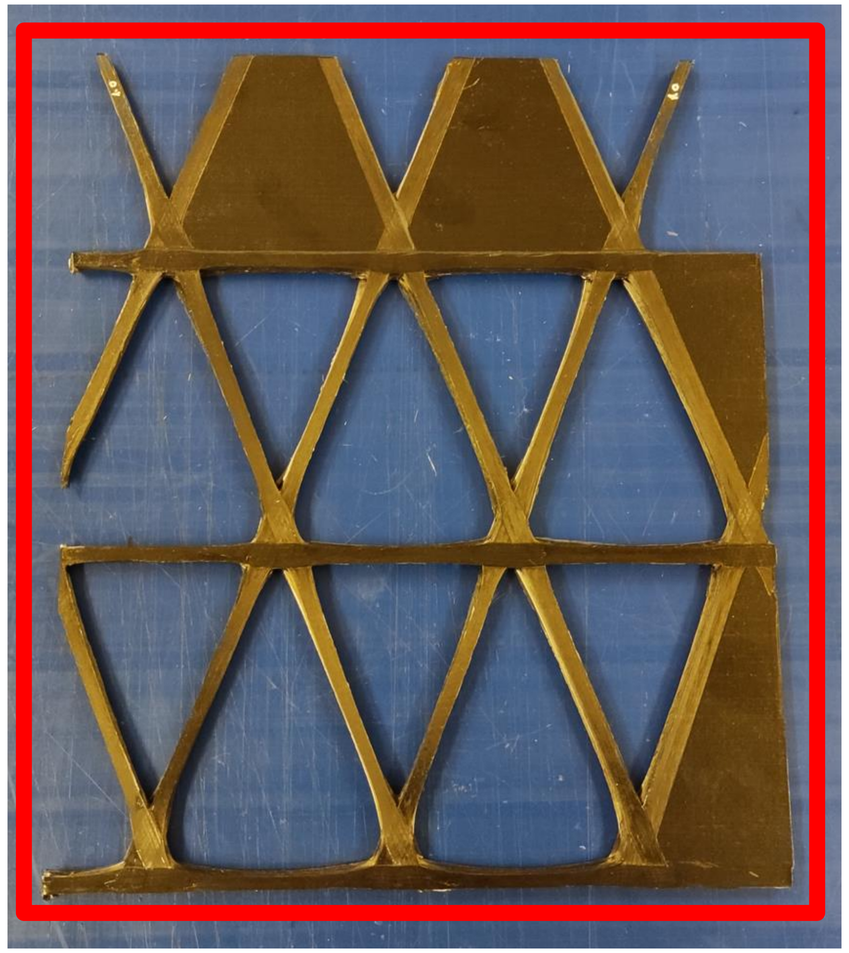


AIRCRAFT RIB DESIGN

- In this study, 3 different sections of aircraft rib design were used and manufactured by hand layup process.
- Panel 1 was manufactured with rectangular geometry. Curved section was used in Panel 2 and 3.
- Identical expansion tooling was used inside the cells. In panel 3, edge blocks were not used.
- Unidirectional carbon fibre reinforced epoxy matrix thermoset prepreg tows were used (Toray T700 TC350).
- The thickness values of the panels are approximately 6mm in ribs/nodes and 3.3mm in patches.

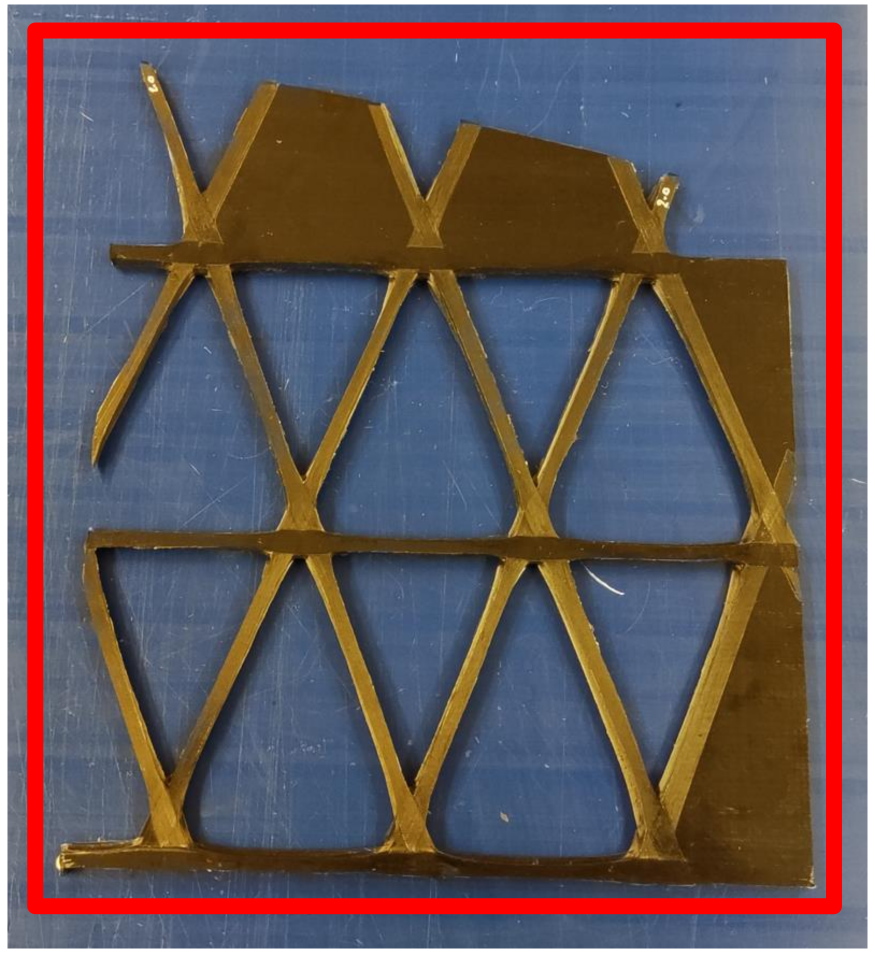
Panel 1

Edge Blocks

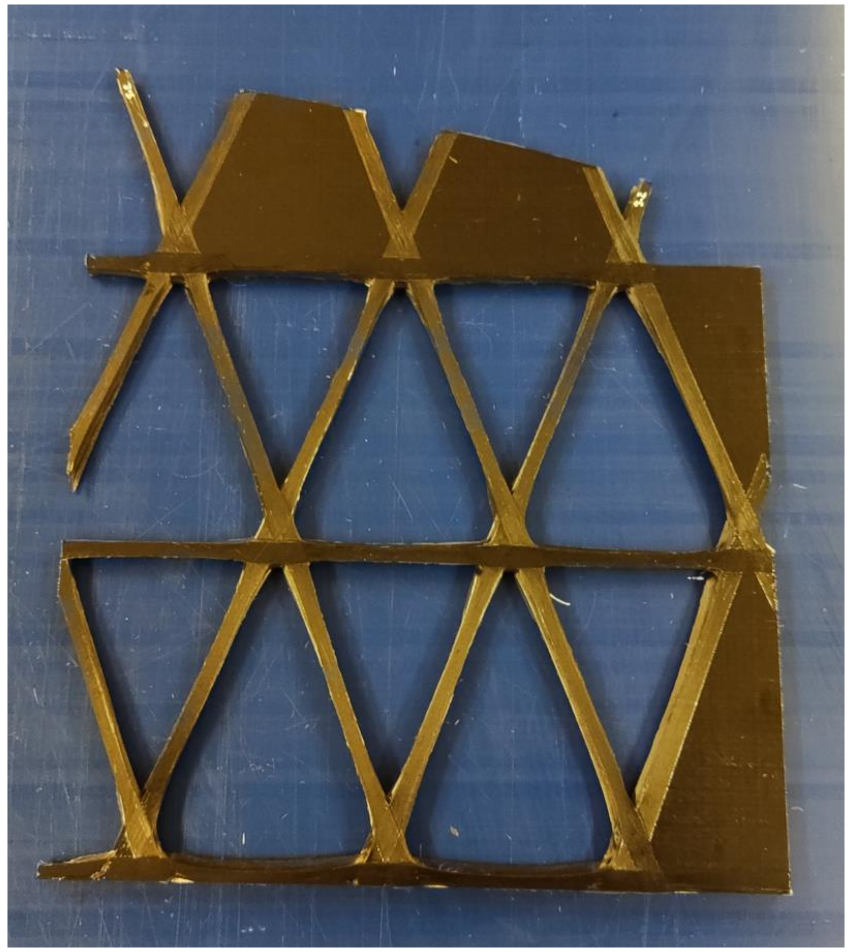


Panel 2

Edge Blocks

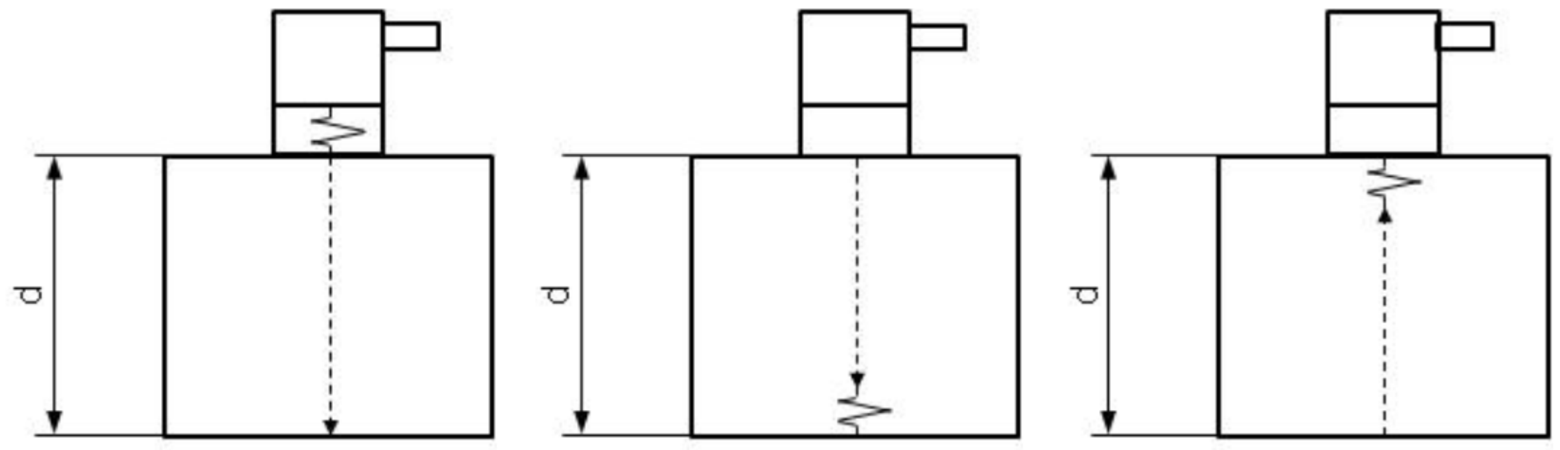


Panel 3



ULTRASONIC C-SCAN METHOD

- Pulse Echo Method



Start of the acoustic pulse at the surface at the time t_1

Impact of the acoustic pulse on the backwall

Impact of the reflected acoustic pulse on the surface at the time t_2

(AITM6-4014)

$$d = \frac{1}{2} \times t \times c$$

Where:

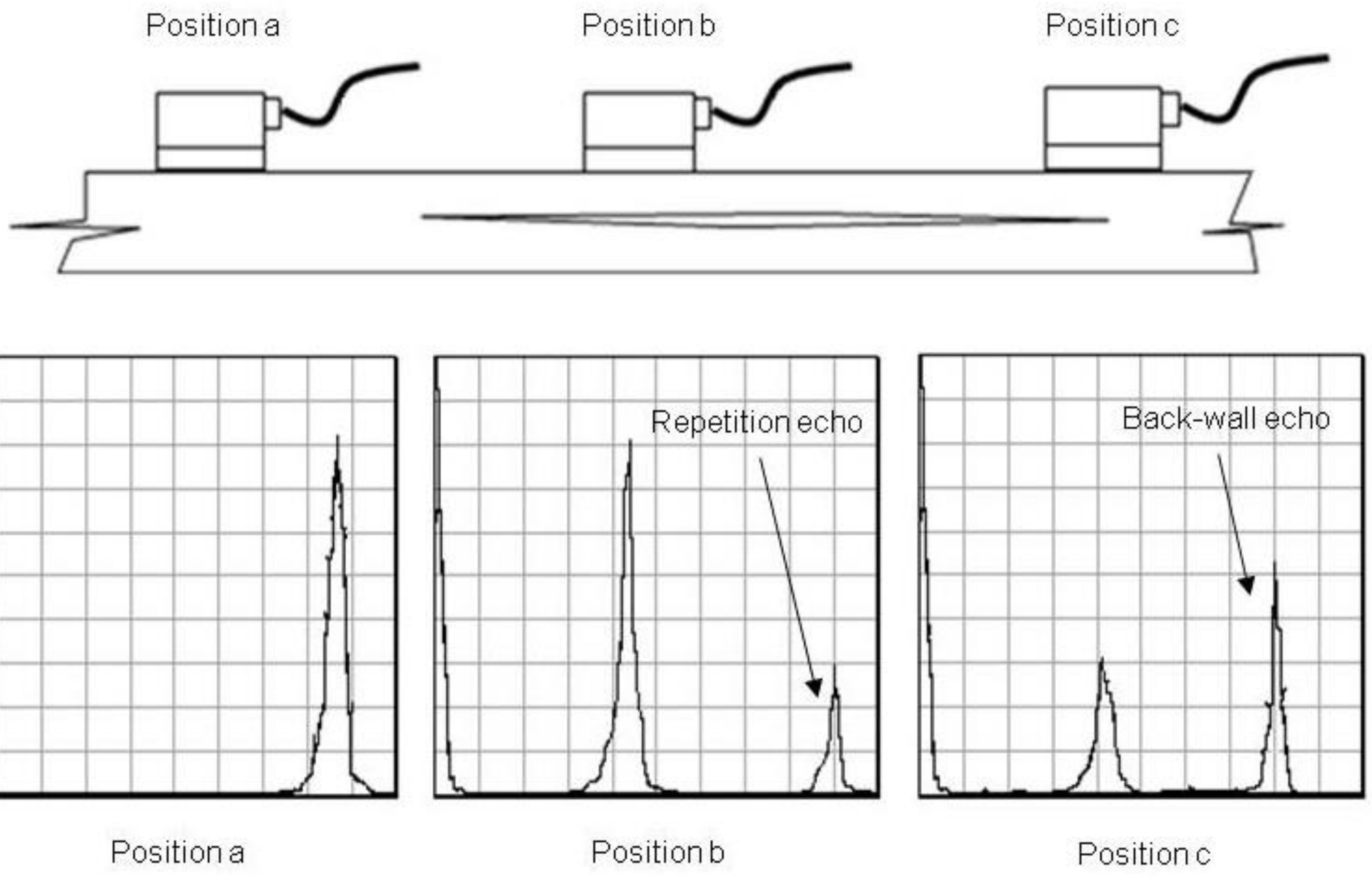
$$t = t_2 - t_1$$

(AITM6-4014)

d: distance

t: time

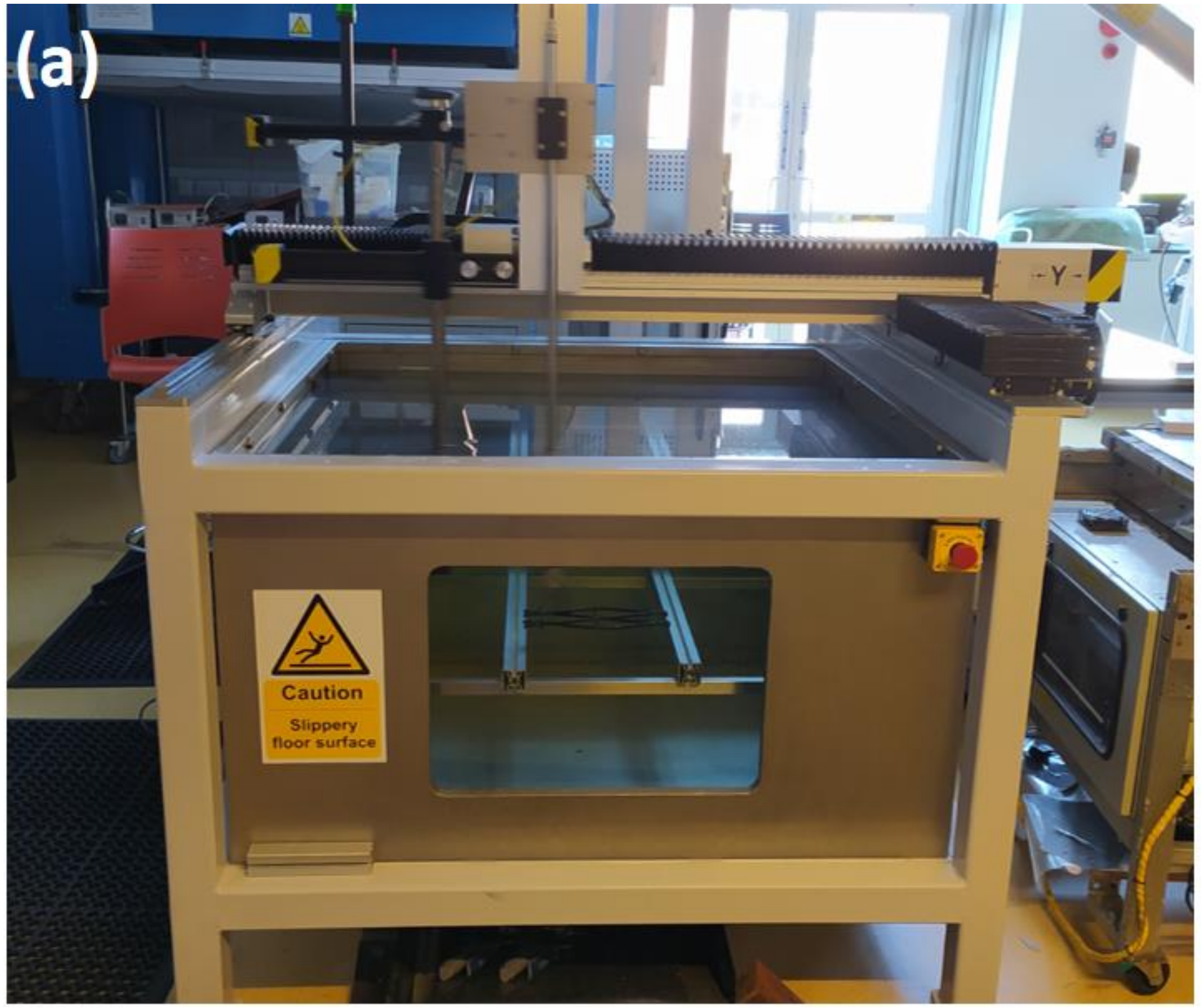
c: velocity



(AITM6-4005)

ULTRASONIC C-SCAN METHOD

- Immersion type Automated Ultrasonic C-Scan bath with 3 axis
- TecScan (TS Series) with 1150mm x 1150mm dimensions and 640mm depth
- 10MHz immersion type of scanning probe was used (Immersion Transducer)

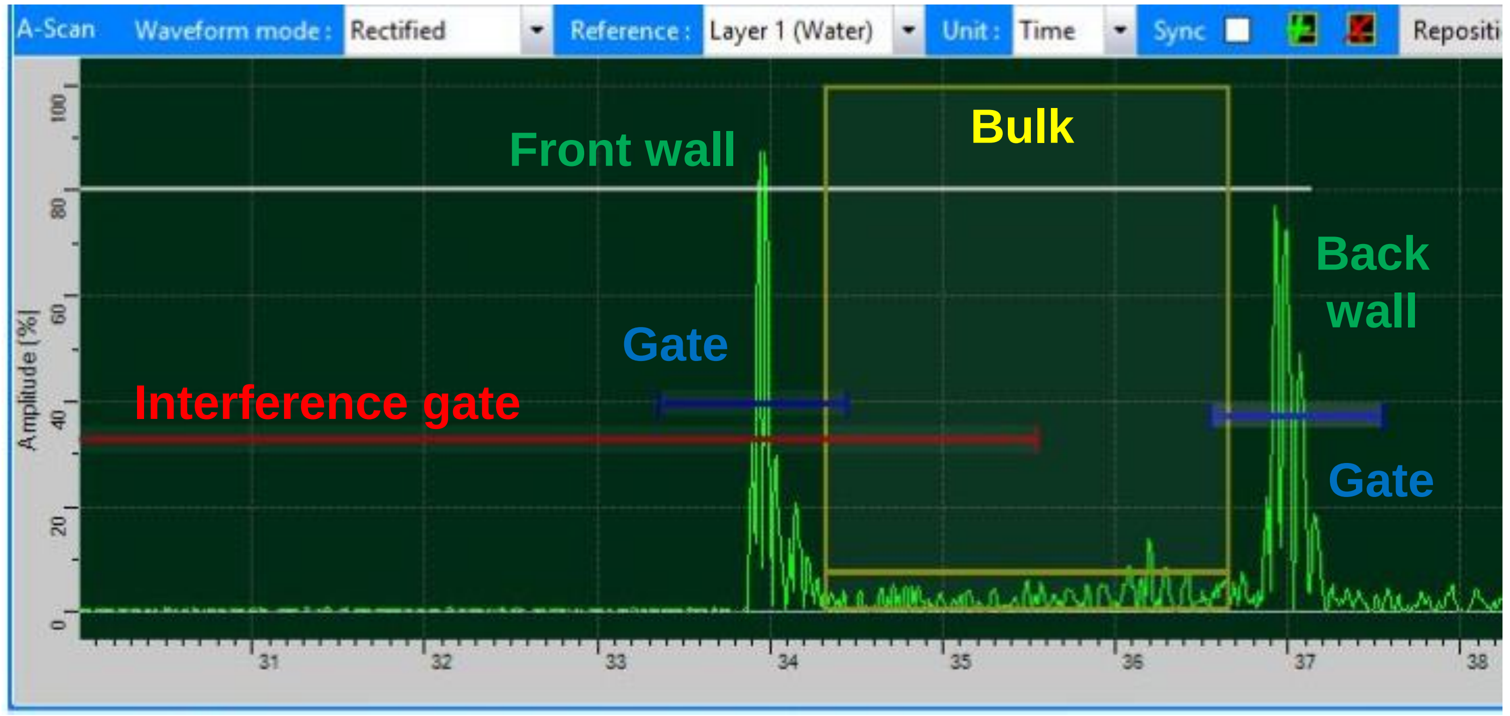


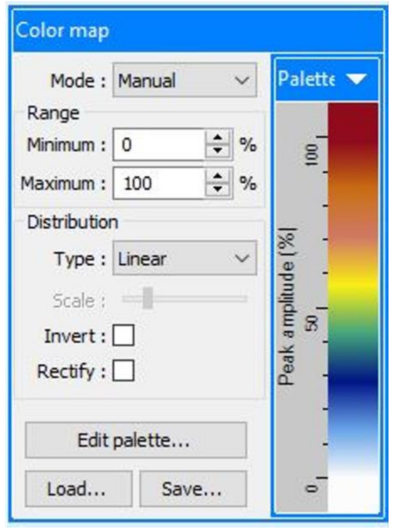
Olympus

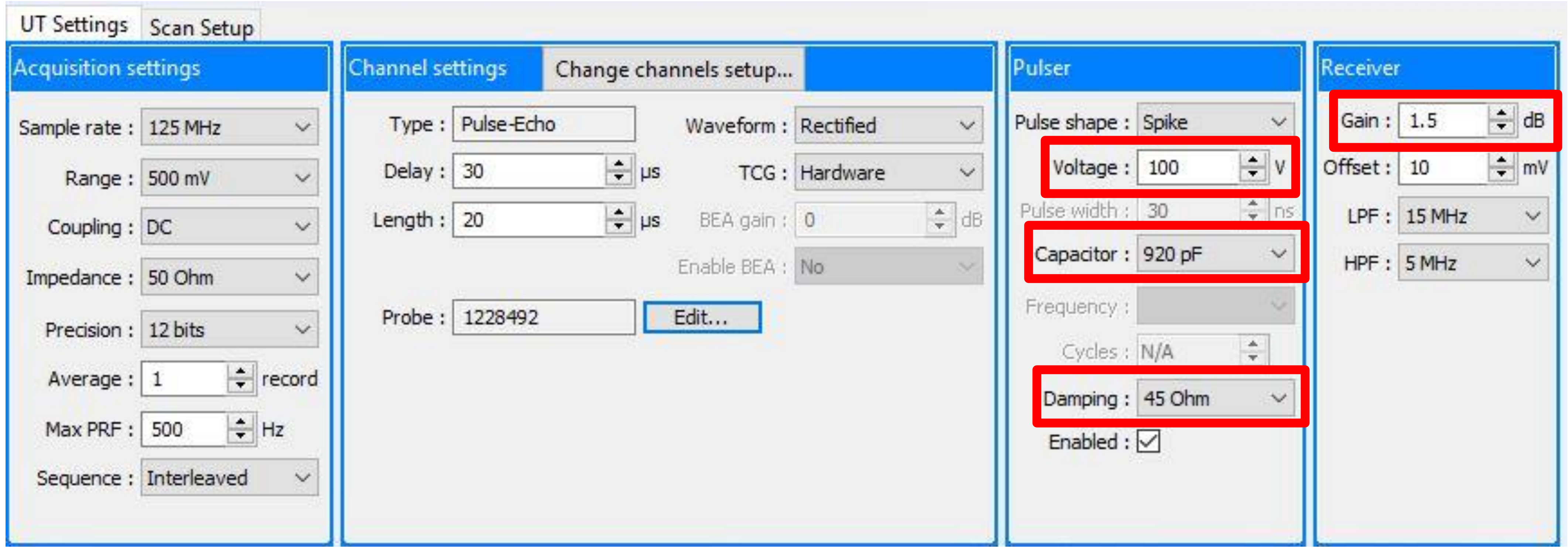
10MHz: V312

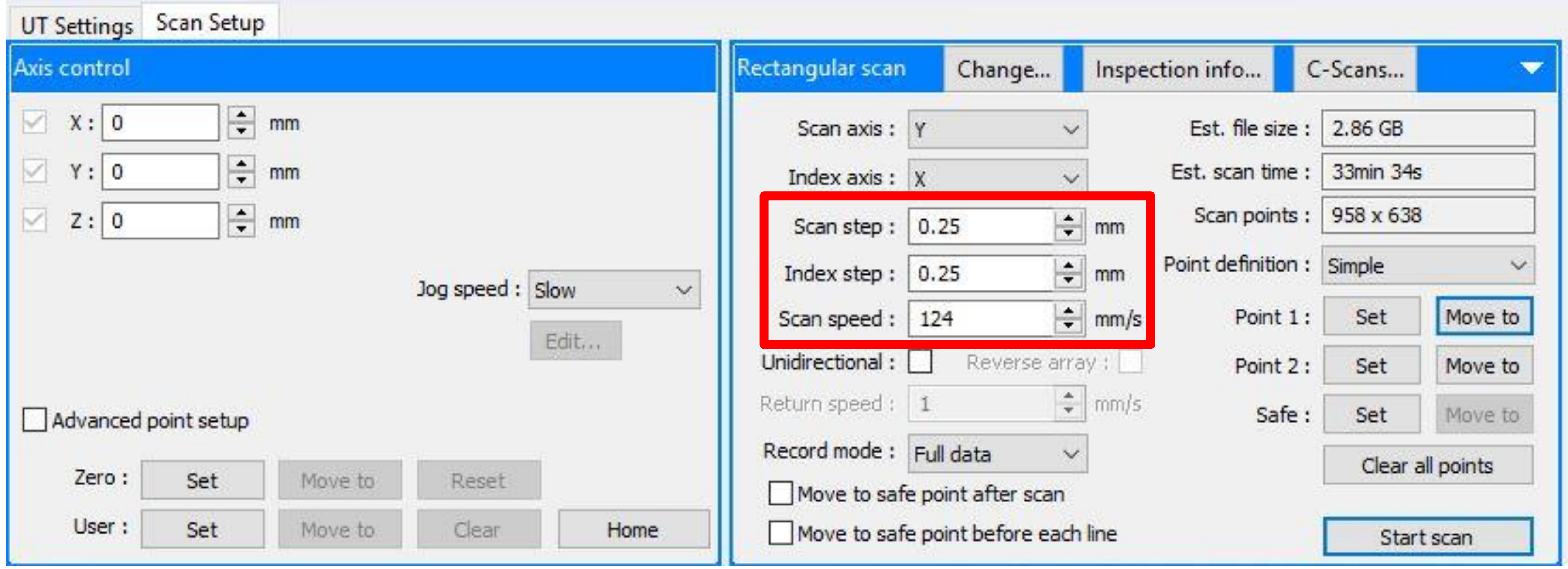
ULTRASONIC C-SCAN METHOD

- Front wall
- Back wall
- Bulk







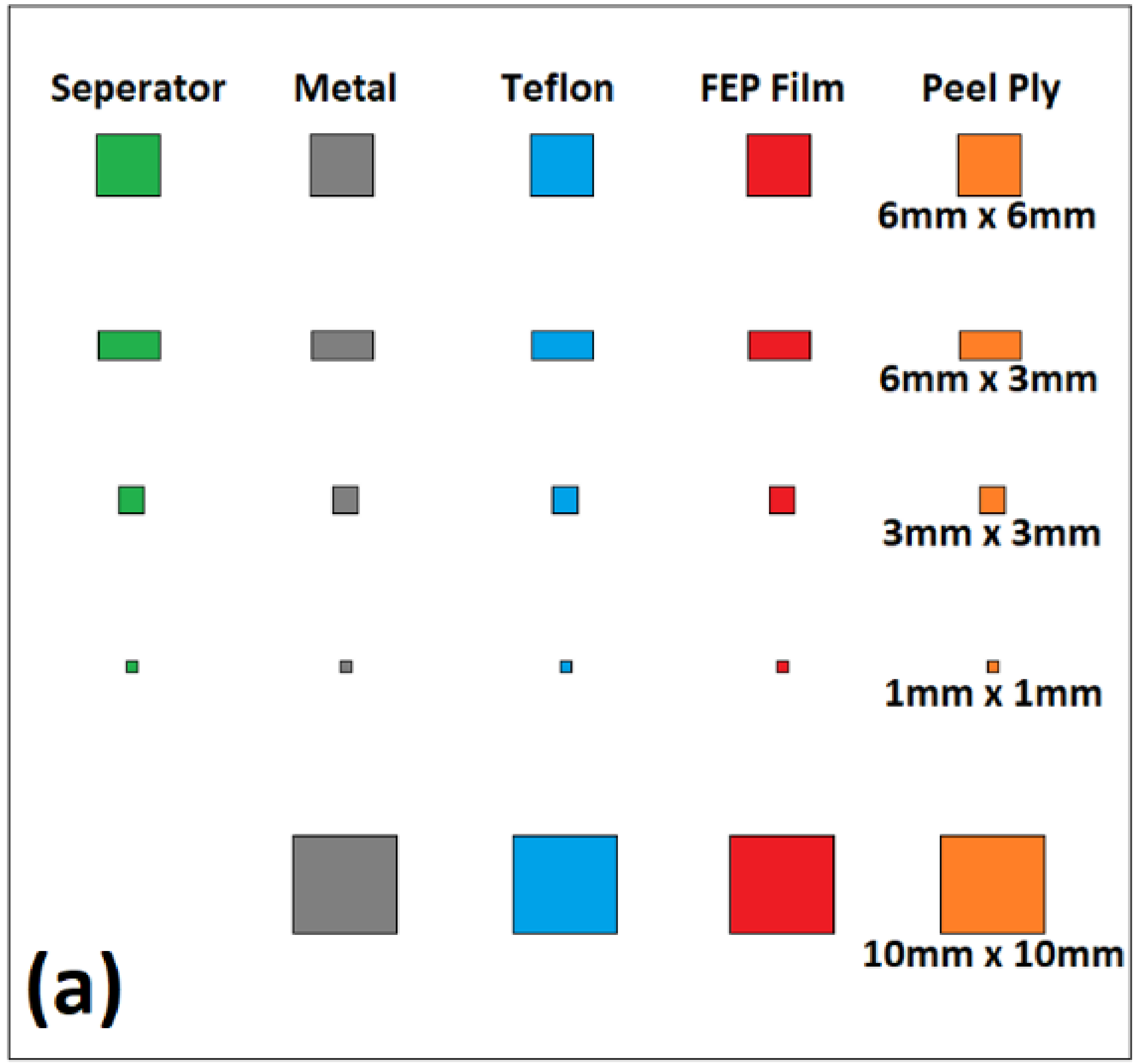


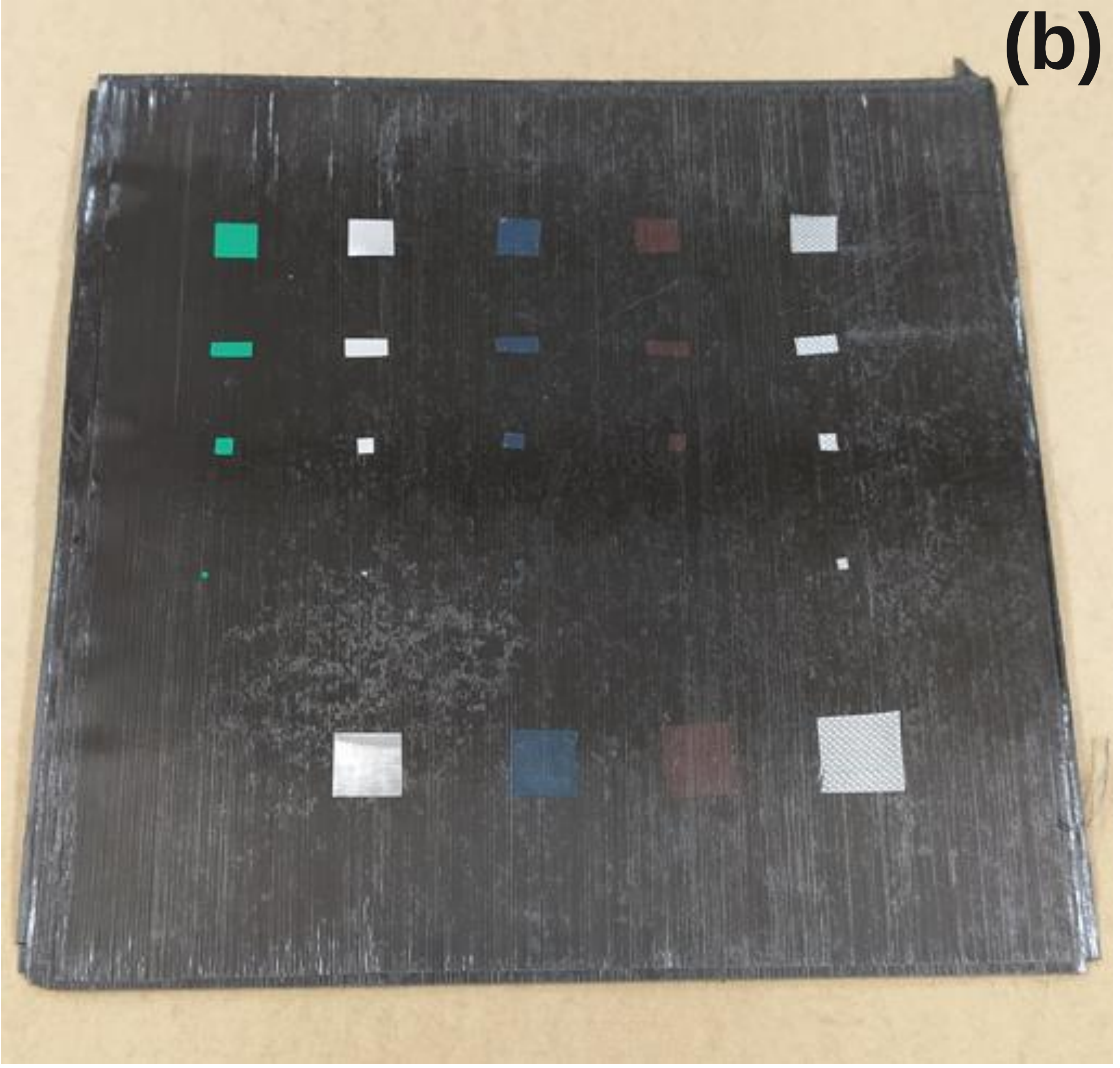
C-SCAN INSPECTION (CALIBRATION BLOCK)

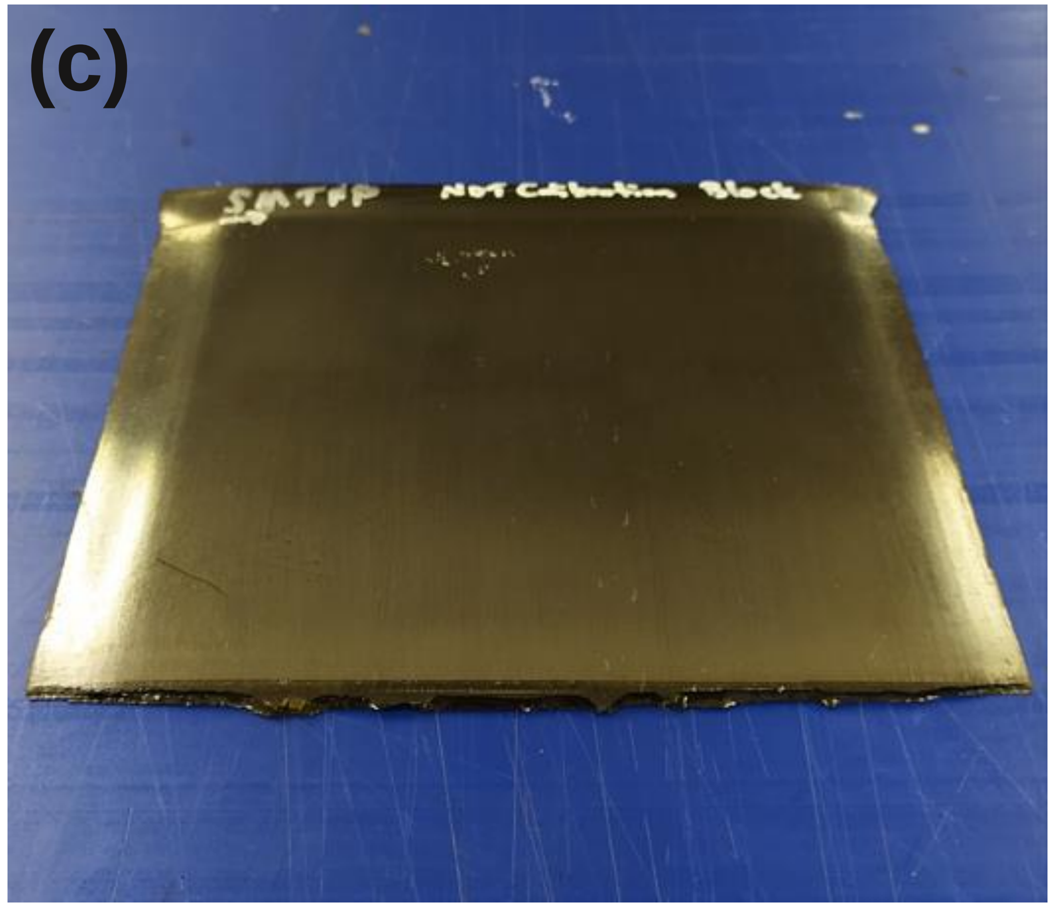
- Calibration Block has 150mmx150mm dimensions with 3.9mm thickness.
- Unidirectional Hexcel 8552-IM7 epoxy matrix thermoset prepreg material was used.
- 5 different types of defects were placed in the mid-ply of the calibration block.
- 1x1mm, 3x3mm, 3x6mm, 6x6mm and 10x10mm defect sizes were used for each defect type.

Defect Types

- Separator
- Metal (Al)
- Teflon (PTFE)
- FEP Film
- Peel Ply







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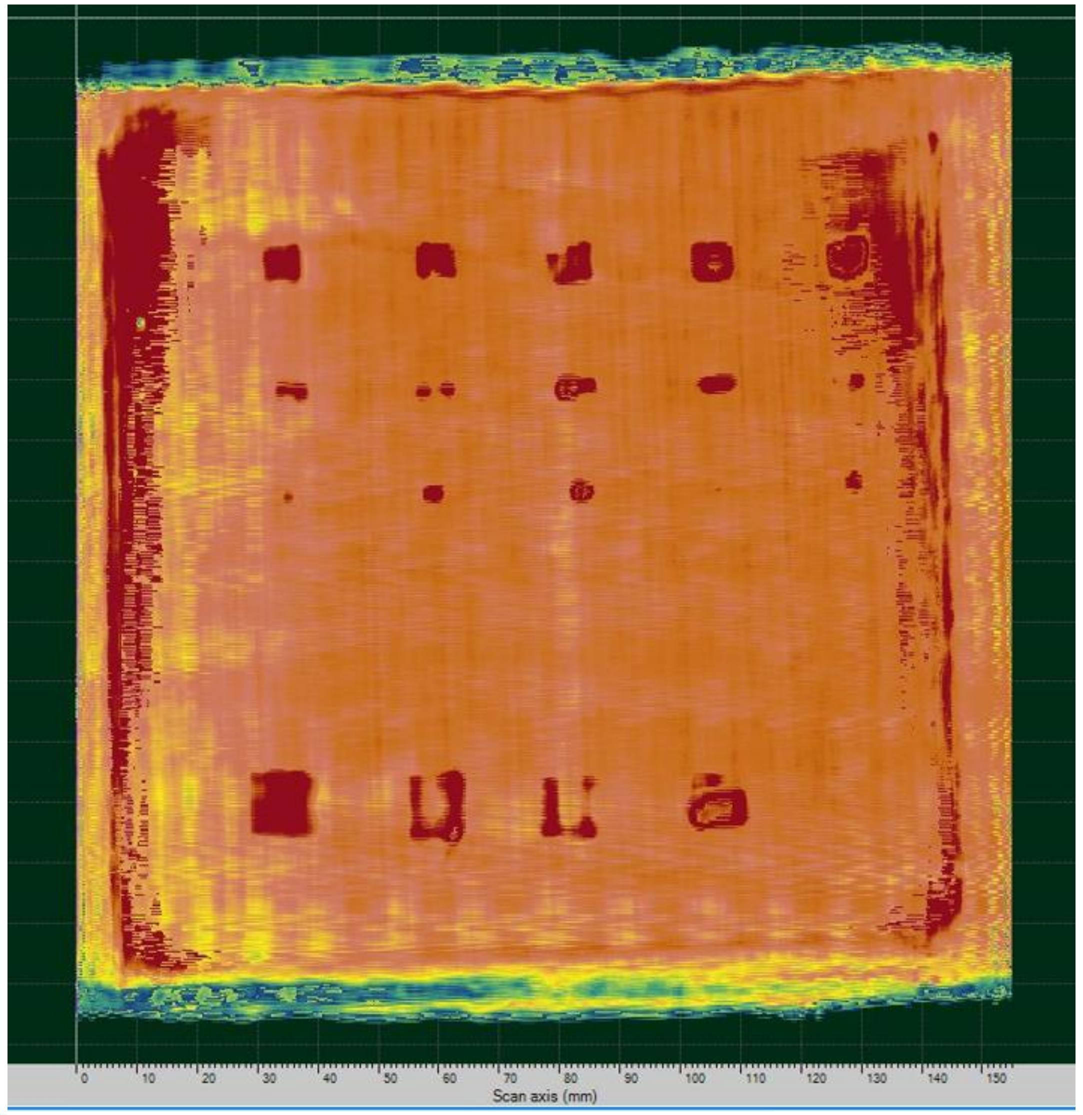
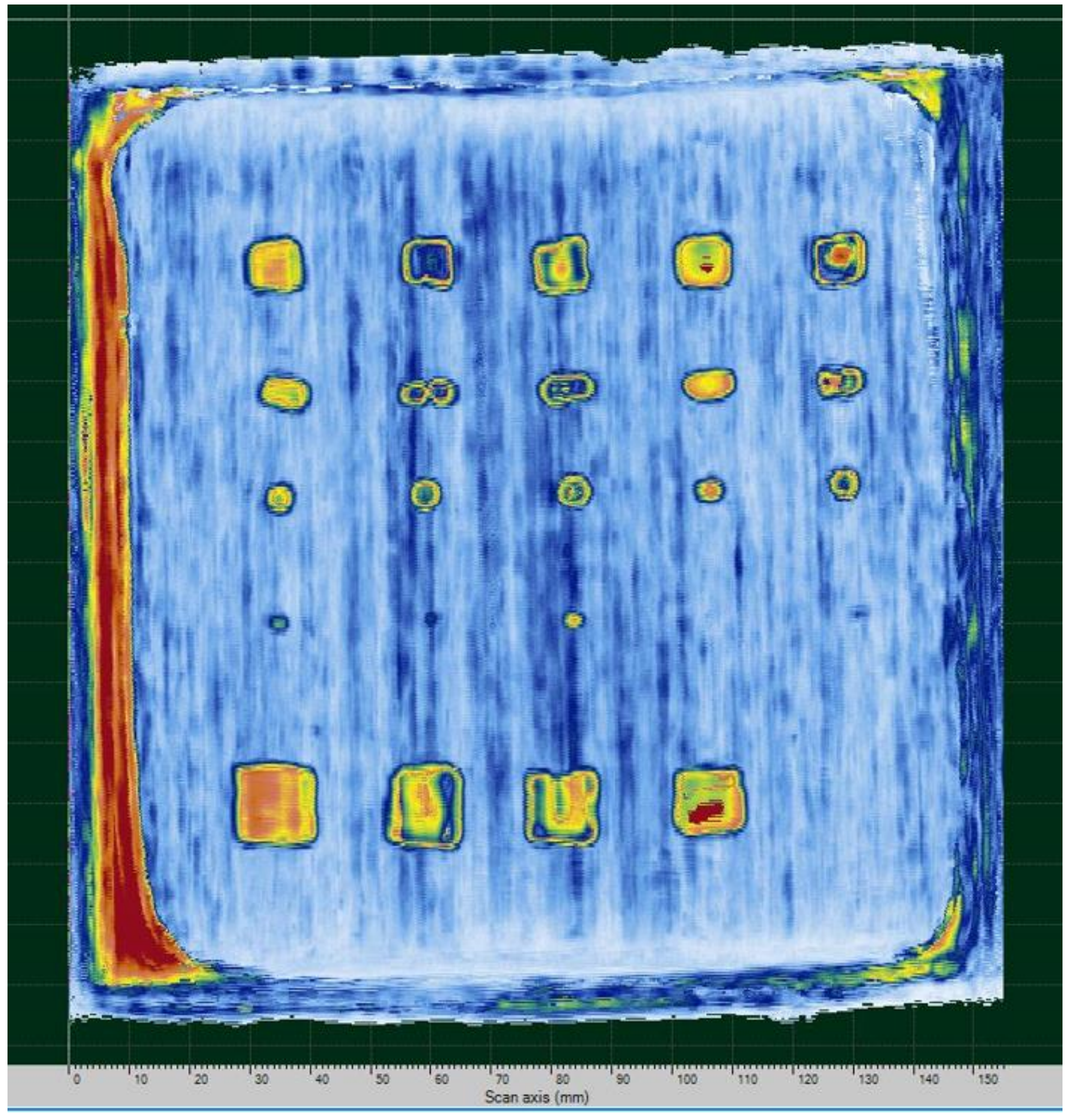
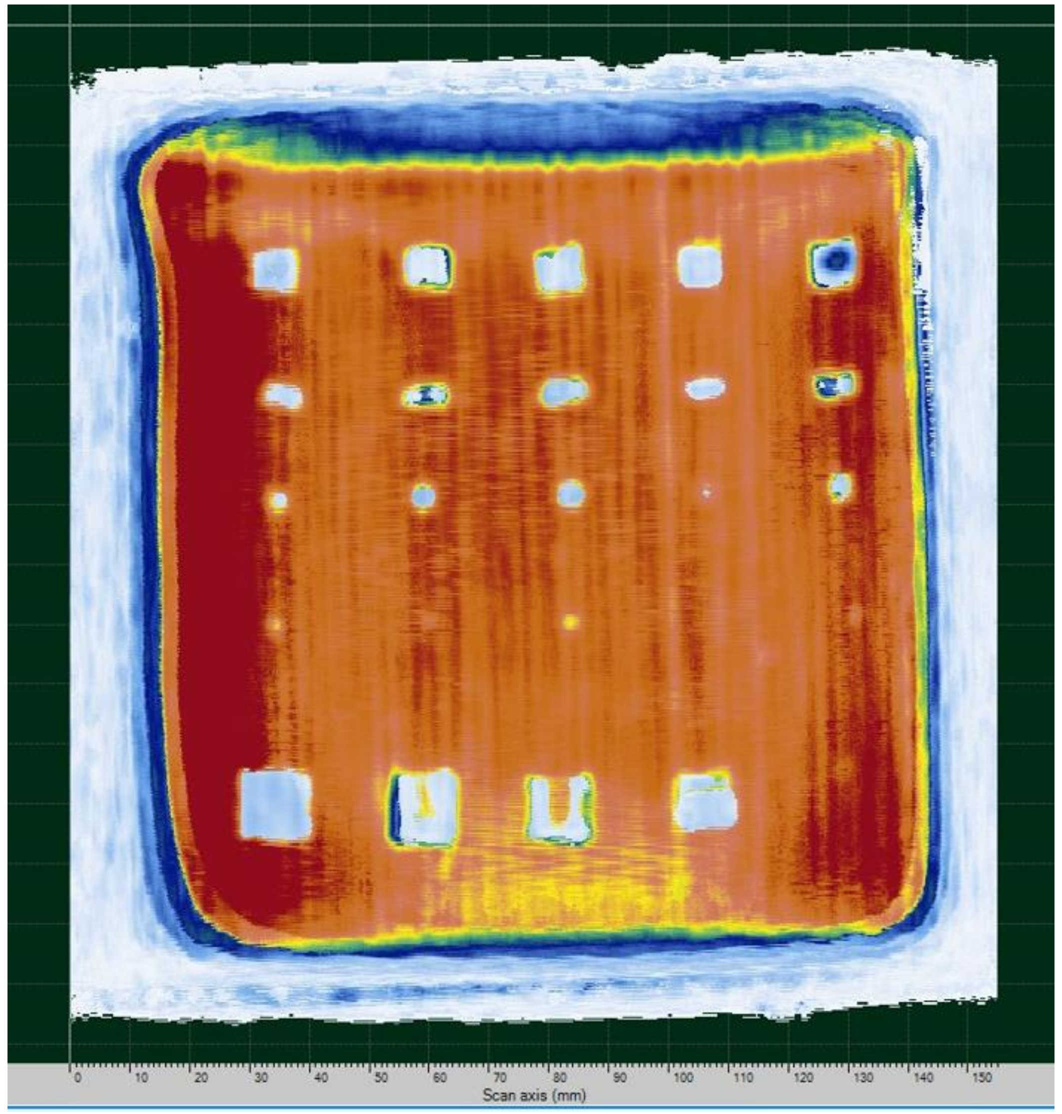
Front Wall View



Bulk View



Back Wall View

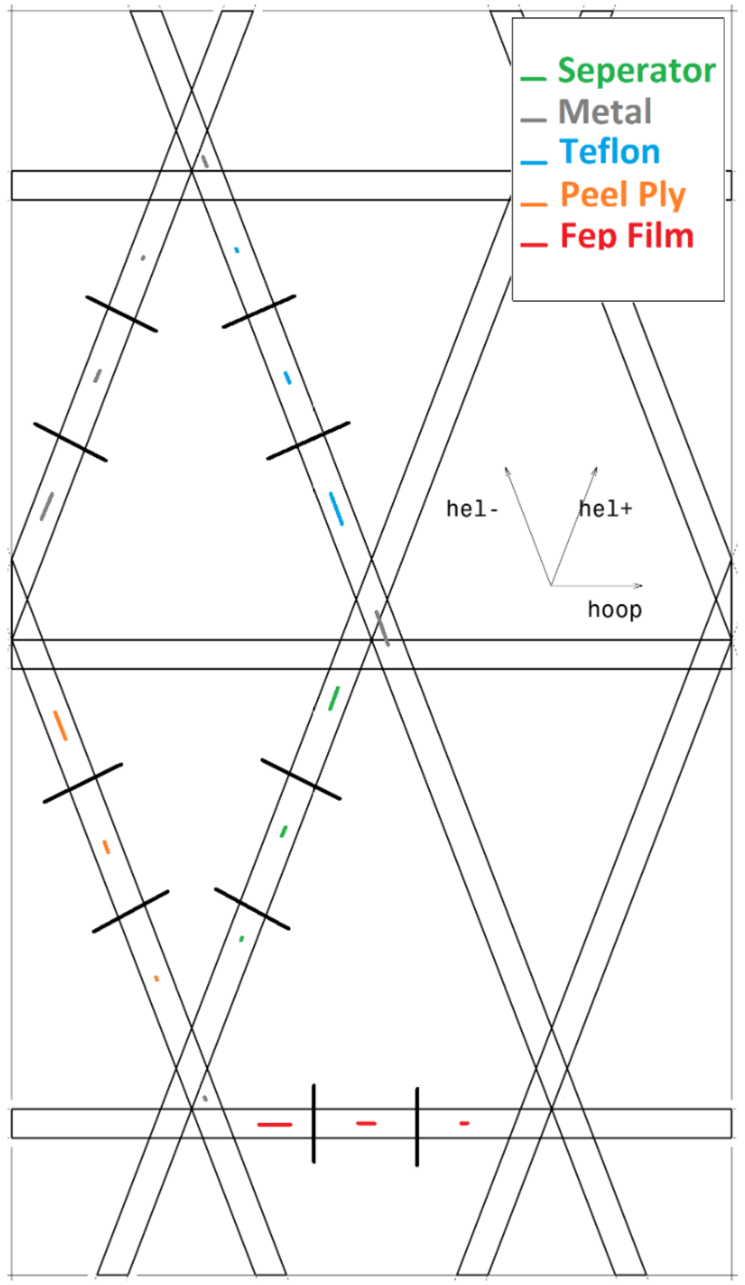


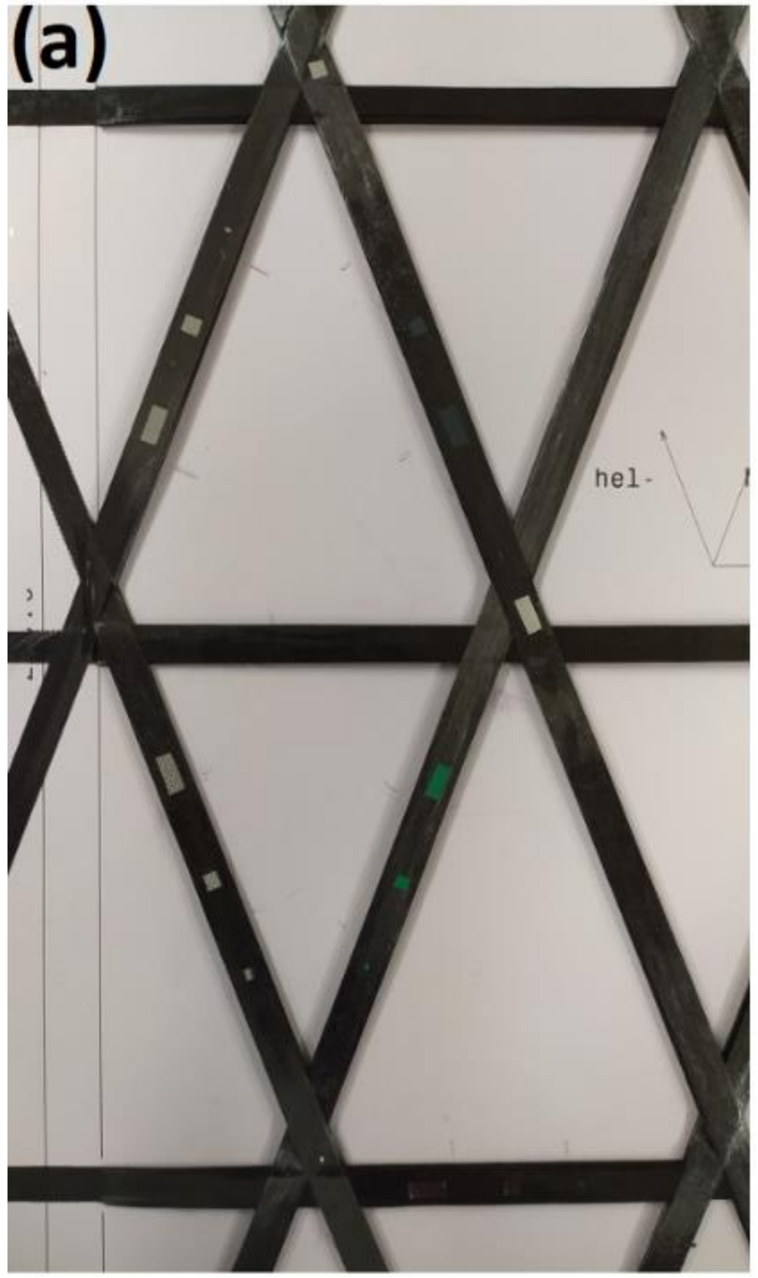
Defect Size

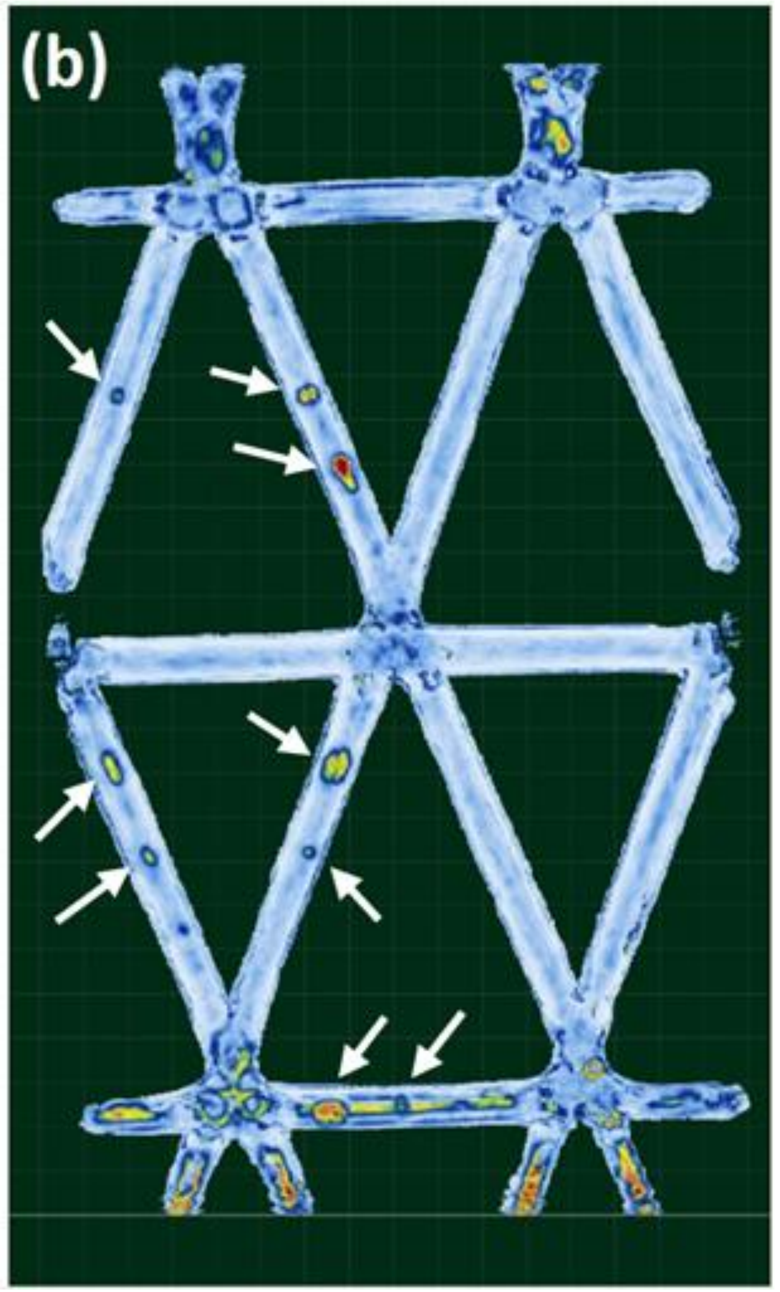
- 10 x 10mm ✓
- 6 x 6mm ✓
- 6 x 3mm ✓
- 3 x 3mm ✓
- 1 x 1mm X

C-SCAN INSPECTION (CALIBRATION LATTICE)

- Similar to calibration block, artificial defects were also created in lattice structure, and it was scanned by 10MHz probe.
- However, only 3 different defects were used due to narrow geometry of lattice ribs. Defect sizes are 1x1mm (small), 3x3mm (medium) and 3x6mm (large) for lattice structure specimen. Defects were placed in the mid place of the lattice.







Defect Size

- Big 6mm x 3mm ✓
- Medium 3mm x 3mm ✓
- Large 1mm x 1mm X

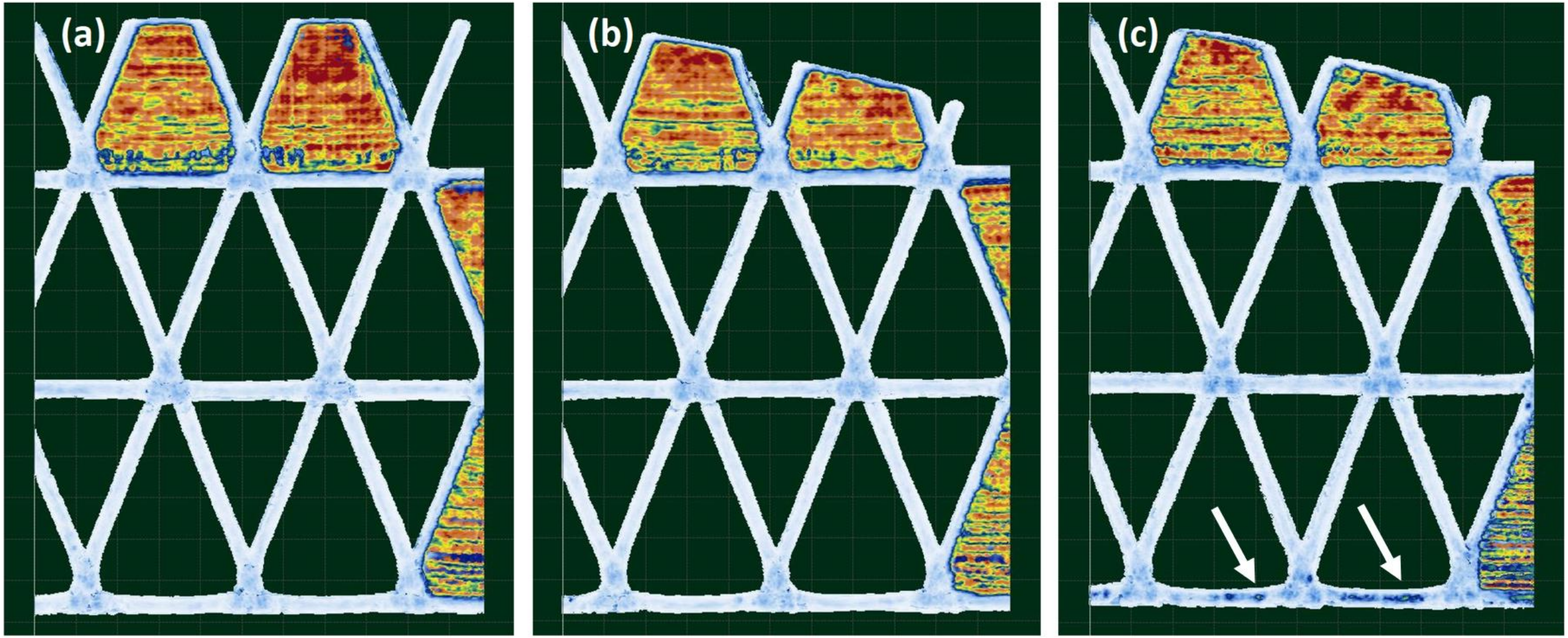
* Large metal defect was disappeared because of surface quality X

* Node regions are not clear because of their complex structures X

C-SCAN INSPECTION (RIB/NODE QUALITY)

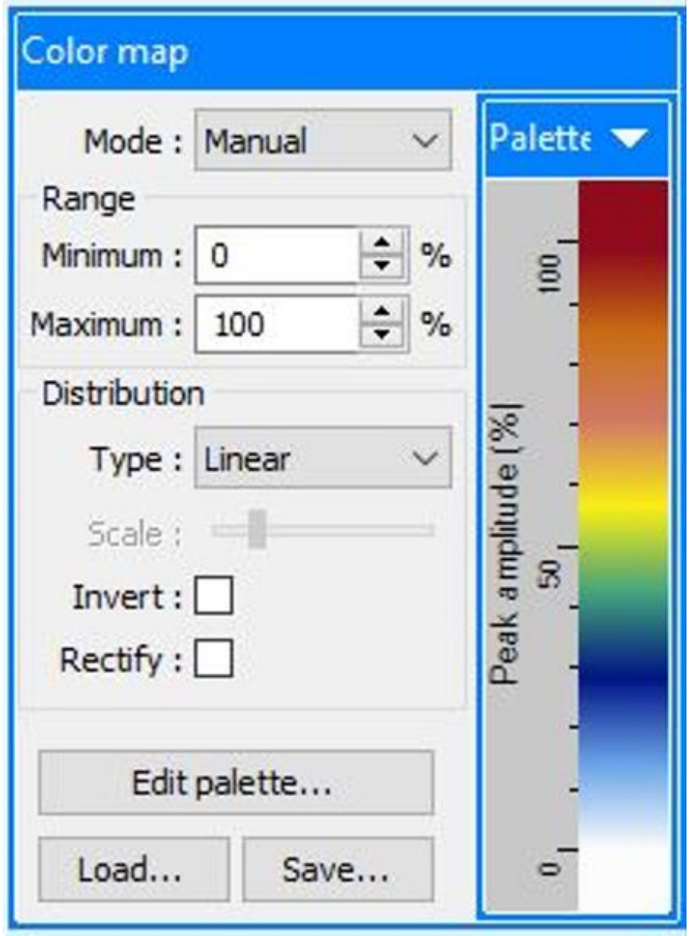
- The quality of ribs and nodes were checked in C-Scan view.

Panel 1	Panel 2	Panel 3

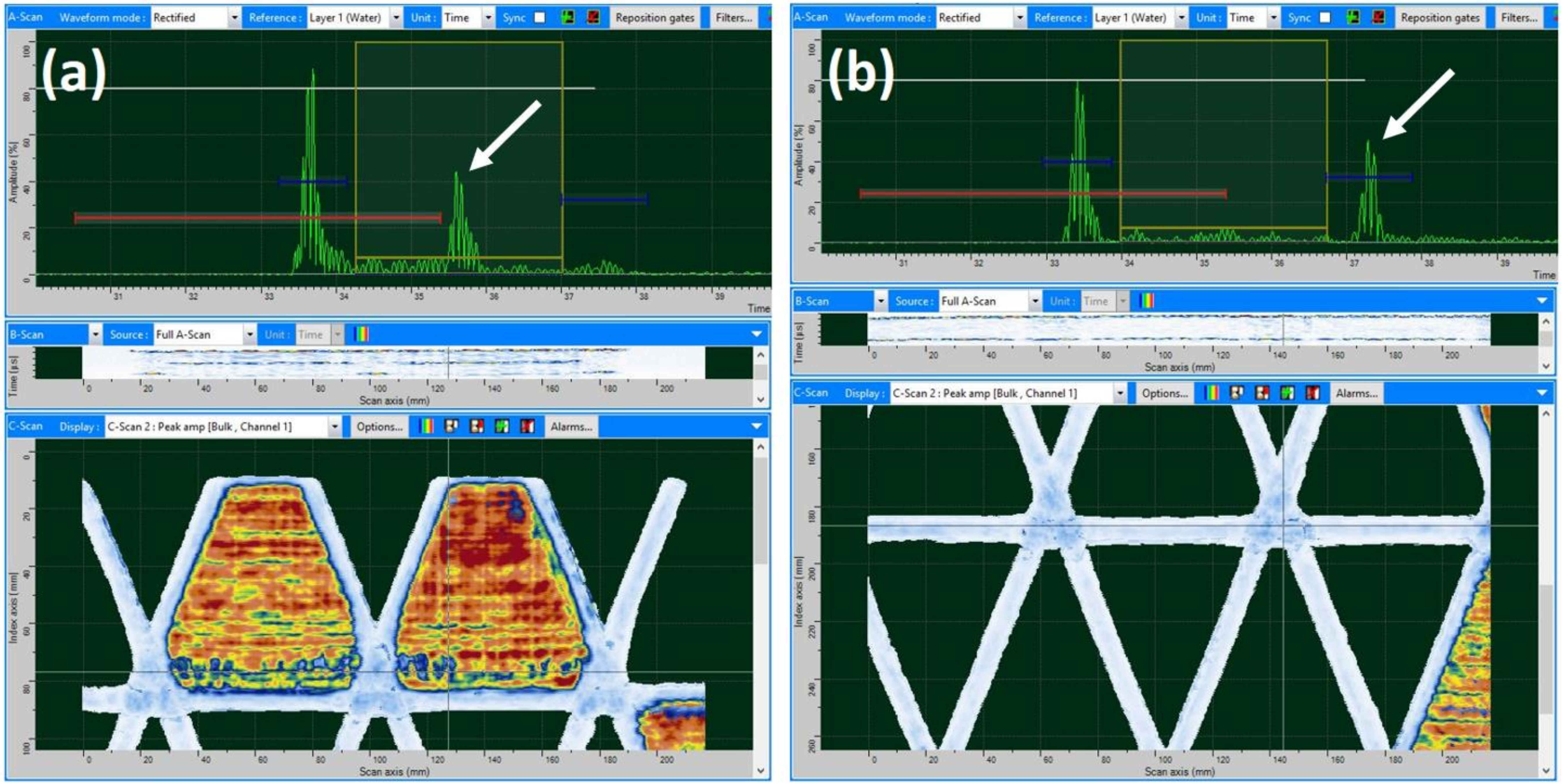


C-SCAN INSPECTION (COLOUR DIFFERENCE)

- The reason of colour difference is because of thickness differences between ribs/nodes and patches. This situation creates double backwall for different thickness values.



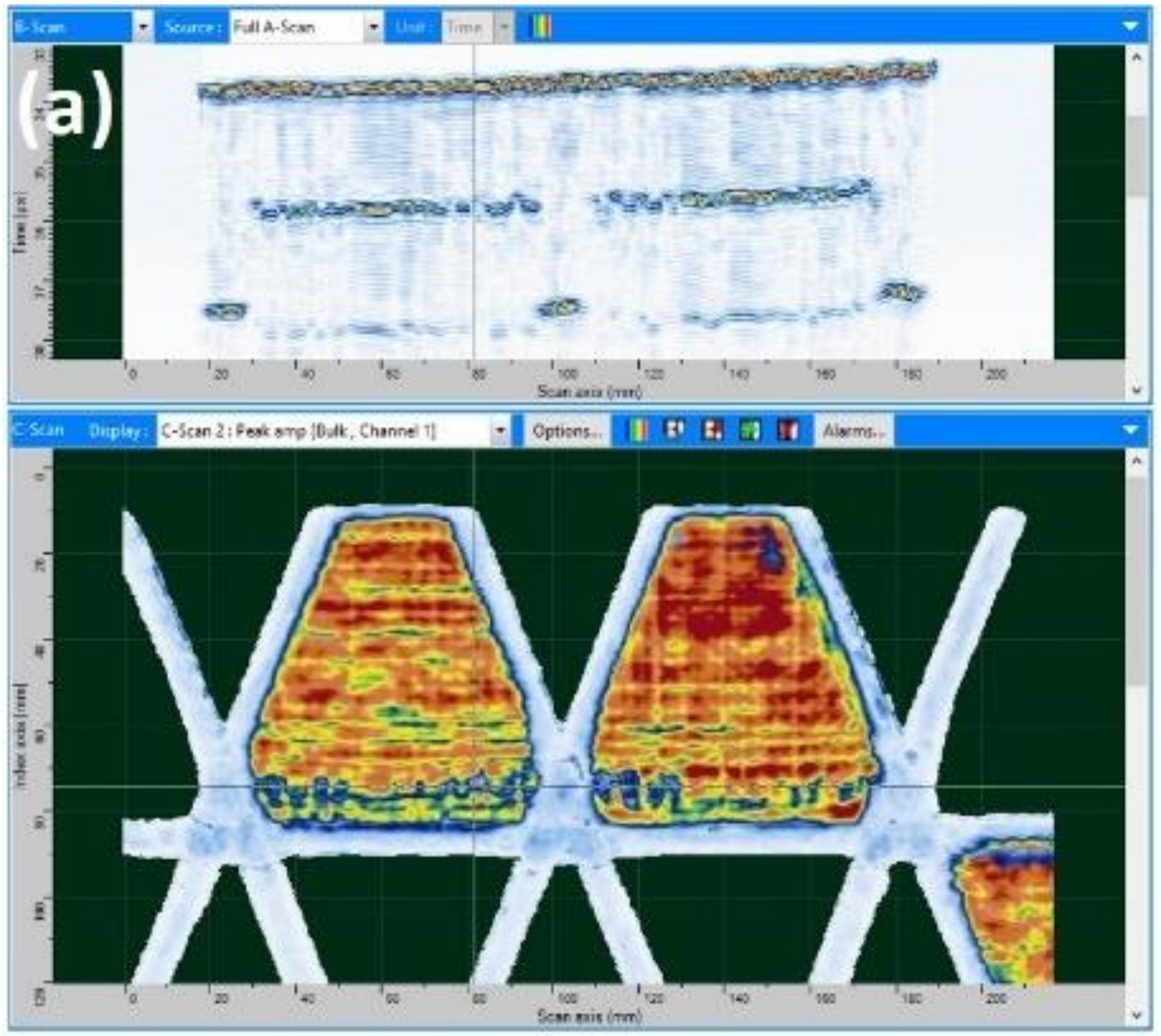
Panel 1

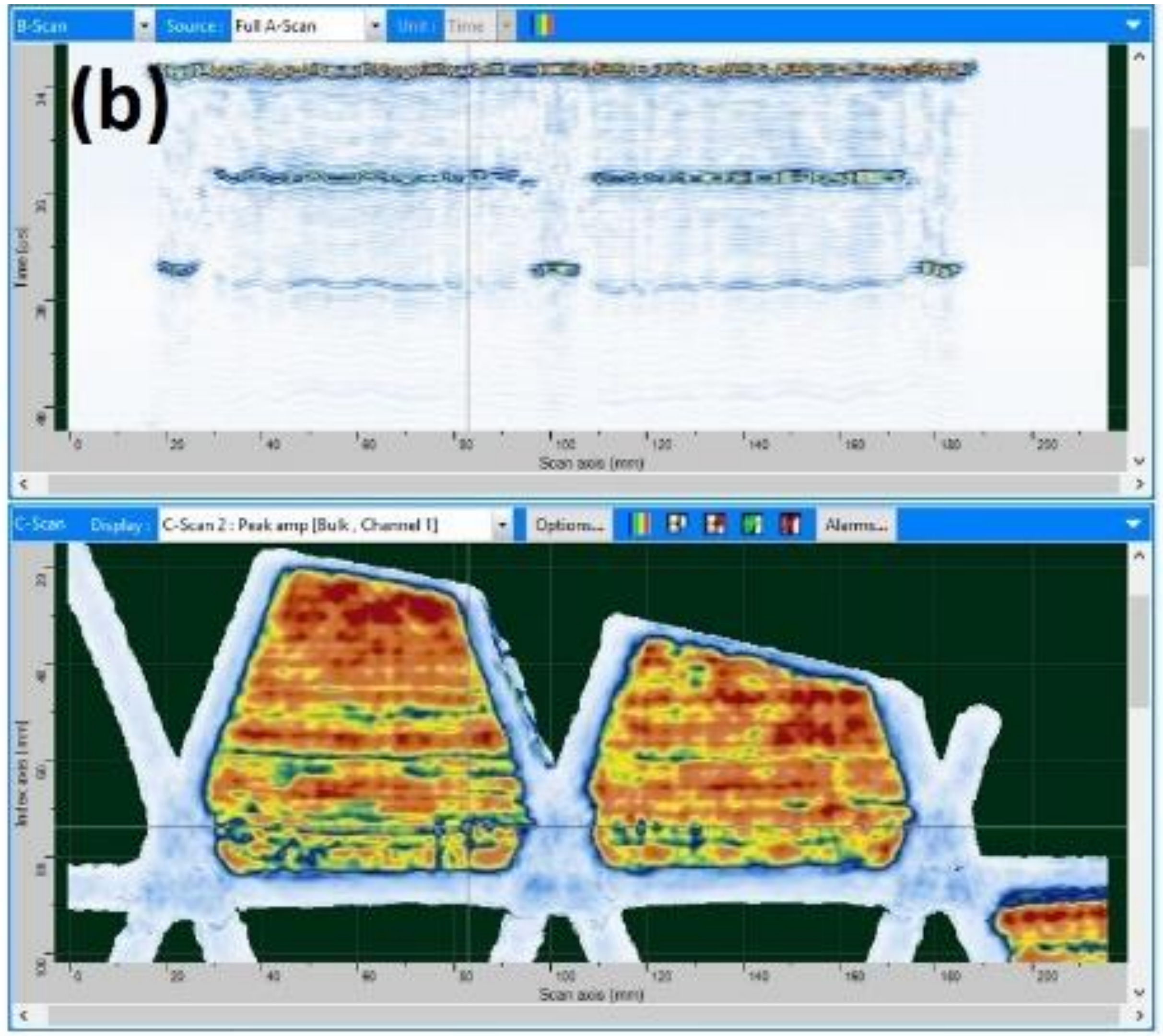


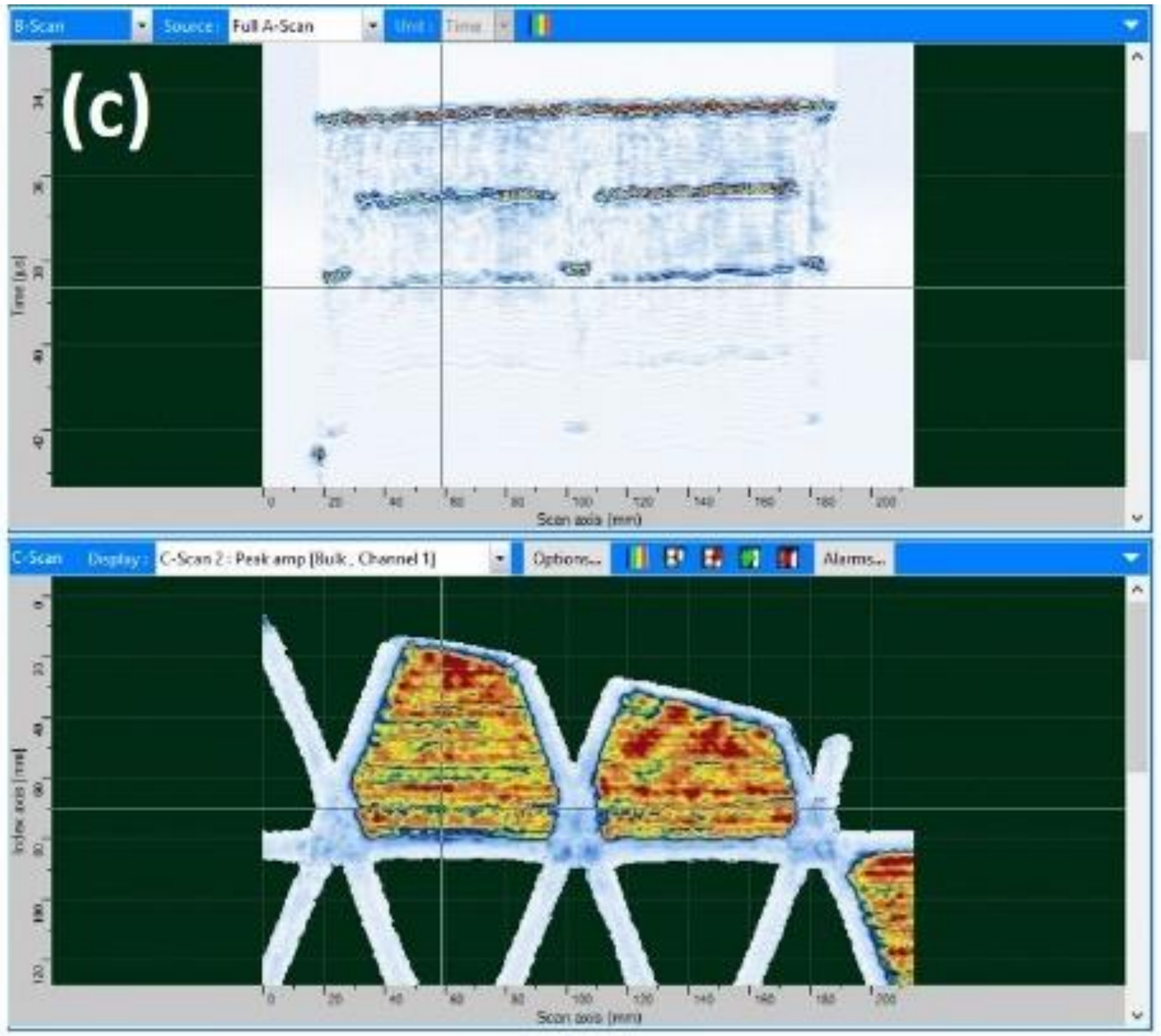
C-SCAN INSPECTION (PATCH QUALITY)

- The quality of patches was checked in C-Scan and B-Scan views.

Panel 1	Panel 2	Panel 3

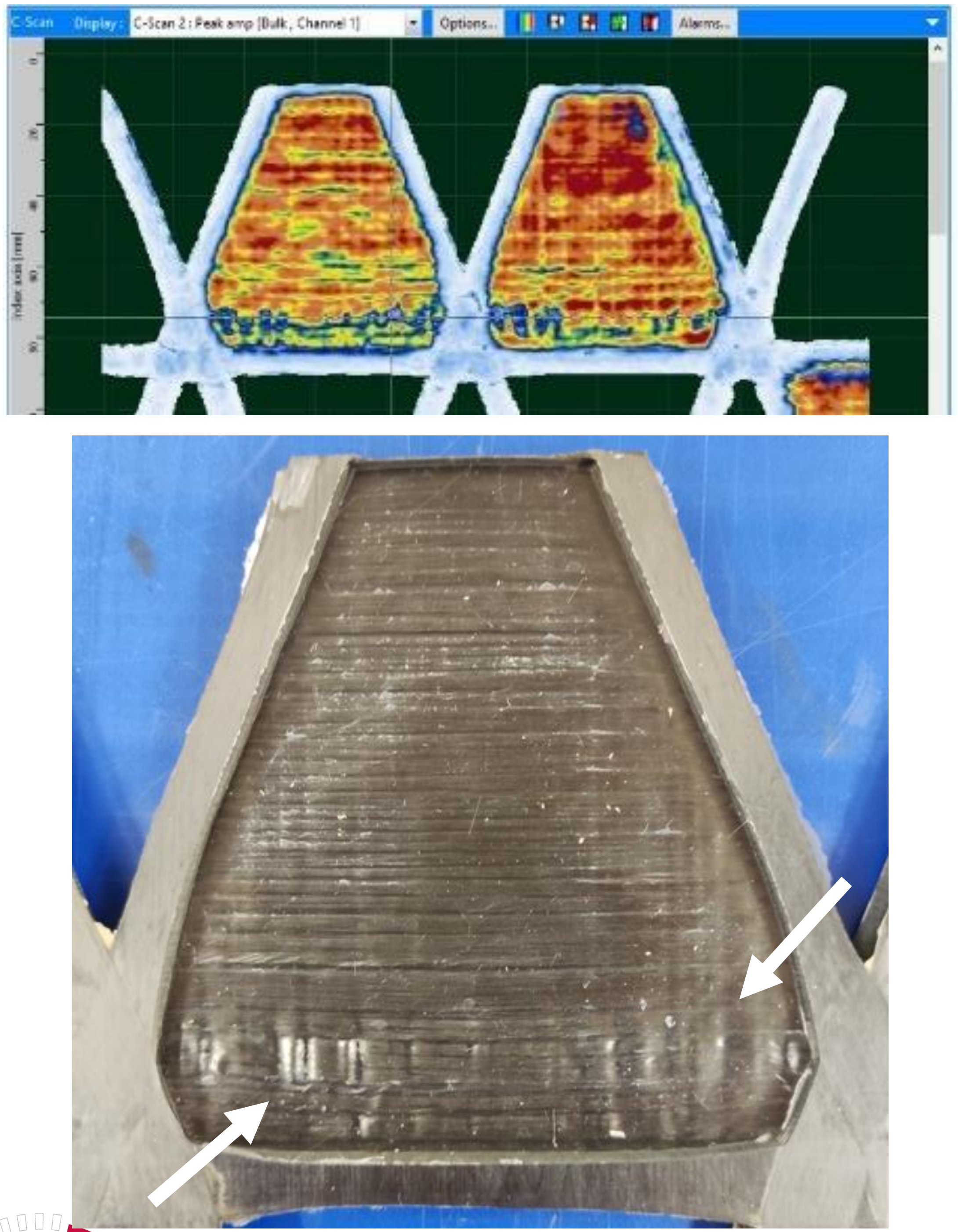
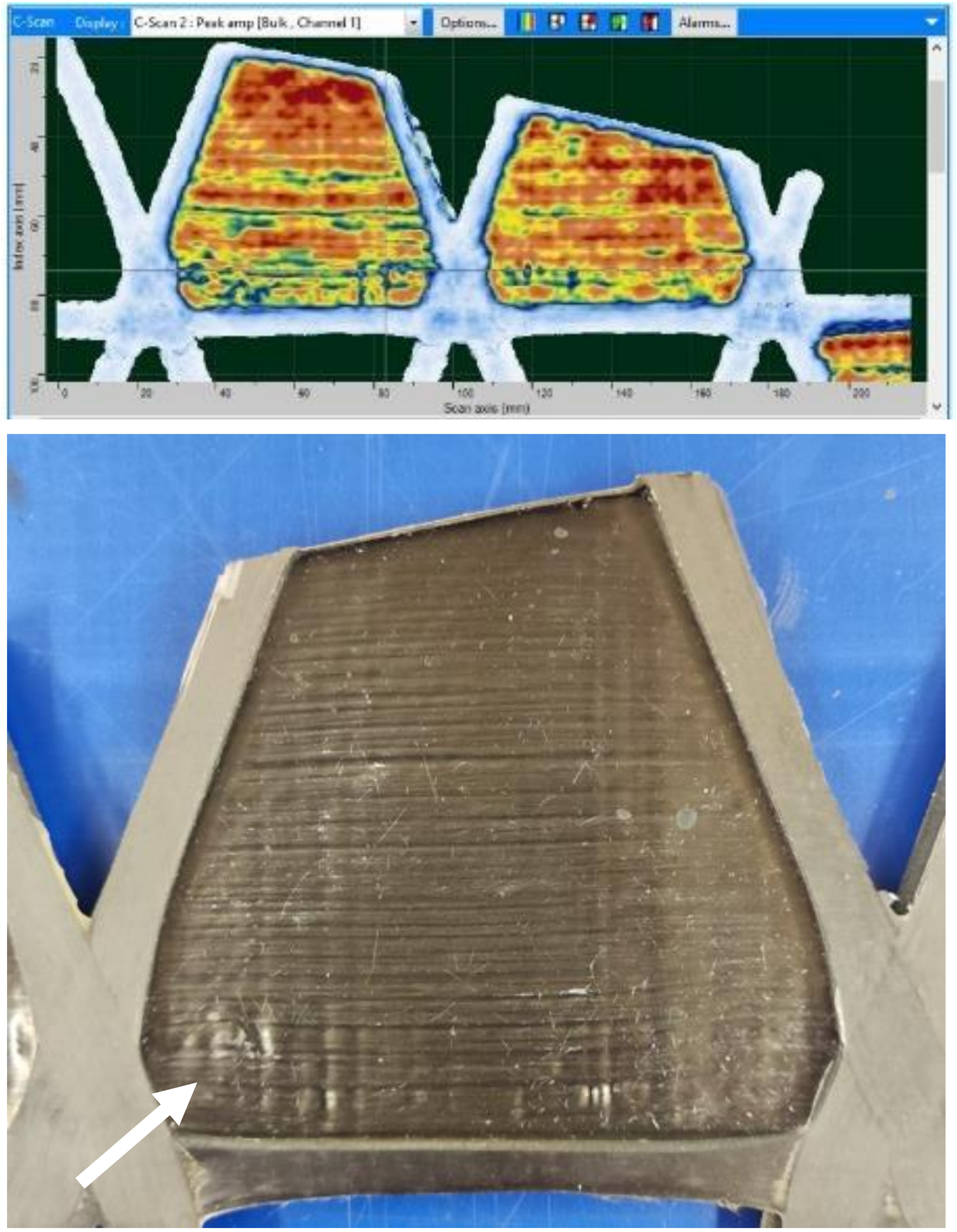
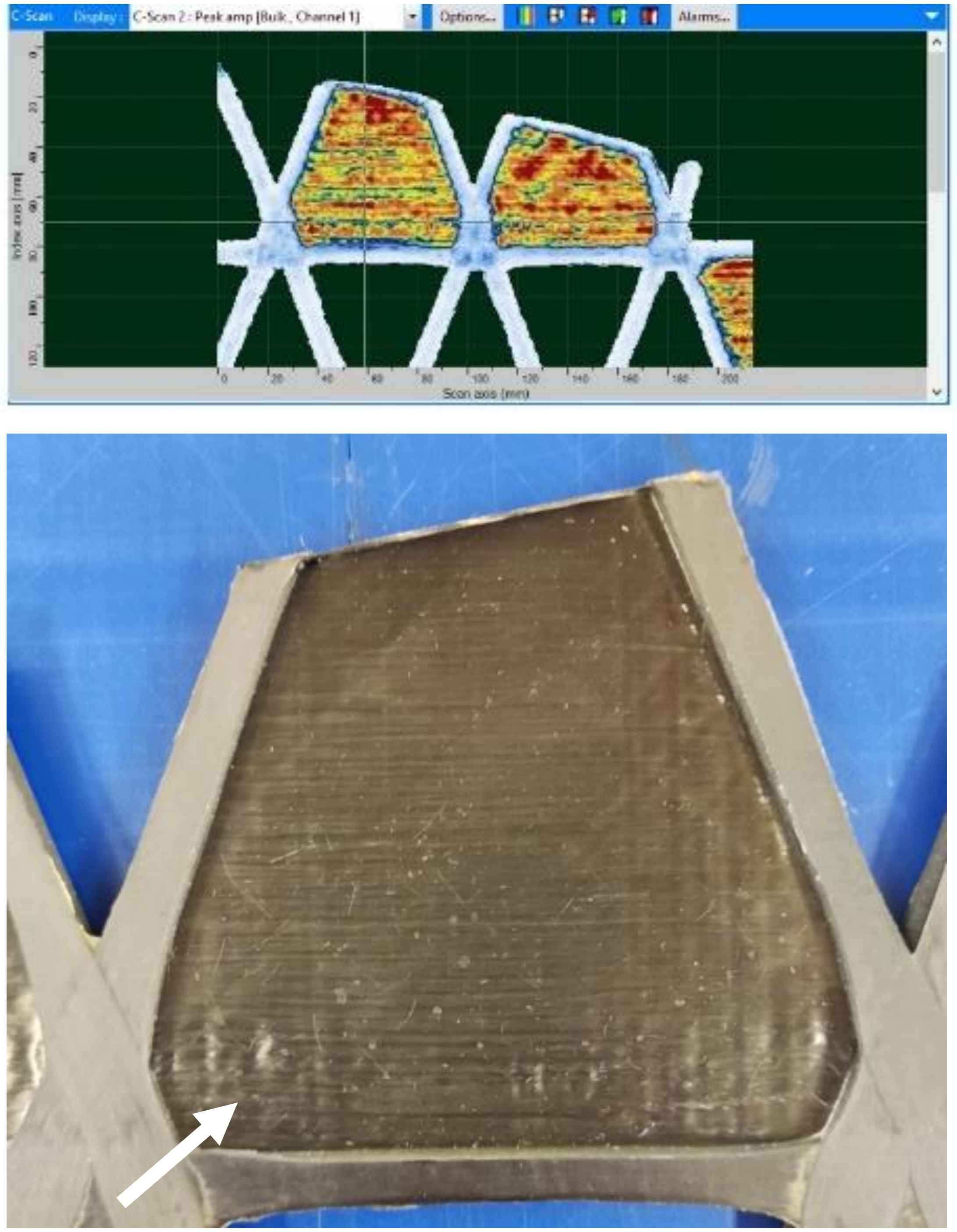






C-SCAN INSPECTION (PATCH QUALITY)

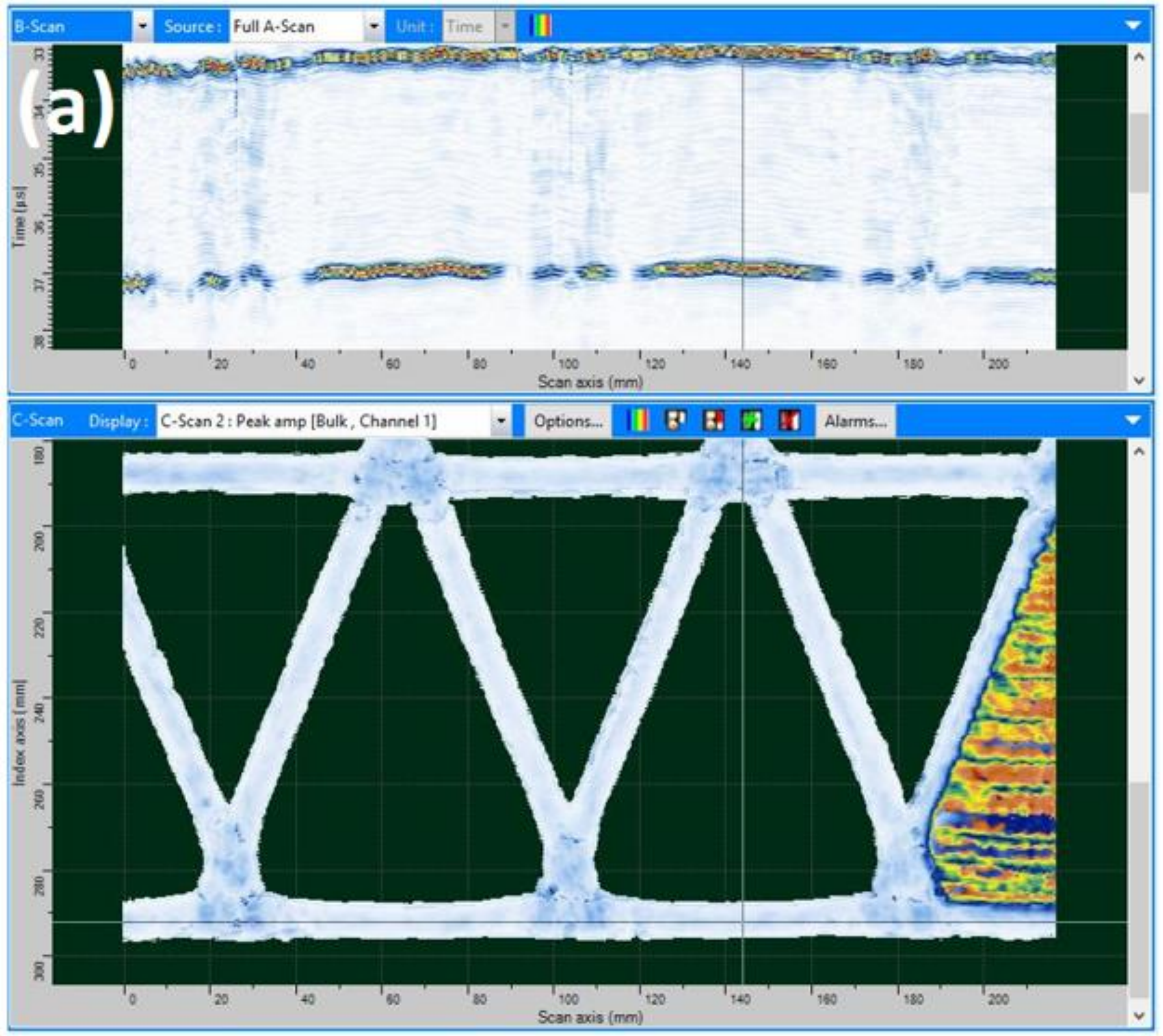
- The quality of patches was checked in C-Scan view.

Panel 1	Panel 2	Panel 3
		

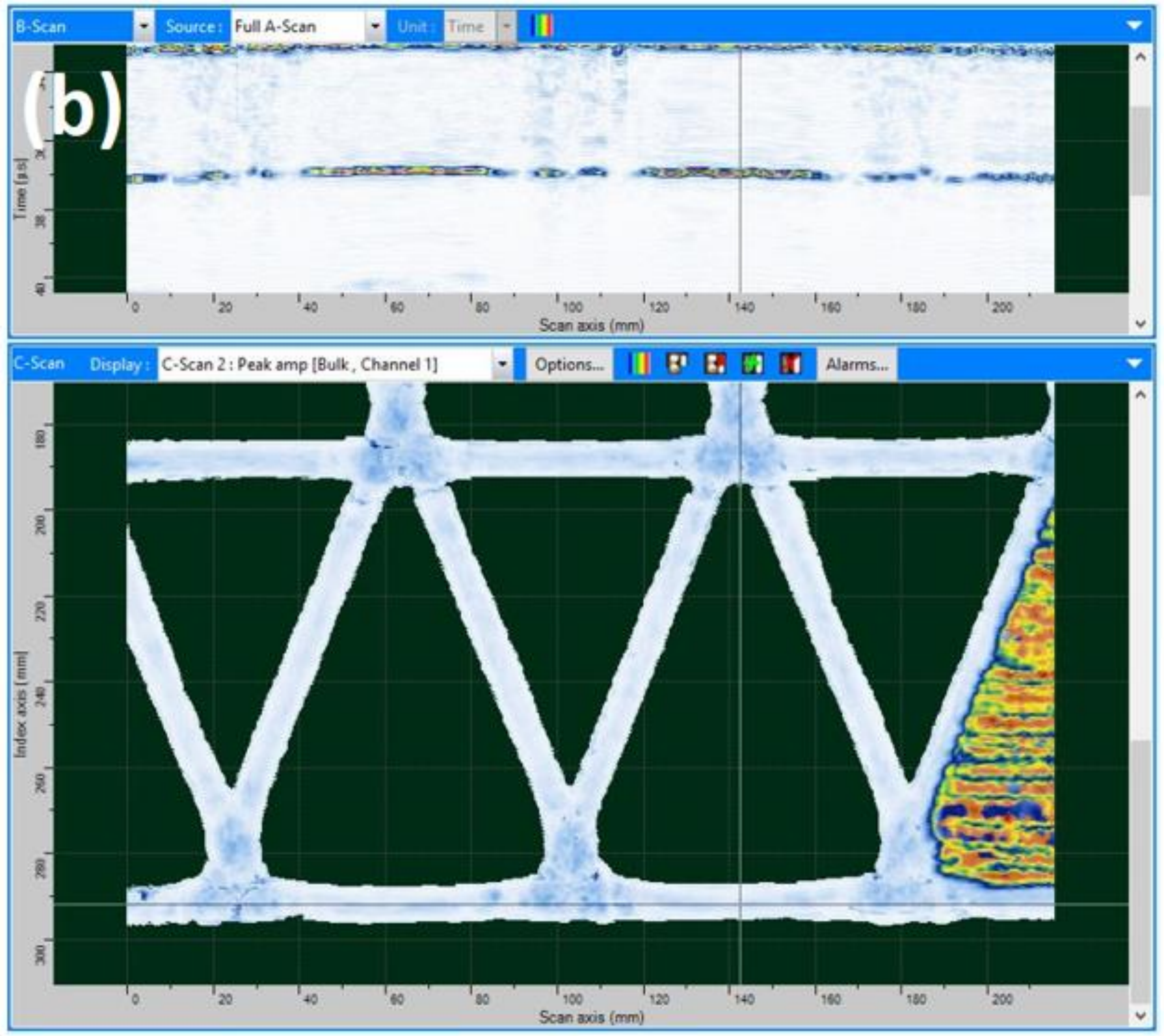
C-SCAN INSPECTION (FULL RIB QUALITY)

- Full rib quality was checked but C-Scan and B-Scan views.
- It was seen that there are internal defects in the Panel 3 which was manufactured without edge blocks.

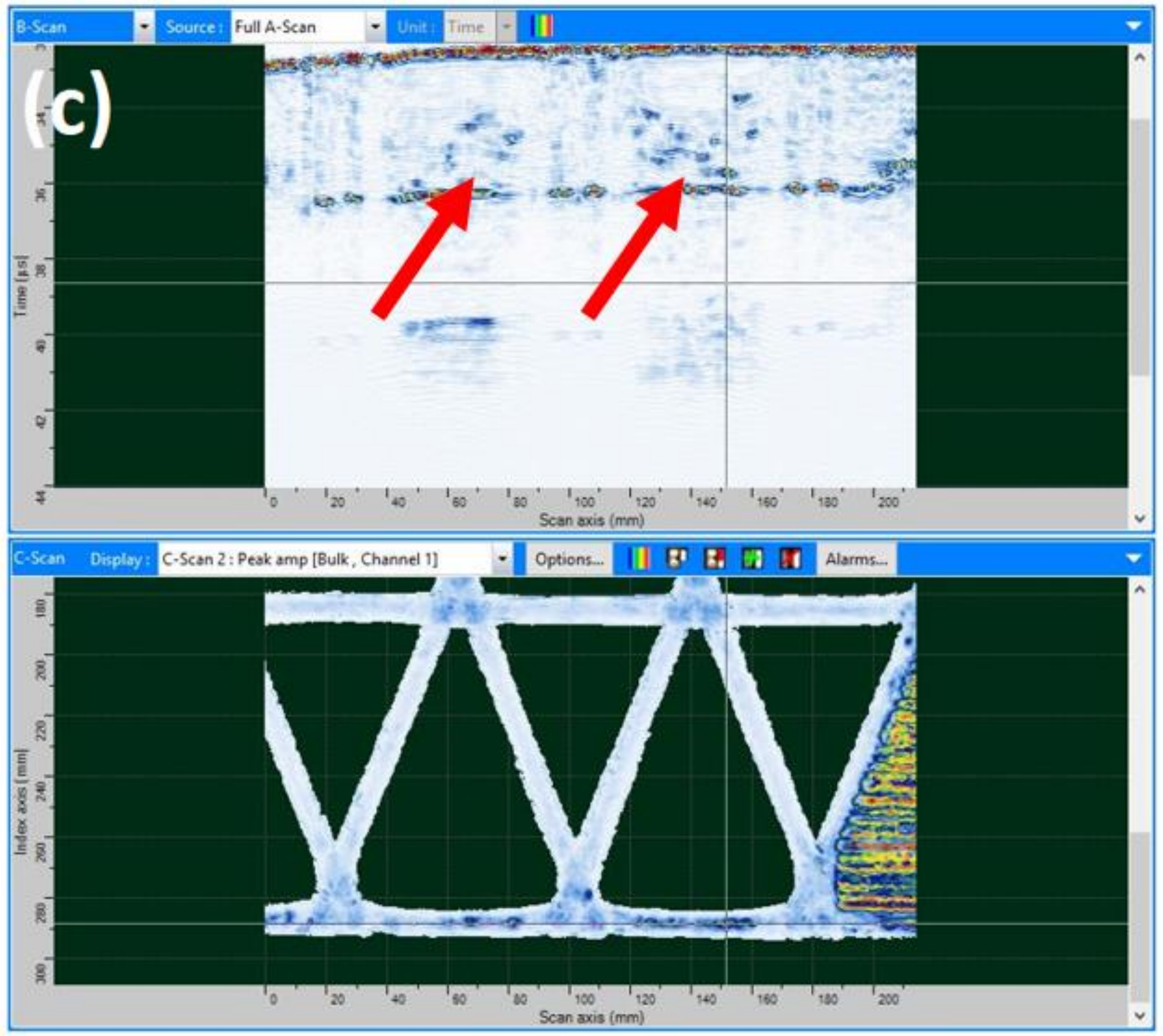
Panel 1



Panel 2

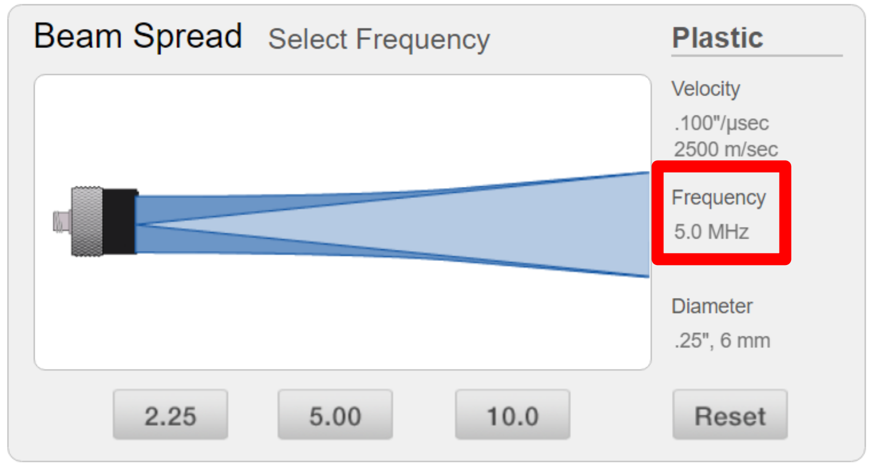


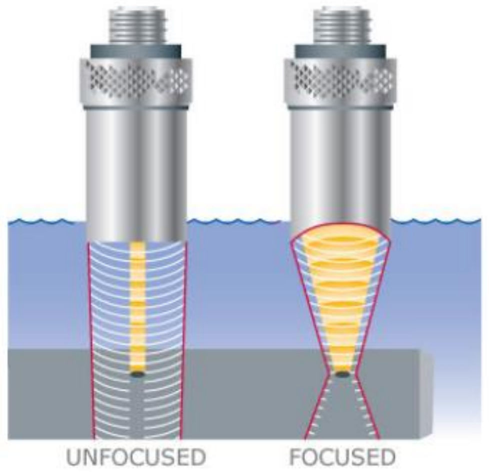
Panel 3



CONCLUSION

- In this study, it was shown that C-Scan inspection can be considered an adequate inspection method for composite lattice structures with patches for aircraft rib application.
- Ultrasonic C-Scan quality inspection method was developed with the help of calibration lattice and block using the regular 10MHz immersion type ultrasonic testing probe.
- 10 different medium and large defects were located in the rib regions of lattice structures and 9 of them were detected. However, some difficulties still remain.
- The regular 10MHz immersion type probe used in the study does not have an adequate resolution to detect a 1mm x 1mm defect in either a 6mm thick UD panel or lattice structures.
- Composite lattice structure node points offer an inspection challenge for ultrasonic C-scanning due to its complex geometry and fibre micro-structure.
- After calibration operation, aircraft rib structures were inspected by C-Scan method. It was seen that edge blocks are needed to eliminate inner defects around the lattice edges.
- Further work can be done to increase the quality of inspection process for the defects smaller than 3mm x 3mm.





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THANK YOU!

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