



LOW-LEVEL PROCESSING APPROACH USING GUI FOR ULTRASONIC C-SCAN DEFECTS DETERMINATION OF COMPOSITE MATERIAL

M. F. Mahmud^{1&2}, Elmi Abu Bakar³, Raiminor Ramzi¹ and M. F. Zainal Abidin⁴

¹School of Mechanical Engineering, Universiti Sains Malaysia, Nibong Tebal, Pulau Pinang, Malaysia

²Faculty of Mechanical Engineering and Manufacturing, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia

³School of Aerospace Engineering, Universiti Sains Malaysia, Nibong Tebal, Pulau Pinang, Malaysia

⁴Advance Materials Research Centre, SIRIM Bhd., Jalan Hi-Tech Park, Kulim, Kedah, Malaysia

E-Mail: mfaisal@uthm.edu.my

ABSTRACT

Ultrasonic testing (UT) are the most common technique used for composite laminated non-destructive (NDT) inspection. In the current practice, the dependency of human interpretation during perform UT resulted in inequality detection issues on inspection process step. This paper presents an improvement of UT approach using graphical user interface (GUI) to provide defect percentage of C-scan image. Several of composite laminated C-scan defect image was identified before the defect percentage being calculated. The intensity difference between defect and non-defect image was calculated in this GUI. Base on this experimental result shows that the defect calculation was reliable which is proved by calibrated image. The different between an ideal and actual defect calculation is 0.69 % are considered insignificant and negligible. The average execution time for three test series is between 7.35 sec to 8.52 sec while the longest time is 9.52 sec. Since the execution time is not exceed 10 sec and acceptable. Instead of application, this GUI, however, able to operate only in offline and flat surface condition.

Keywords: ultrasonic testing, image processing, composite laminated, graphical user interface.

INTRODUCTION

The inspection process is highly demanded in aircraft manufacturing industries. The type of inspection process basically depend on several aspect included material properties, dimension, the shape to be inspected. Some inspection process required naked eyes for cosmetic type of defect such as scratches, dented, pinhole that occurred on a surface panel while some inspection required low-frequency ultrasonic probe in order to detect an inter-layer flaw in the thicker panels such as bond, crack and void. In the current situation, human visual inspection for a long time cause eye strain and irritation, blurred vision, headache, stress and neck pain [1]. This problem will lead to low productivity and cause miss interpretation of defect detection where the quality control is questionable and required a further cross verification stage. Therefore, the development of computer-based inspection method being crucial works in order to cross check the inspection quality done by inspection operator.

In the past few years, a lot of research in defect detection of composite material has been done widely. Variety of techniques applied for defect inspection included pulsed eddy current thermography for surface crack detection [2], pitch-catch ultrasonic for subsurface defect detection [3], non-contact laser ultrasonic imaging technique on surface defect detection [4], flatbed scanner image for composite laminates surface detection [5] and ultrasonic pulse-echo measurement on composite laminates panel [6]. However, this approach requires a complex procedure for defect determination and difficult to trace back the inspection history of inspected parts. Therefore, the user-friendly and traceability of quality inspection become necessary for improvement purpose. In this developed GUI, image enhancement improved the image quality especially for the exact size of defect and

edge detection. In the current application, image enhancement approaches are successfully applied in x-ray inspection for medical purpose as done by Paolo Irrera and his research team [7]. Besides, image enhancement also been applied for defect detection in complex shape of aircraft composite using thermography [8] and ultrasonic approach [9]. These research, however, focus more on image enhancement process where none of them finalize until end user application.

In this paper, the self-developed GUI for defect percentage calculation applies both ultrasonic immersion pulse-echo scanning technique and image processing approach in order to compute and determine defect percentage of fiberglass composite laminates (FGCL) panel. The developed GUI act as cross-check approaches for quality inspection engineer to verify the inspection result performed by inspection operator. Besides, this GUI enables the user to record the inspection result if necessary. Based on cross-checking and traceability function, this GUI is suggested for inspection industries use especially for non-destructive test application.

METHODOLOGY

a) Overall flow chart

In this study, the overall research as shown in Figure-1 below can be classified into several process flow. The process is starting from C-scan image acquisition by using ultrasonic scan equipment. Then, recorded a c-scan image which is input image was displayed in GUI axes before perform image enhancement using adjustment function. After that, the enhanced image was evaluated and adjustment was made in order to avoid blur image before convert into a gray level image. Once image pre-processing phase completed, the next step is defect



analysis which is consist of pixel selection, calculation of defect percentage area and finally evaluation of defect percentage. Further defect percentage calculations are discussed in result and discussion part.

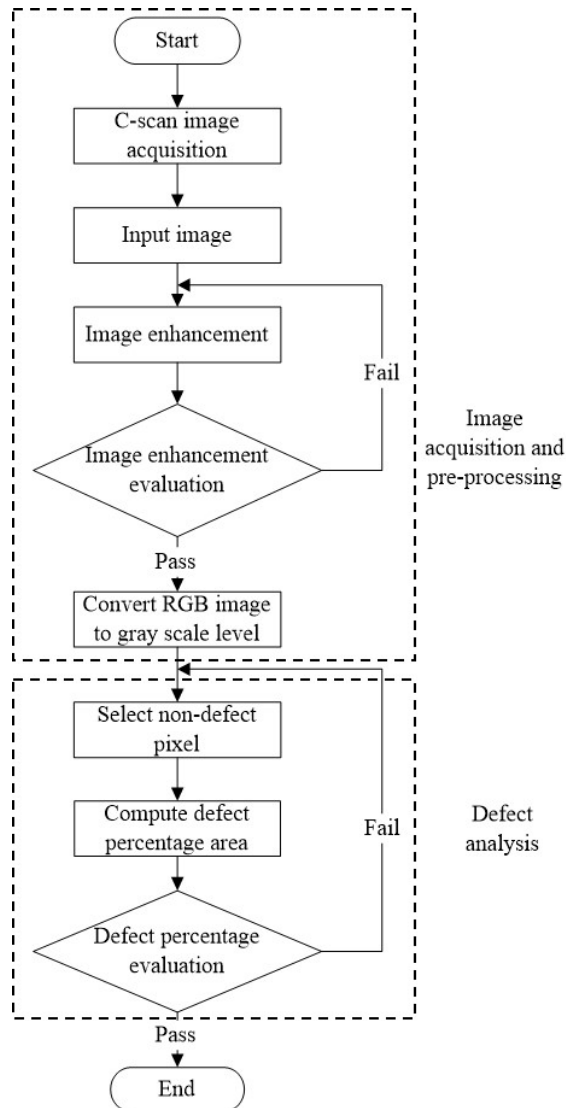


Figure-1. Overall process flowchart.

b) C-scan image acquisition

In this research, FGCL with 7.4 mm thickness is used. Before acquiring an ultrasonic C-scan image, certain parameter setup has been following such as gap distance control, type of transducer used, gate positioning setup, sound velocity, sampling frequency and type of filter. Since this C-scan image was acquired from immersion ultrasonic scanning equipment, the sample must be fully immersed at least 20 mm from water surface level in order to avoid the sample moving during scanning operation as shown in Figure-2. However, it also can be fixed using sticky tape between the surface of FGCL sample and holder block.

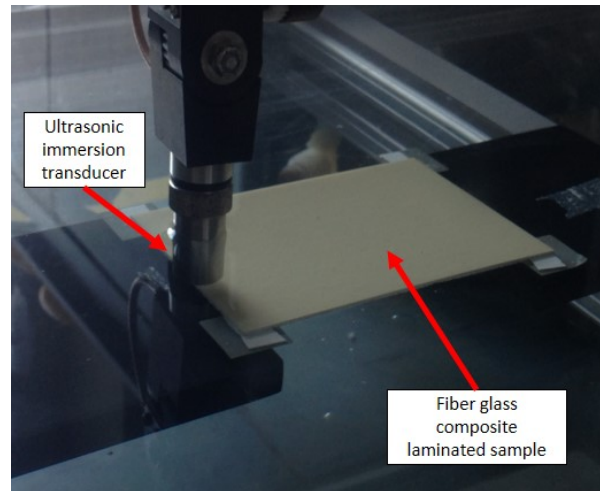


Figure-2. Immersed ultrasonic scanning system.

Figure-3 shows the ultrasonic device setup. This equipment used UltraPAC system together with UTWin software for data acquisition, scanning movement control and imaging purpose. This ultrasonic scanning device able to scan up to 200 mm/s speed with scanning resolution as low as 0.1 mm. However, the higher the resolution used, the higher the storage size and will cause time delay effect if the storage size was too large. Once scanning completed, the C-scan image was converted into ASCII file format for further analysis. Through this data, it can be re-plot using Matlab for further image and signal processing analysis.

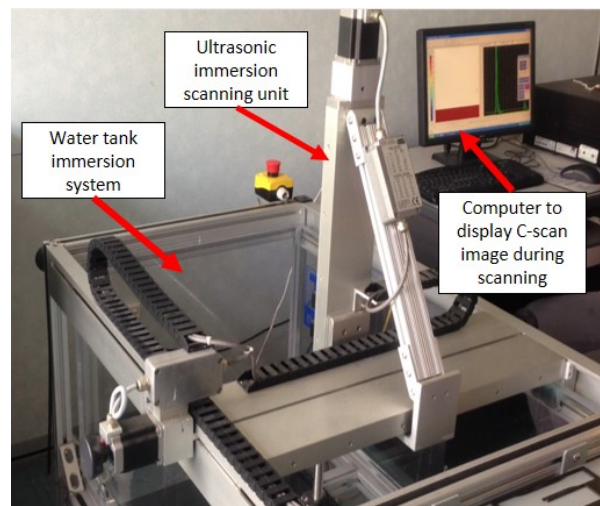


Figure-3. Overall ultrasonic scanning setup.

c) Image enhancement

Image enhancement is an adjustment process to improve the quality of digital image for a specific application. For an example, by removing noise, sharpen or brighten an image makes the image easier to identify. Image enhancement method basically is based on several



techniques included point operation, spatial operation, transform operation and pseudo-colouring. In general, simple intensity transformation and histogram processing commonly applied in point processing approaches while low pass and high pass filtering setup are used in frequency domain techniques. Spatial filtering approaches have determined by smoothing and sharpening the filters while pseudo-colouring perform transform the monochrome image into RGB transformations.

However, instead of difficulties, the most challenging task in image enhancement is how to quantify the enhancement criterion for a satisfactory result. In this study, the author adjusts the intensity values in the grayscale image in the range between 1% up to 100% where that data is saturated at low and high intensity of the image. This adjustment then will increase the contrast of the input image. Slider box in this GUI functions as intensity adjustment for the user-friendly purpose during enhancing the input image.

d) Percentage of defect

Based on the percentage of defect algorithm as shown in Figure-4 below, once input image was enhanced to improve the exact size of defect and edge detection, the pre-processed image then convert to grayscale format. The purpose of this process is to reduce the unwanted image information from three layers of information in the form of red, green and blue known as RGB image to just single information which is a gray scale from 0 to 255. Despite gray scale image, the user still can identify the defect region easily without compromise the inspection quality.

Algorithm: Percentage of Defect
(1) Run Matlab GUI
(2) Show identified input image
(3) Image adjust, the actual image Low in, $X_i > \text{High In value}$. (until getting clear defect image)
(4) Convert RGB image to grayscale
(5) Pixel selection, in non-defect region
(6) Compute the $X_{(k)}$ intensity value, $k = \text{desired value}$
(7) Show the pixel and percentage of defect
(8) Reset, clear image and text box
Return step 2, for different input image

Figure-4. Percentage of defect algorithm.

Once the defect region identified, the percentage of defect area is calculated. This process starts by differentiating the selected pixel value in defect region with others. Then the desired defect % was gained as follow equation 1.

$$\text{Defect \%} = \frac{\sum N_d}{\sum N_{all}} \times 100 \quad (1)$$

Where a total number of selected pixel value, $\sum N_d$ is divided with the total number of pixel on entire input image frame, $\sum N_{all}$ before multiply by 100.

RESULTS AND ANALYSIS

There are several experimental results discussed in this topics. In the beginning, calibration test was performed in order to ensure the reliability of defect percentage result. Then, several type of ultrasonic C-scan image is used to determine the defect percentage calculation. Finally, the last experimental result to be discussed is execution time study during calculating defect percentage in a variety of input image. The purpose of this study is to know the time range of developed GUI during execution. The detail of calibration, defect percentage and execution time result are discussed in the following section.

a) Calibration result

Figure-5 below show the calibration result of developed GUI using binary block image. The total size of this square block image is 79242 bytes (282 x 282 bytes). The ratio between black and white for this calibrated input image is known as 50%. The percentage of defect result for this GUI is reliable since it shows the same result as calibrated input image info.

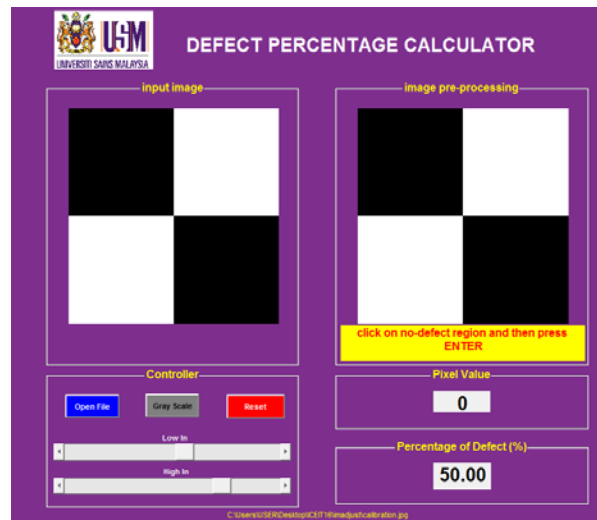


Figure-5. Calibration results.

b) Defect percentage result

There is two type of C-scan input image have been tested in this experiments which are drilled holes as an artificial defect and another one is delamination defect. Figure-6 shows a C-scan image of drilled holes FGCL panel. The total area of inspected FGCL panel is $16 \times 10^3 \text{ mm}^2$ (200 mm length x 80 mm width) while total drilled holes area is $2.29 \times 10^3 \text{ mm}^2$ for 9 holes of 6 mm diameter.



Base on ideal condition, the total ratio between drilled holes and FGCL panel area is 14.31 % while GUI shows 15.00 %. The different between ideal and actual result is 0.69 % which is still in acceptable range.

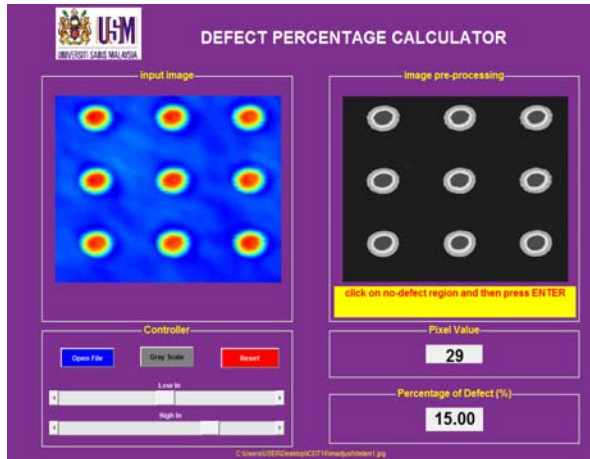


Figure-6. Drilled hole scanning result.

The following experiment is using the C-scan image of FGCL delamination defect. Since calibration test and comparison test have been done in the previous section, this experiment has no comparison data deal with the ideal situation because it almost impossible to perform it. Base on Figure-7 below shows the delamination region is marked as red in colour. The defect percentage of defect calculated by using this GUI is 59.63 %.

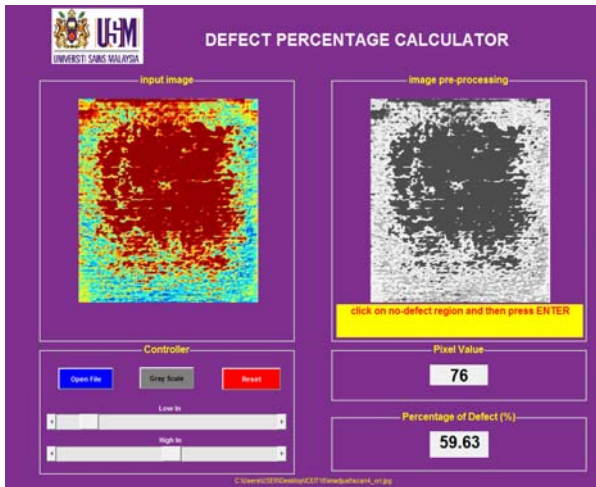


Figure-7. Delamination result.

c) Time study result

Figure-8 below shows C-scan input image for execution time study. Each test is repeating three times to ensure the reliability of execution time study. The defect image includes in this study was drilled holes as an artificial defect and 2 types of delamination defect.

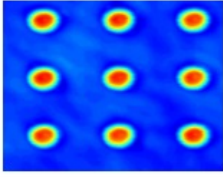
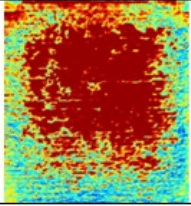
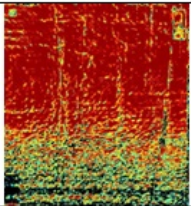
Defect Image	Type of defect
	Drilled holes
Test 1	
	
Test 2	Delamination 1
	
Test 3	Delamination 2

Figure-8. C-scan input image for time execution study.

Base on Table-1, the longest execution time is 9.21 sec for delamination 1 type of defect while the shortest execution time is 6.64 sec for drilled holes defect. Thru this result, it's clearly shows that complex image required more time to execute. However, the average execution time for all test series is below 10 sec which is affordable for inspection operation.

Table-1. Defect execution test.

No	Test	Execution time (sec)	
		Actual time (sec)	Average time (sec)
01	Test 1a	7.63	7.35
02	Test 1b	6.64	
03	Test 1c	7.79	
04	Test 2a	9.21	8.52
05	Test 2b	8.42	
06	Test 2c	7.94	
07	Test 3a	8.34	8.34
08	Test 3b	8.92	
09	Test 3c	7.78	

CONCLUSIONS

The developed GUI for defect percentage calculation of C-scan image is demonstrated using image processing approach. The reliability of defect percentage



result is proven according to calibration result where there are no different between binary box image information with defect percentage calculation result. Besides, the different between ideal and actual defect percentage calculation as low as 0.69 % is considered insignificant and negligible. Moreover, average execution time during defect percentage calculation did not affect overall inspection operation time since it consumes less than 10 sec. Hence, the functional of this developed GUI as a cross verification tool for quality engineer are suggested.

ACKNOWLEDGEMENTS

The author would like to thank the Ministry of Education (MOE) Malaysia for funding support through FRGS research grant (203/PMEKANIK/6071296), PRGS research grant (203/PAERO/6740041), USM Innovative Seed Fund (1001/PAERO/AUP100236) and awarding him UTHM Academic Staff Training Scheme.

REFERENCES

- [1] U.S Department of Labour. 1997. Working Safely with Video Display Terminals (OSHA 3092). 200 Constitution Avenue, N. W., Room N3101, Washington, DC 20210, United States. 99(1): pp. 1-33.
- [2] Liang Cheng and Gui Yun Tian. 2011. Surface Crack Detection for Carbon Fiber Reinforced Plastic (CFRP) Materials Using Pulsed Eddy Current Thermography. *IEEE Sensor Journal*. 11(12): pp. 3261–3268.
- [3] W. Y. Leong and Liu Wei. 2009. Structural Health Monitoring: Subsurface Defects Detection. 35th Annual Conference of IEEE Industrial Electronics 2009, (IECON 2009). 1(1): pp. 4326–4330.
- [4] W. Zheng, H. T. Wang, G. Y. Tian, G. X. Hu, X. M. Yang and M. Wan. 2014. Application of a non-contact laser ultrasonic imaging technique in surface defect detection. 2014 IEEE Far East Forum on Nondestructive Evaluation/Testing (FENDT). 1(1): pp. 30–33.
- [5] M. F. Mahmud, M. Z. Mohamed Pauzi and Elmi Abu Bakar. 2013. Flatbed Scanner Image and Single Ultrasonic Rangefinder Technique for Composite Laminates Defect Detection. *IEEE International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA 2013)*. 1(1): pp. 1–5.
- [6] M. F. Mahmud, Elmi Abu Bakar, A. R. Othman, A. R. Tamzi and CY Goh. 2015. Fiber Glass Composite Laminates (FGCL) Measurement using 3 Axis Pulse Echo Scanning Unit. *Jurnal Teknologi*. 76(1): pp. 147–155.
- [7] P. Irrera, I. Bloch and M. Delplanque. 2016. A Flexible patch based approach for combined denoising and contrast enhancement of digital X-ray images. *Medical Image Analysis*. 28(1): pp. 33–45.
- [8] T. D'Orazio, C. Guaragnella, M. Leo and P. Spagnolo. 2005. Defect detection in aircraft composites by using a neural approach in the analysis of thermographic images. *NDT&E International*. 38(1): pp. 665–673.
- [9] A.N. Sinclair, J. Fortin, B. Shakibi, F. Honarvar, M. Jastrzebski and M.D.C. Moles. 2010. Enhancement of ultrasonic images for sizing of defects by time-of-flight diffraction. *INDT&E International*. 43(1): pp. 258–264.