Using Phased Array Ultrasonic Testing Technique for damage detection of a flat boat hull

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Abstract

The utilization of composite materials is expanding in various applications in the design of various components because of their unique properties of high strength, low weight and greater corrosion resistance. Due to the complex composition matrixes of composite materials the need for non-destructive testing method that is effective in the inspection and evaluation of these structures is inevitable.

This paper focuses on the detection of a flat boat hull using Ultrasonic Phased Array Technique. Ultrasonic Phased Array is a technique that has the ability to use a single transducer assembly of multiple elements to steer, focus and scan beams on the inspected components. The SONATEST VEO+ Phased Array Flaw detector was used for damage detection. Due to the ability of imaging by B and C-scans the evaluation and characterization of damage within the flat boat hull was reliable and fast. The results in this paper have shown that Phased Array is a suitable and reliable Ultrasonic Technique for detection of damage in a flat boat hull.
1. Introduction

Numerous industries are utilizing composites materials for buildings, bridges and structures such as boat hulls, aerospace, automotive, and military due to their beneficially mechanical characteristics such as great strength, high corrosion resistance and low weight. [1]. A composite is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure [2]

Due to the complex manufacturing processes involved, these structures are susceptible to flaws during production [1]. This brings to a need for a Non-destructive testing method that is effective in the inspection and evaluation of these structures. Non-destructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the service ability of the part or system. Suitable NDT methods are selected according to the type of the material being tested [3].

Ultrasonic techniques have been the most widely used non-destructive testing and evaluation (NDE&T) method to analyse internal defects occurring inside a structure. Ultrasonic testing is based on the detection and interpretation of reflected ultrasonic waves by defects [3]. By taking into account the maximal amplitude of ultrasonic echoes, the nature, size and orientation of defects can be characterized. However, the detection of defect in composite materials poses a great challenge to ultrasonic non-destructive testing due to the high attenuation of ultrasonic signals that probably could be caused by the properties of the constituent materials, fibre orientation and the stacking sequence of the composite materials.

The inhomogeneity of composite materials makes the ultrasonic testing complicated [7]. Due to an-isotropic structure of the composite materials, it is therefore required to modify the techniques to find the most appropriate and accurate process for detecting flaws and anomalies in composite materials

This paper focuses on the detection of a flat boat hull using Phased Array Ultrasonic Testing Technique (PAUT). PAUT is an advanced ultrasonic technique and it can be applied in any situation where traditionally conventional ultrasounds are applied. PAUT is a technique that has the ability to use a single transducer assembly of multiple elements to steer, focus and scan beams on the inspected components.

The main objective of this paper is to evaluate the possibility of PAUT technique for the integrity and structural evaluation of composite materials. The composite structure that was inspected in this project was a flat boat hull made of multi axial XC900 composite manufactured by Formax CBX900. This structure is in-homogenous which results in varying ultrasonic wave propagation speed which makes the inspection to be challenging due to high attenuative materials, complex geometries, variation in thickness dimensions. This study seeks to find out if PAUT is very efficient and reliable regarding defect detection in flat boat hull panels.
2. Inspection Technique/Principle of PAUT

PAUT is an advanced UT technique that can be used to determine component quality and detect failure and discontinuities in structures. Its efficiency comes from the combination of utilising multiple miniaturised transducers and time-delays to shape the ultrasonic sound beam in a desired angle and focus depths, through to one probe which then performs several different inspections without the need of changing the transducer assembly [8].

A phased array probe houses an array of ultrasonic transducers which are acoustically insulated from each other. By pulsing the elements with different time-delays, the angle of the ultrasonic sound is ‘steered’ to a specific angle, focus-point or both [8].

3. Test specimen and Experimental procedure

The SONATEST VEO +16:64 PAUT flaw detector was used with a SONATEST wheel probe scanner that consist of a 5MHz,64 element and 0.8 mm pitch probe. Figure 2 below shows the experimental set up of the PAUT technique used.

Figure 2: Experimental set-up.
In this study three boat hull composite panels were used for testing, including carbon fibre and foam composites to evaluate the effectiveness of PAUT technique on composite material. Figure 3, 4 and 5 show the three panels which were used for inspection.

![Figure 3: Panel A - vacuum infused plate](image1)

![Figure 4: Panel B - Carbon fibre plate](image2)

![Figure 5: Panel D - Cut-off sandwich panel](image3)

Panel "A", is a plate that has been vacuum infused and made with a total of 11 layers of CBX 900. In the test piece there was an area where a piece of plastic layers was placed to simulate a defect.

Sample "B", which was made by using two 9 mm carbon fibre plates which were bonded together with "Spa bond 340 from Gurit, in the same sample there was an area where the spa bond was not placed and it was done to simulate a void defect between the two plates.

Sample "D" was an off cut sandwich panel, to simulate a dis-bond defect between carbon fibre skin and foam core.

The test panels were immersed in a shallow water-bath to provide consistent and easy coupling. The wheel probe generally utilises a fine water mist in usage. The overall length of the wheel probe was about half the length of the panels which made it difficult to scan 100% inspection on the test panels, but scanning was carried out centre to edge over the test panels to try to cover 100% inspection on the panels.

### 4. Results and discussion

UT-Studio Analysis PC software was used to analyse the results. All analysis were carried out using amplitude comparison, and it was not possible to present depth analysis with the PAUT instrument used at this point, Although the depth of the defect was confirmed
using the conventional Pulse Echo Technique. The images below represent the results obtained on the test panels used in this study.

The images below shows the Top View and B-scan results obtained in test panel A of flat boat hull.

![Figure 6: Top view results of Test Panel A](image)

The defect was detected towards the edge (corner) of the panel which indicates a void.

![Figure 7: B-Scan view results for test panel A](image)

The B-Scan section was taken through the horizontal line @11.12mm and extracting the backwall echo (BWE) which was hidden by the defect. (The BWE was around 16 mm mark). This panel was more difficult to image due to the shallow depth of the defect, but...
utilising the B-Scan it was seen @E7 where the trough reflection of the layers were inhibited by the insert.

The images below shows the Top View and B-scan results obtained in test panel B of a flat boat hull.

**Figure 8: Top view results of test panel B**

The panel was scanned in three different directions since it was not possible to have a scan across the complete defect. The blue region on the top view images indicates a defect free area which is a bonded region, whereas the yellow to orange colour indicates a defective area.
The BWE was utilised as a confirmation on the B-Scan view where @E3 there was no backwall, even at left and right above marker 19.72 there is no back wall at either sides.

The images below shows the Top View results obtained in test panel D of a flat boat hull.

Two scans were taken at approximately 90 degrees and the blue region indicates the area which is bonded and defect free and @E3 it indicates the area which had a dis-bond.
4.1 Summary of the defects obtained in the test panels.

Since composites are inhomogeneous materials, the form of defects and their effect on mechanical performance is quite different and more complex than metallic materials. Most of the indication found in these panels were dis-bonding or delamination which is one of the most usual defect found in composite materials and it may be caused by separation of adjacent layers due to weakening of interface layers between them, or due to inclusions, insufficient curing temperature and improper laying of laminate.

5. Conclusion

It can be concluded as it was seen in the results of this study that PAUT is an effective and reliable technique for detection of damage in multi axial carbon fibre composite material of the flat boat hull panels. There were restrictions such as not able to perform 100% inspection due to the panel size. It was also not possible to utilise scan encoding, therefore positional detailing of the scan results was not achieved. Due to lack of availability of lower frequency probe, the 5MHz frequency used was not optimal on the type of carbon fibre inspected, as 'correct 'level of sound penetration was not possible. Future works will still be carried out regarding this study for procedure writing purposes of inspection of flat boat hulls panel using PAUT technique and also to modify the results obtained as depth measurements were also not recorded in this study.

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