CASE STUDY – MONOLITHIC COMPOSITE PLATE

TFM – ASA: Non-Destructive Testing

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1. INTRODUCTION

NDT is study to determine the mechanical properties without any damage to the system and also to find any defects occurred during various stages in the life cycle of an object due to various loads acting on them by the surrounding. Hence, we perform a case study on an object with unknown defects to access them throughout various NDT methods to find the defects through variation in its properties.

Non-destructive testing (NDT) is the analysis method used to inspect the characteristics and conditions of objects, parts, systems and materials without intrusive methods. Some of them range from surface visualization to incorporation of x-rays and ultrasonic methods. A safe method of inspection since it can cause less damage to the product/part of the object while still maintaining its structural integrity and also most testing methods being harmless to people working around the inspection process. Non-Destructive testing can help to be precise in locating defects in objects and cost effective without the need to have a destructive testing method. This testing method is usually used around aeronautical, automobile, marine engineering and any other heavy to light industrial sectors.

In this case study a monolithic composite plate is considered. This material is non-conductive and non-ferromagnetic by nature. These properties help us to define the selection of NDT methods from the available methods. The dimensions of the plate are as follows: Length – 300 mm, Width – 200 mm and Thickness – 5 mm. The plate is made up of 18 plies of Matrices RTM6 and carbon fibre with following layups [-45°/0°/45°/45°/0°/-45°/-45°/0°/45°] _s. We want to figure out the internal defects in the composite plate.

2. ANALYSIS OF PROBLEM

We have to test a monolithic composite plate, non-ferromagnetic and non-conductive. The defect present in this ply is due internal delamination.

2.1. PRESELECTION OF APPLICATION OF METHODS

The following methods excluded are:

1. Penetrant testing
2. Magnetic particle inspection

3. Eddy current

The reason for excluding the methods mentioned are:

- **Penetrant testing (non-emerging defects)**: Since the defects are not surface level the penetrant testing cannot be used to find the defects.
- **Magnetic particle inspection:** Since the material used is not magnetic in nature, magnetic particle testing cannot be used to find the defects.
- **Eddy current:** Since the material is not electrically conductive, Eddy current method cannot be used to find the defects.

The methods that can be performed are:

1. Infrared Thermography
2. Ultrasounds

The reason for including the methods mentioned are:

- **Infrared Thermography:** The defects maybe present either in upper or the lower part of the body, we can use infrared thermography to find the approximate location of defects and this information can be used as reference in ultrasounds method.
- **Ultrasounds:** The defect type here is internal delamination and ultrasound can be used to find these kinds of defects, because its capable of finding orientation of defects.

3. ANALYSIS OF PRESELECTED METHODS

3.1. INFRARED THERMOGRAPHY

The infrared thermography is based on emissivity of radiation emitted by bodies. They can show the surface and sub surface defects. Using the thermography, we can find the location of the defects when subjected to heat and captured by the infrared thermography. All bodies have their own emission. Using infrared camera we capture this radiation, but to find defects we need to excite the material using heating appliances and cool them to find the defect. To find all the defects we need to excite and cool down at different time intervals and different picture frames, optimizing these will show all the defects of the object. Hence, we optimize the image frames and time steps for excitation we find the defects at all locations and every side to get the location of defects based on the images observed.

3.2. ULTRASOUND TESTING

The Ultra-sound method is used to find the distance and depth of the defects in an object. The object is placed in water and using ultrasound radiation through probes the emission is passed through the object and by observing amplitude fluctuations we can find out the defects. At amplitude fluctuation apart from the reference we segregate them and find the time steps and using the speed of reflection and time we find out the respective distance of the defects. You have to calculate the minimum frequency to be able to separate the echoes in order to measure the thickness in reflection. Table 1 refers to the speed of longitudinal waves in the given materials during testing the object.

Table 1: Velocity of Longitudinal Waves for different materials

Materials	Velocity of longitudinal waves
Air	340 m/s
Water	1480 m/s
Composite (in direction of thickness)	3000 m/s

Hence, we perform the ultrasonic testing to find the location, depth and nature of defect with help of infrared thermography using its results for location of defects present in the composite plate.

4. NDT PROCEDURE

4.1. INFRARED THERMOGRAPHY

a. Launch the module of the software
b. Place the Composite sample under the camera and ensure the image is set.
c. Turn on the Halogen for not more than 10s. After turning off the halogen and waiting, to make sure the temperature is stable and homogeneous on the part, put your hand everywhere on the part and do the previous step again.

d. Define excitation time and number of images to be required
e. After the experiment is completed, the image burst processing begins starting at the defined start image on the selected number of frames.
f. The thermogram representing the average temperature of the selected image is drawn during processing.
g. The histogram representing the distribution of response times is displayed at the end of processing. It is possible to improve the contrast of the image resulting from the processing by modifying the two cursors present on this histogram.
h. The software plots for each pixel the temperature as a function of time. For each pixel, the temperature decreases exponentially as a function of time. And it is the decreasing coefficient that is represented. The larger the factor, the more "Yellow" we can see, the faster is the cooling, Lower the factor, the more it appears "purple" and the slower is the cooling.

4.2. ULTRASOUNDS

a. Keep the transducers outside the medium(water) and calculate the velocity of air using time of excitation.
b. Now keep the transducers inside the medium and calculate the velocity of water using time of excitation inside the water.
c. Now keep the transducers between the part and check for the defect amplitude in A-scan between first echo and surface echo.

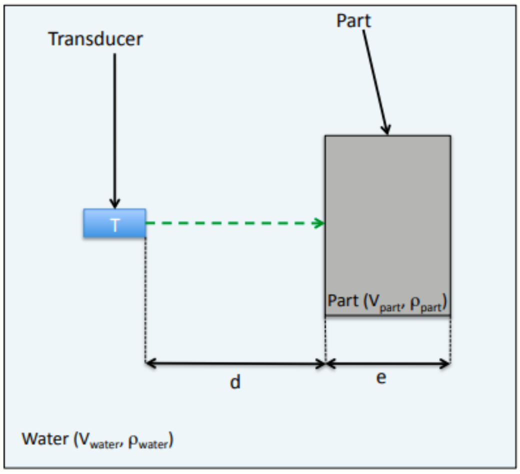

Fig. 1: Longitudinal waves transmission throughout the object without defect

d. Now set the system of transducers with two end points of the component and scan the whole component using the transducers and obtain A, B and C-scan data.

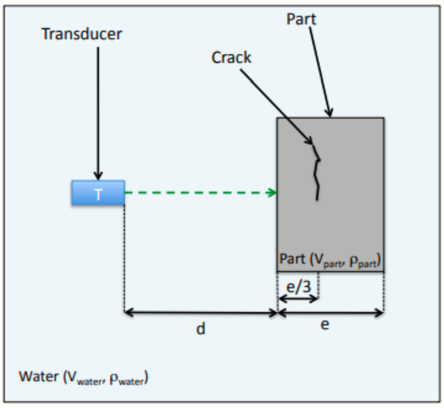

Fig. 2: Longitudinal waves transmission throughout the object with defect at distance e/3

e. Remove the part from the medium and measure the dimensions of the component using vernier calliper then cross verify the values of thickness obtained using transducers.

f. Conclude about the defects present inside the composite. And calculate the thickness using distance formula from Equation 1.

$$S = \frac{D}{t} \quad \ldots\ldots(1)$$

Where S = Speed of longitudinal waves

D = Distance from the transmitter to the object

T = Time taken to transmit the light for one entire cycle

5. CONCLUSION AND RESULTS

Analysing the situations for performing tests within the time limit of the course as discussed in above sections we had chosen 2 methods Thermography and Ultrasounds. Starting with thermography might help to detect the location of defects much faster.

5.1. THERMOGRAPHY

To test the composite plate using thermography we need to change the time of excitation and number of images to reach the optimum defect in the entire plate and on both directions of the plate.

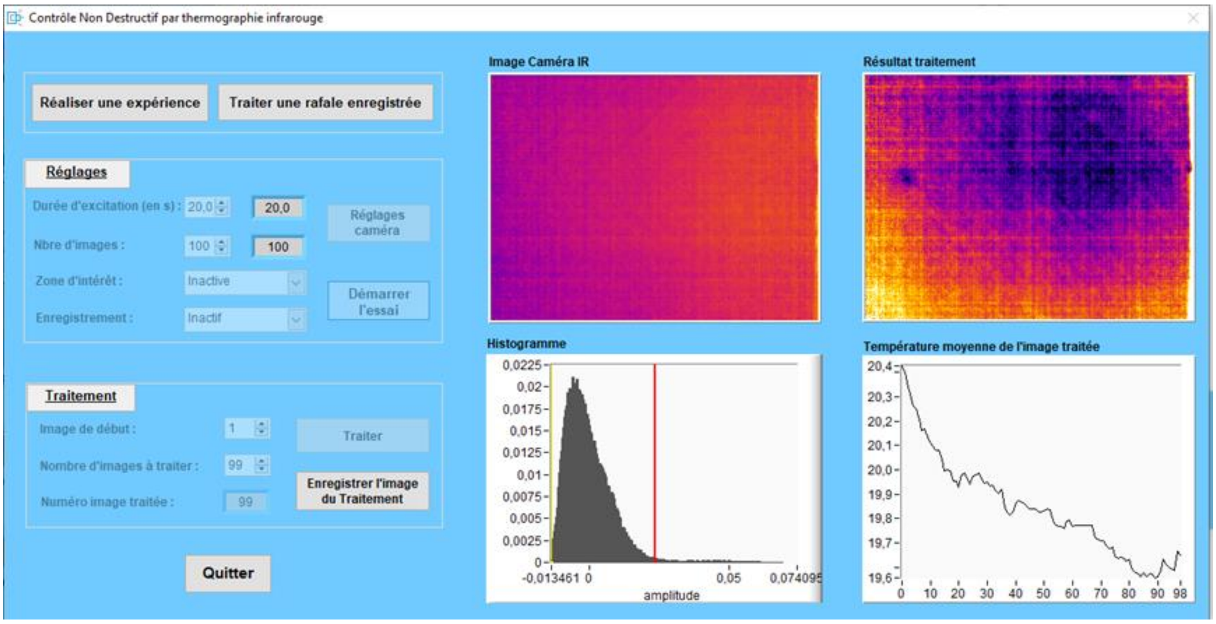

Fig. 3: Image of defect for Time excitation of 20s and 100 number of images

From Fig. 3 we observe that, at excitement duration of 20 seconds and number of images at 100, the above defects were found, but from the obtained results we can see that the cooldown time was very high. Fig. 4 represents the excitation time was reduced to 15 seconds and number of images to 80, we obtained a result where, a better visibility of defect was found.

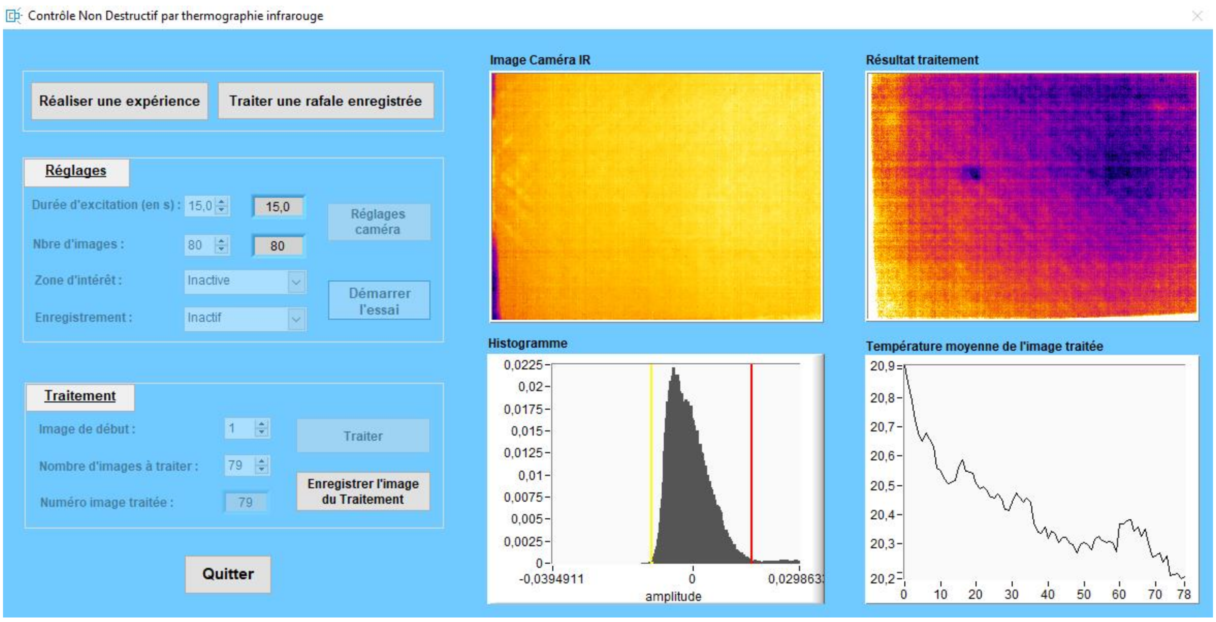

Fig. 4: Image of defect for Time excitation of 15s and 80 number of images

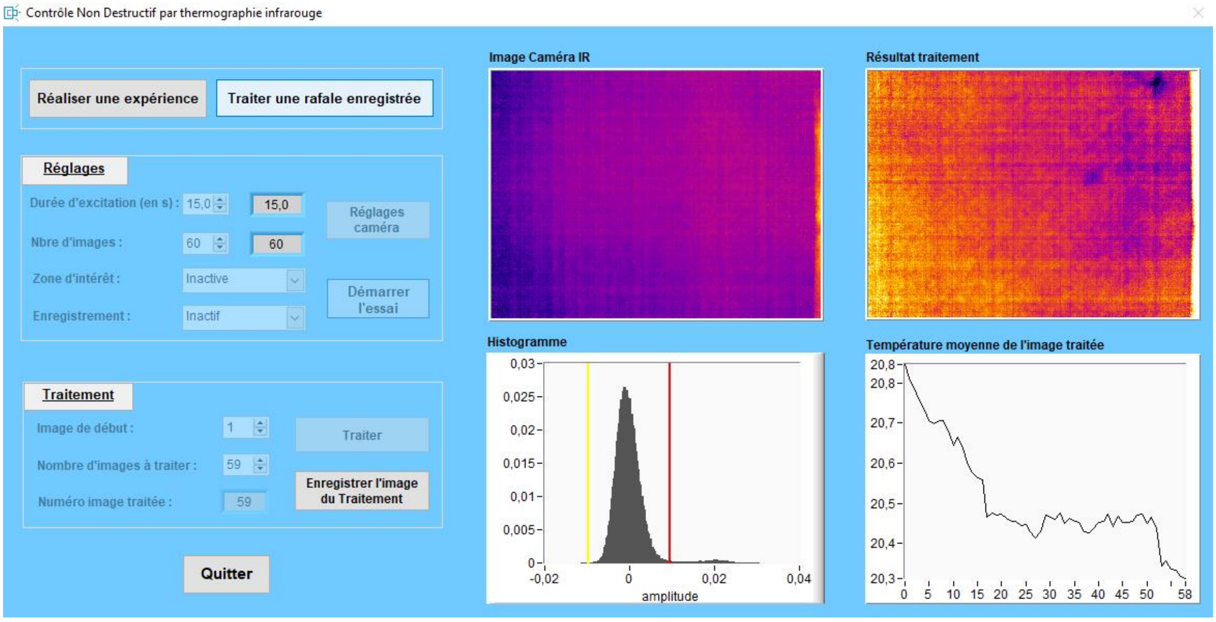

Fig. 5: Image of defect for Time excitation of 15s and 60 number of images

Similar to the above case, number of images were further reduced to 60 and the defect was visible more clearly than previous case, and we could confirm the presence of defect from this face of the composite plate which could be observed in Fig. 5.

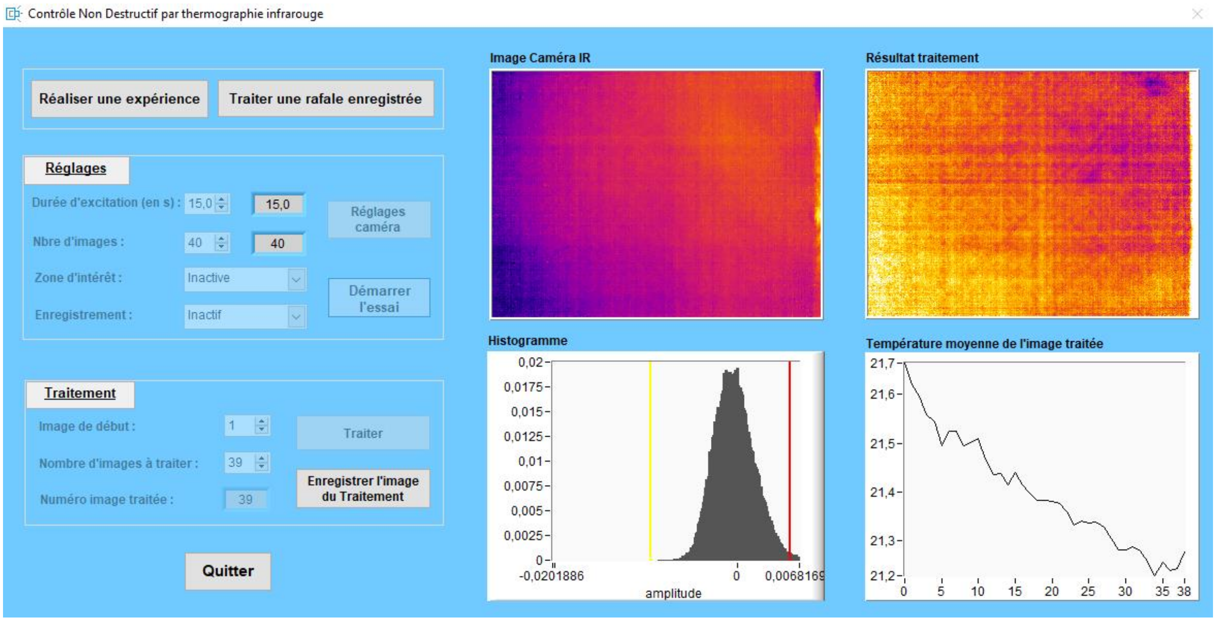

Fig. 6: Image of defect for Time excitation of 15s and 40 number of images

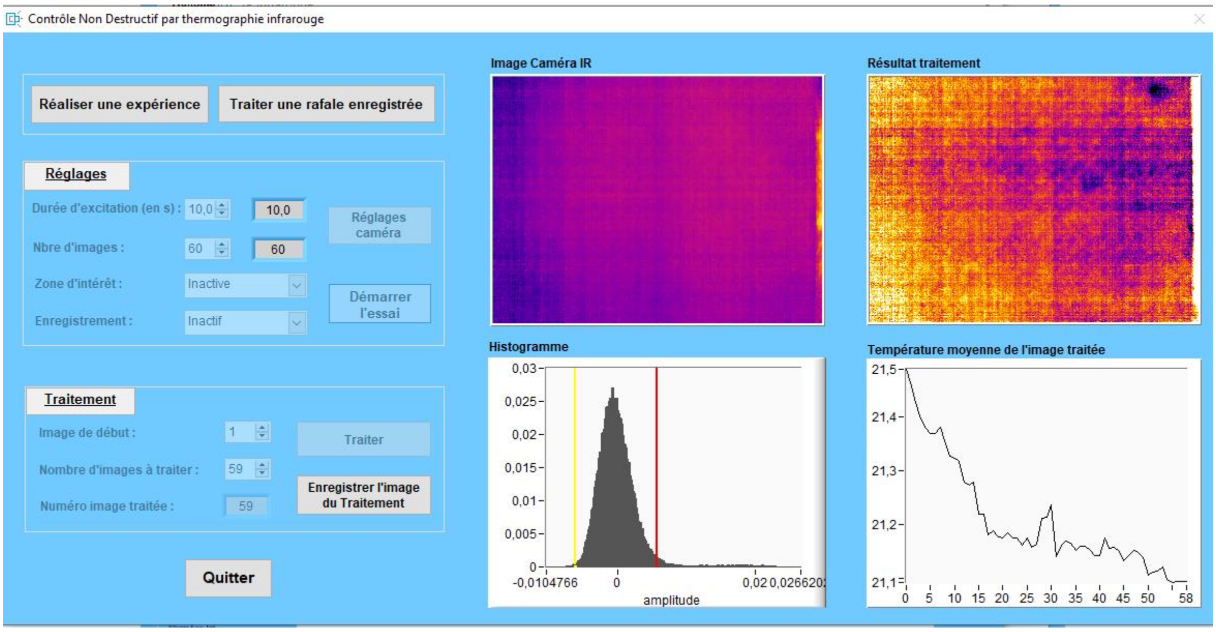

Fig. 7: Image of defect for Time excitation of 10s and 60 number of images

Further, the composite plate is moved to check for defect at different location on composite plate and then the excitation and number of images were further reduced and the above results were obtained, where the defect was visible at the top right corner on the screen and no other defects were detected in the Fig. 6.

In the above case, the composite plate was flipped and with excitation time of 10 seconds and number of images at 60, we can confirm that the defect is present at the same place after flipping the composite plate which is observed in Fig. 7. Similar to the above case, the flipped composite plate was adjusted to check for other errors and then the excitement time and number of images were given as 10 seconds and 60 images respectively, and we could observe that no other defects were found shown in Fig. 8.

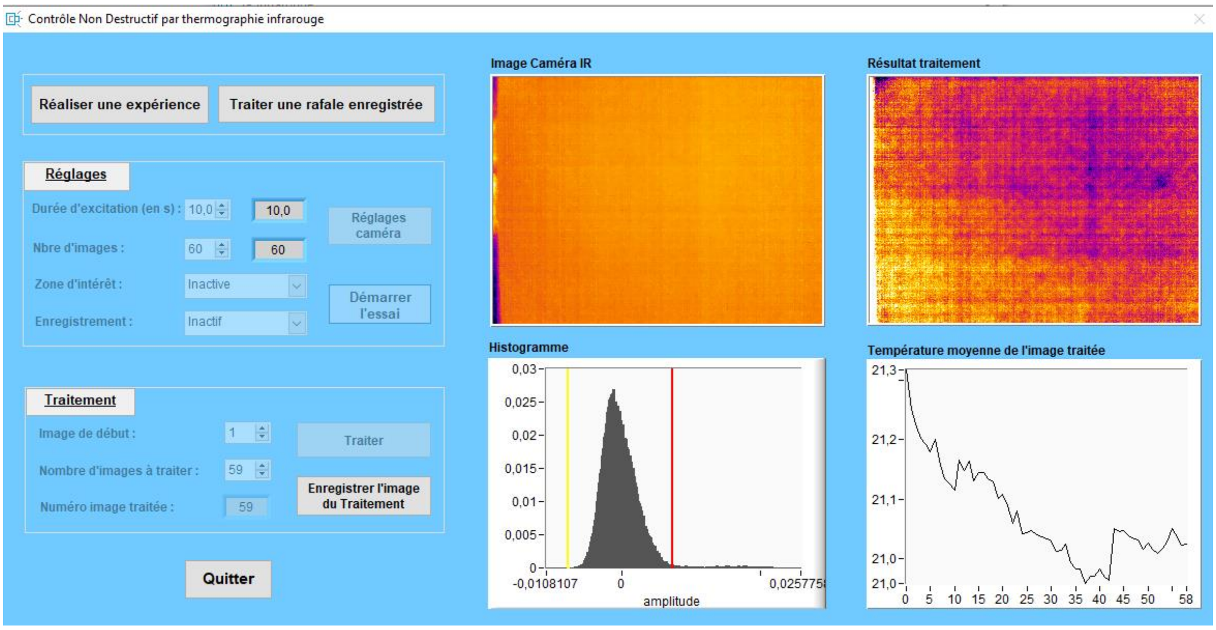

Fig. 8: Image of defect for Time excitation of 15s and 40 number of images

And there was another minor defect detected at one corner of the composite plane which is evenly spread out, and we are assuming that this defect might have evolved from continuous usage of the component and might be because of the water entering the inner parts of the composite plate, which can be further confirmed by using the ultrasound testing method.

5.2. <u>ULTRASOUNDS</u>

Ultrasound can be performed in 2 ways either transmission or reflection. Starting with transmission the position of defect could be found and through this area with dimesions of defect could be found easily. The plate was fully scanned using partial resolution so that the approximate location of the defect in the plate can be found. After full scan it was found that the plate has a defect at the upper right section of the plate observed in Fig. 10. The schematic of the defect location is shown Fig. 9.

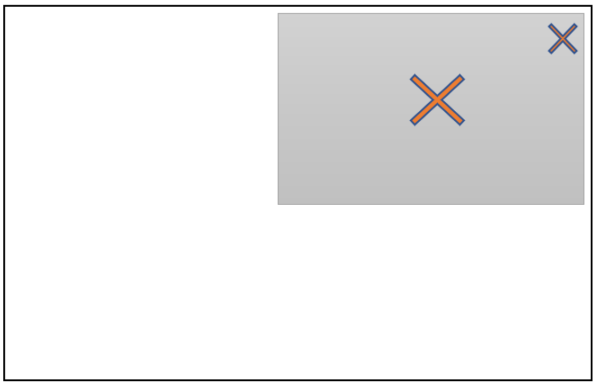

Fig. 9: Schematic diagram showing location of detected defects

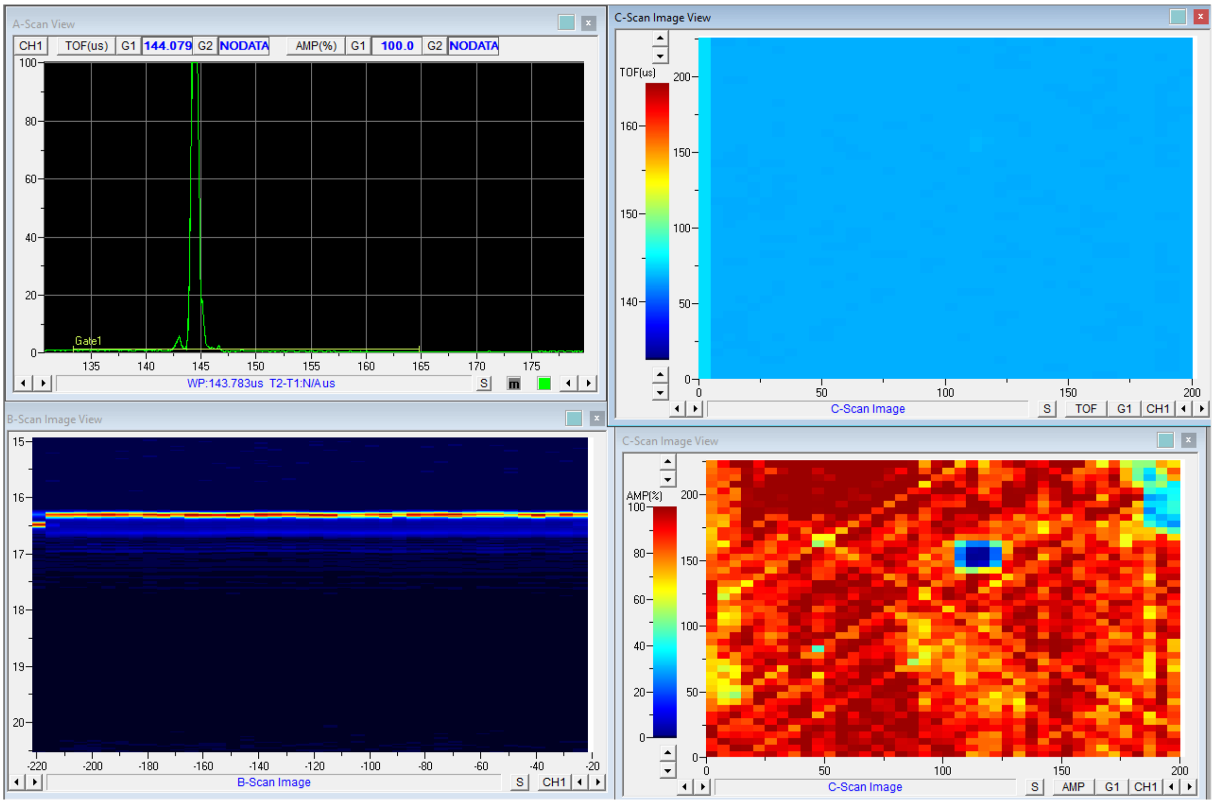

Fig. 10: A-, B- and C-Scan for entire composite plate

After this step a small parameter is taken for consideration for setting up the coordinates in the Ultrasound machine. The upper part is then scanned with high resolution of the scan so that more precision in A, B and C scan data can be extracted which can be observed in Fig. 11. This gives a high-resolution image in C-Scan with colour legend of dark blue depicting the area of defect and colour legend of orange/ yellow areas depicting no defects. And as can be seen the new section of the part used with new coordinated shows defect at left bottom corner. Apart from this, there has been another minor defect on the top right corner with light blue scale of the colour legend. This gives an inference that due to immersion of the part in the fluid medium multiple times during the test due to water insertion in the part layers this defect has been generated on a minor scale.

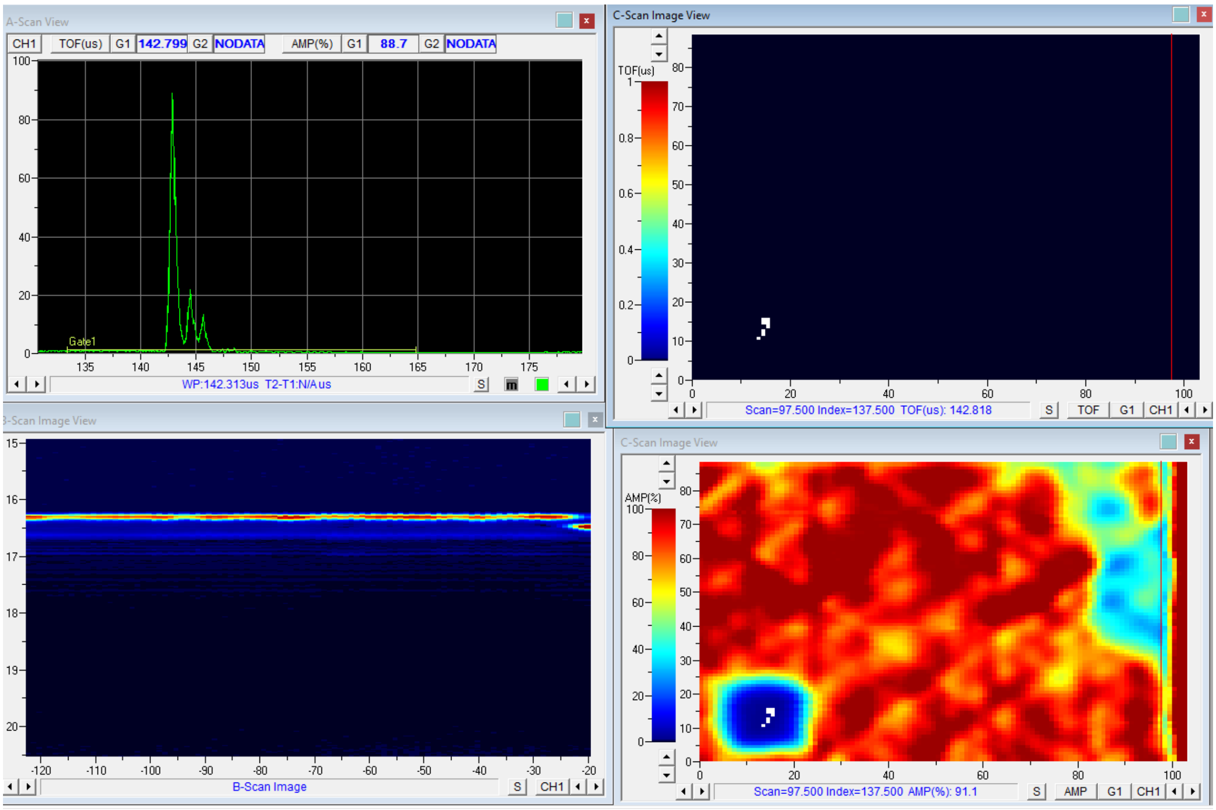

Fig. 11: Focussed A-, B- and C-Scan of the composite plate

From Fig. 10 of the entire scan we get the co-ordinates of the major and minor defect as

Major Defect : x-start: 124 & 103.5 mm & y: 127.25 & 149.5 mm
Minor Defect : x: 181 & 200 mm & y: 124 & 180 mm

From this we can measure the area of the major and minor defects. The formula to calculate area using co-ordinates is Area = $(x_2-x_1)\times(y_2-y_1)$. The calculations of area goes as follows :

Area of Major defect : (124-103.5) × (149.5-127.25) = 456.125mm^2
Area of Minor defect : (200-181) × (180-124) = 1064mm^2

Reflection of the ultrasounds has been performed, where in the major defect has been detected. But in this case the minor defect is not be seen precisely. From the available images we find that the depth of defect can be found approximately from 0.1 mm to 0.4 mm, which represent depth as 0.3mm and 0.1 mm from the surface of the plate as observed in Fig. 12, Fig. 13 and Fig. 14. Due to time constraint the position of gates to detect the depth using time of flight is not considered. But, using B-scan the depth calculation has been performed.

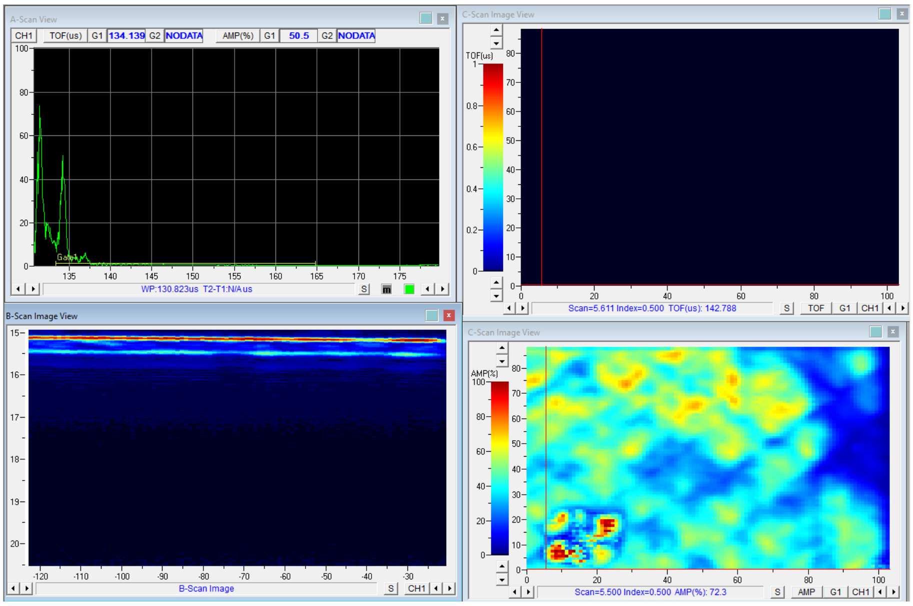

Fig. 12 A-, B- and C-Scan using reflection at focussed are of the plate (weak resolution)

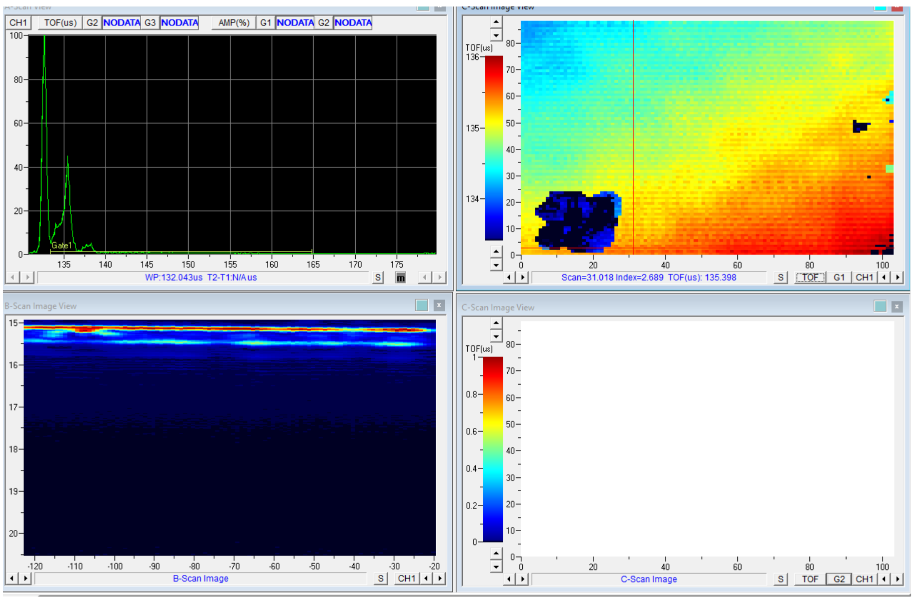

Fig. 12 A-, B- and C-Scan using reflection at focussed are of the plate (medium resolution)

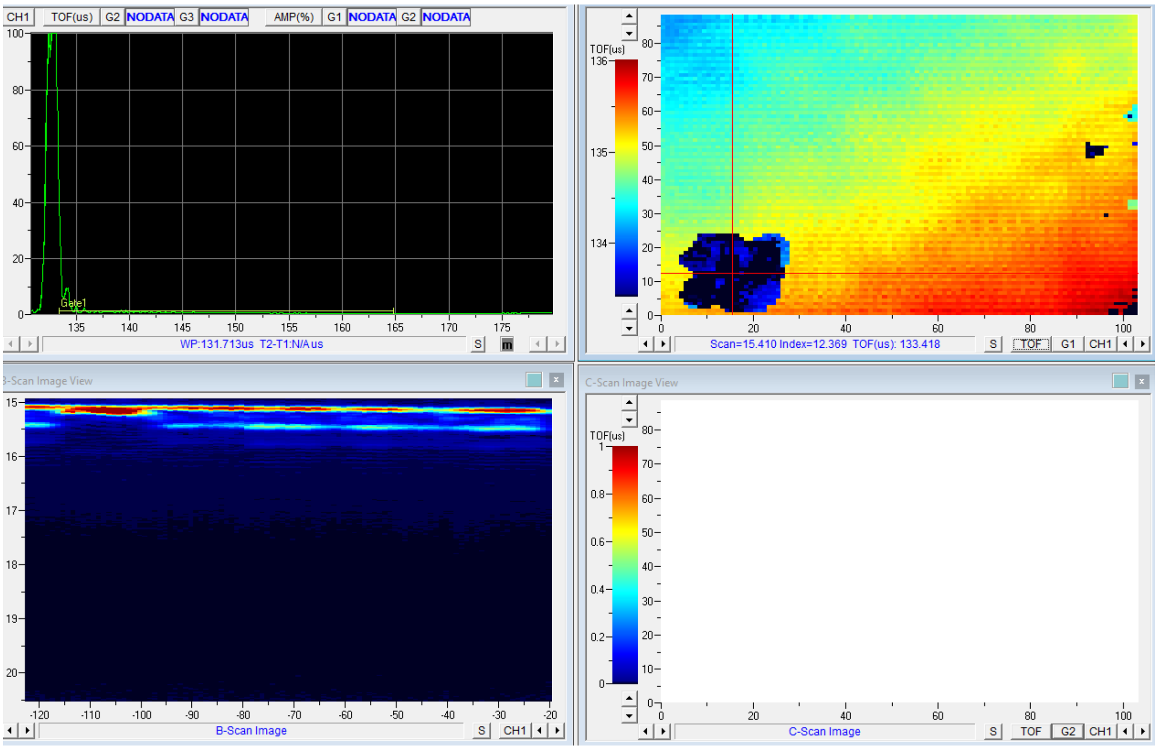

Fig. 12 A-, B- and C-Scan using reflection at focussed are of the plate (good resolution)

This completes the procedure to scan the part using ultrasound machine with low and high resolution with complete part scanning and section of part having the defect.

Fig. 13 and Fig. 14 are showing the original plate with defects been highlighted and also the placement of the composite plate in the ultrasonic machine inside water.

Fig. 13: The composite plate with defects highlighted in the front and back end of the plate respectively

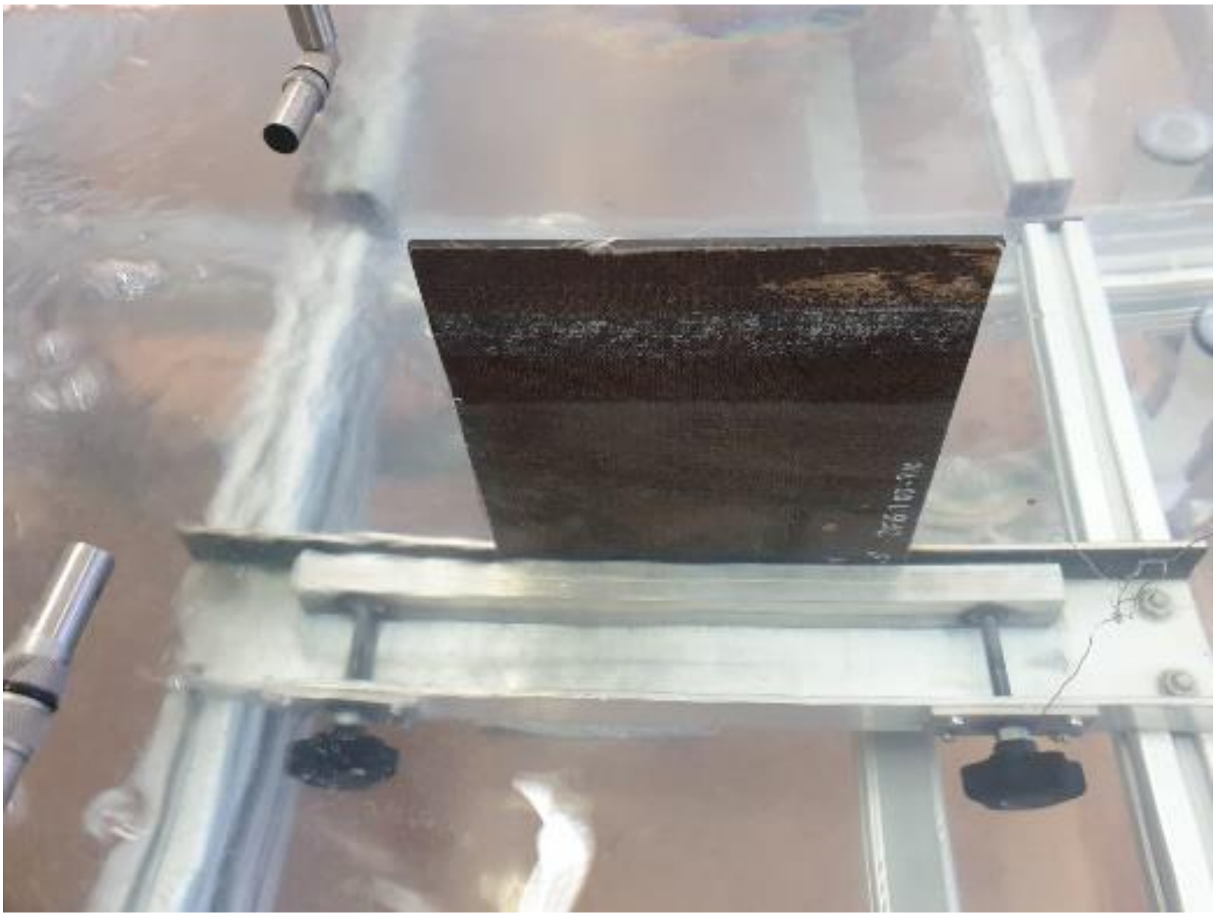

Fig. 14: The composite plate immersed in the water and placed in the ultrasonic apparatus

6. FUTURE ASPECTS

If we had further more time, we could have used the vernier calliper to physically find the dimensions of the defect, and we could use it to compare the results to the dimensions which we obtained by using ultrasound technique.

We could have performed calculations based on A-Scan in the case we had no time constraint. Allowing time of flight measurement using gate location specified in the A-scan and furthermore evaluation of the depth of defect.

And also measuring the defect from other side of the composite plate can help to find the defect more visibly or clear.

Also, if the X-ray imaging equipment would have been there the defect would have been detected more precisely with dimensions and location of the defect.

7. CONCLUSION

From this entire testing using different apparatus we find the defect location, it's area and the depth of the defect if observed. As in our case study we have used specifically infrared thermography and ultrasonic testing. Infrared thermography detects a defect but not the dimensions or any other data regarding the geometry. So if in any application where rejecting a part by just observing a defect this method can be used else also for finding a defect exists or not as it is very easy and quick to use among all the NDT methods. Now using ultrasonic for testing is a really challenging task as it contains various scans such as A, B and C-scan which requires time for performing and also analyzing the scans. But the advantage it provides for acceptance and rejection of a part through measing the dimesions and depth of the crack in the plate gives very good results.

Observing this Non-destructive testing has really made life more simpler to find the defect which can reduce the destruction or failure of the part harming the society, human's and nature than compared to destructive testing which waste's our material, time and incurs a huge cost which can still incur a defect which could not be observed by a naked eye.