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Corrosion Assessment using Advanced Ultrasonic Measurement Technique

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Abstract. This paper describes the remaining wall thickness assessment using Ultrasonic Testing Phased Array (UTPA) technique. A steel plate of thickness 15 mm consists of machined simulated corrosion with various thicknesses, depths, shapes, and sizes were used in this work. Manual corrosion scanner is attached with GE Phased Array (PA) thirty-two elements (transmitter and receiver) Dual Matrix probe of 5 MHz with 1.5 mm pitch is used. The scanner then applied firmly on the plate to execute the inspection. From the result, the relevant indications from the A, B and C-Scans display are collected and analysed. The outcome of the study revealed that UTPA technique is capable to collect a high density of measuring point of thickness compared to the conventional UT technique such as Ultrasonic Testing Thickness Gauge (UTTG).

1. Introduction

Corrosion assessment is essential to estimate the service life of the pipeline, tank, boiler, pressure vessels etc. by assessing the extent of damage due to erosion or corrosion. The reduction in wall thickness of engineering structure will cause catastrophic asset failures and forced shutdown in plant. Conventional ultrasonic testing such as UTTG is extensively used to measure the remaining thickness or defect sizing of engineering structure. However, the current practice facing several limitations such as time consumption, low probability of detection (POD) and dependent on operator experiences [1].

Alternatively, the limitations of conventional UT method can be resolved by advanced UT technique. Advanced UTPA is a multi-element of small crystals housed in a single unit. The phased array beam can be steered and shaped electronically. For example, each element can be pulsed individually and varying by the time pulses along the row of elements. Desired angle and focus can be achieved by implying the constructive interference principle of the individual waves [2].

The current conventional UT crystal probe using in conventional UT has limited movement and angle of beam divergence produce high probability to miss defects whereas UTPA can optimizing the POD of defects due to sweeping the propagation of waves as shown in Figure 1.



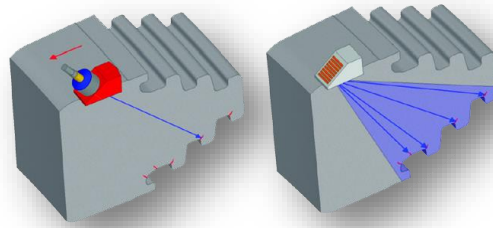


Figure 1. Comparison between capability of conventional UT and UTPA.

2. Results and discussion

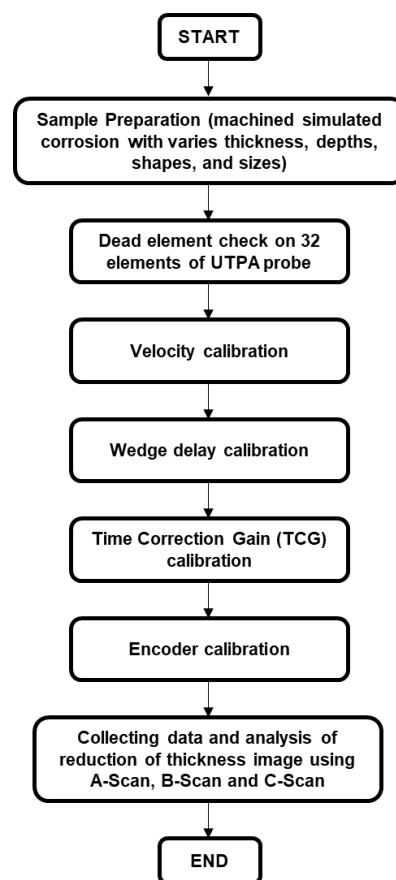


Figure 2. The flow chart of corrosion assessment using UTPA technique

The flow chart as shown in Figure 2 shows the study begin with sample preparation using machined simulated corrosion sample with various thicknesses, depths, shapes of corrosions and sizes as shown in Figure 3 and Table 1, 2 and 3 respectively below.

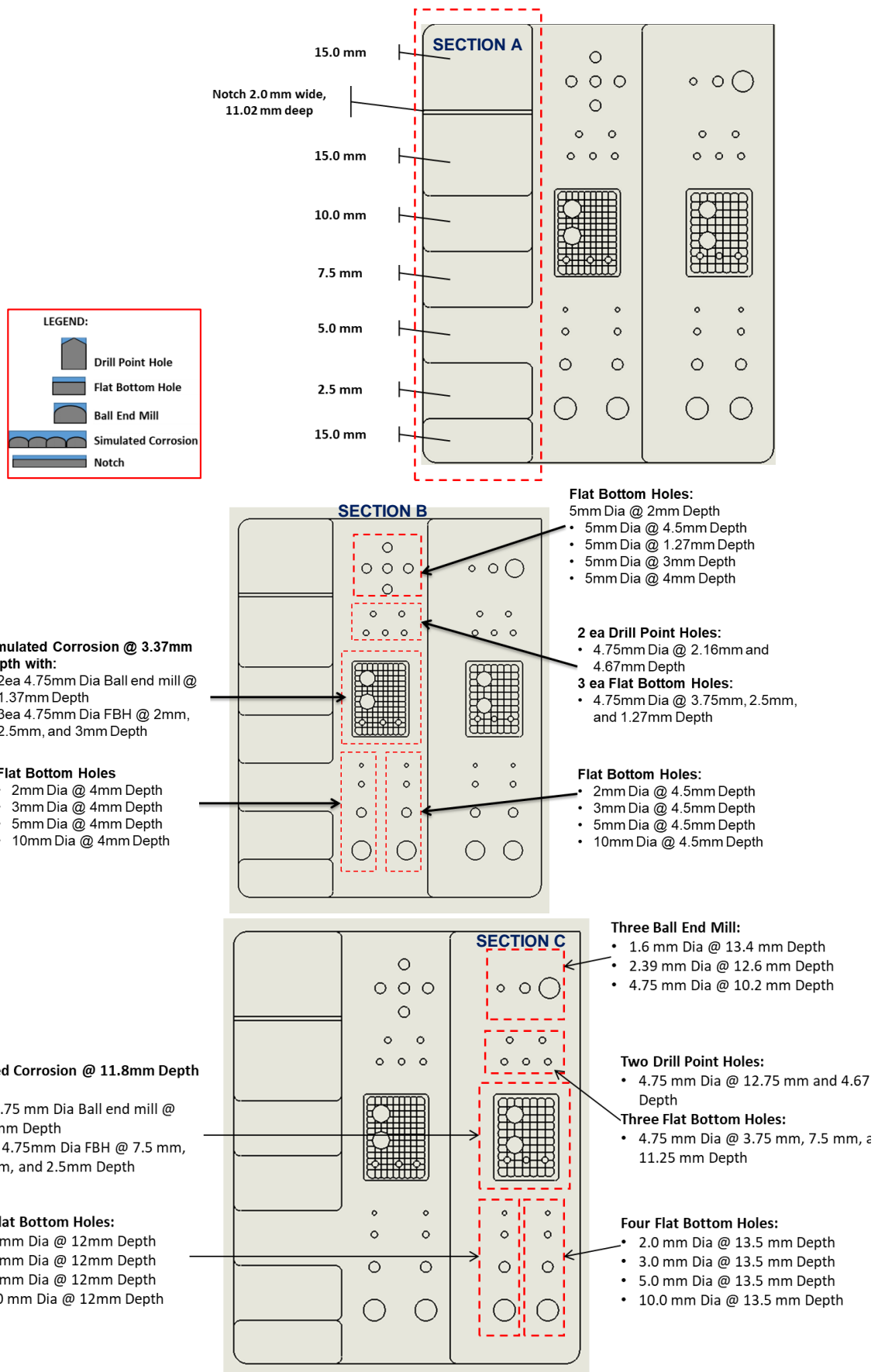


Figure 3. Specific information on machined simulated corrosion divided with section A, B and C.**Table 1.** Varies thickness of fabricated simulated corrosion, Section A

Section A (all unit in mm)	
Thickness 1	15.0
Thickness 2	2.5
Thickness 3	5.0
Thickness 4	7.5
Thickness 5	10.0
Thickness 6	15.0
Notch, 2.0 mm wide	
Thickness 7	11.02

Table 2. Varies thickness of fabricated simulated corrosion, Section B

Section B (all unit in mm)	
Five flat bottom holes with 5.0 mm diameter	
Depth 1	2.0
Depth 2	4.5
Depth 3	1.27
Depth 4	3.0
Depth 5	4.0
Two drill point holes with 4.75 mm diameter	
Depth 6	2.16
Depth 7	4.67
Three flat bottom holes with 4.75 mm diameter	
Depth 8	3.75
Depth 9	2.5
Depth 10	1.27
Simulated corrosion with 3.37 mm depth	
Two ball end mill with 4.75 mm diameter	
Depth 11	1.37
Depth 12	1.37
Three flat bottom holes with 4.75 mm diameter	
Depth 13	2.0
Depth 14	2.5
Depth 15	3.0
Four flat bottom holes with deferent diameters	
Diameter	Depth
2.0	4.0
3.0	
5.0	
10.0	
Four flat bottom holes with deferent diameters	
Diameter	Depth
2.0	4.75
3.0	
5.0	
10.0	

Table 3. Varies thickness of fabricated simulated corrosion, Section C

Section C (all unit in mm)	
Three ball end mill with different diameter and depth	
Diameter	Depth
1.6	13.4
2.39	12.6
4.75	10.2
Two drill point holes with 4.75 mm diameter	
Depth 1	12.75
Depth 2	4.67
Three flat bottom holes with 4.75 mm diameter	
Depth 3	3.75
Depth 4	7.5
Depth 5	11.25
Simulated corrosion with 11.8 mm depth	
Two ball end mill with 4.75 mm diameter	
Depth 6	10.3
Depth 7	10.3
Three flat bottom holes with 4.75 mm diameter	
Depth 8	7.5
Depth 9	5.0
Depth 10	2.5
Four flat bottom holes with deferent diameters	
Diameter	Depth
2.0	
3.0	
5.0	12.0
10.0	
Four flat bottom holes with deferent diameters	
Diameter	Depth
2.0	
3.0	
5.0	13.5
10.0	

The testing was carried out using MENTOR UT and the apps or software was developed using MENTOR CRREAT. The dead element check was performed using GE's Phased Array (PA) Dual Multi (DM) probe of 5 MHz with 1.5 mm pitch to ensure all the thirty-two elements (transmitter and receiver) within the probe is in good condition. The velocity of calibration block was determined by attaching the probe firmly on two different thickness of step-block, which is 5.0 mm and 15.0 mm to acquire the velocity (5960 m/s) of carbon steel in the system. The determination of delay of sound propagation between the probe and the exit point of the focal law in the wedge by applying the probe firmly at 15.0 mm thickness of step-block. Time Correction Gain (TCG) calibration was calibrated and recorded with on thickness 2.5 mm, 5.0 mm, 7.5 mm, 10.0 mm, and 15.0 mm. This a method is to compensating for a reduction in signal amplitude with increasing range from thickness or reflectors of equal area. This is achieved by increasing the system gain with time so that the signals appear of equal amplitude at 80% Full-Screen-Height (FSH). The encoder for x and y-axis on scanner need to be calibrated to ensure the distance recorded in the system is within the acceptance tolerance. Lastly, data of remaining thickness were collected and analysed using A, B and C-scans display. All the methodology are shown in Figure 4.

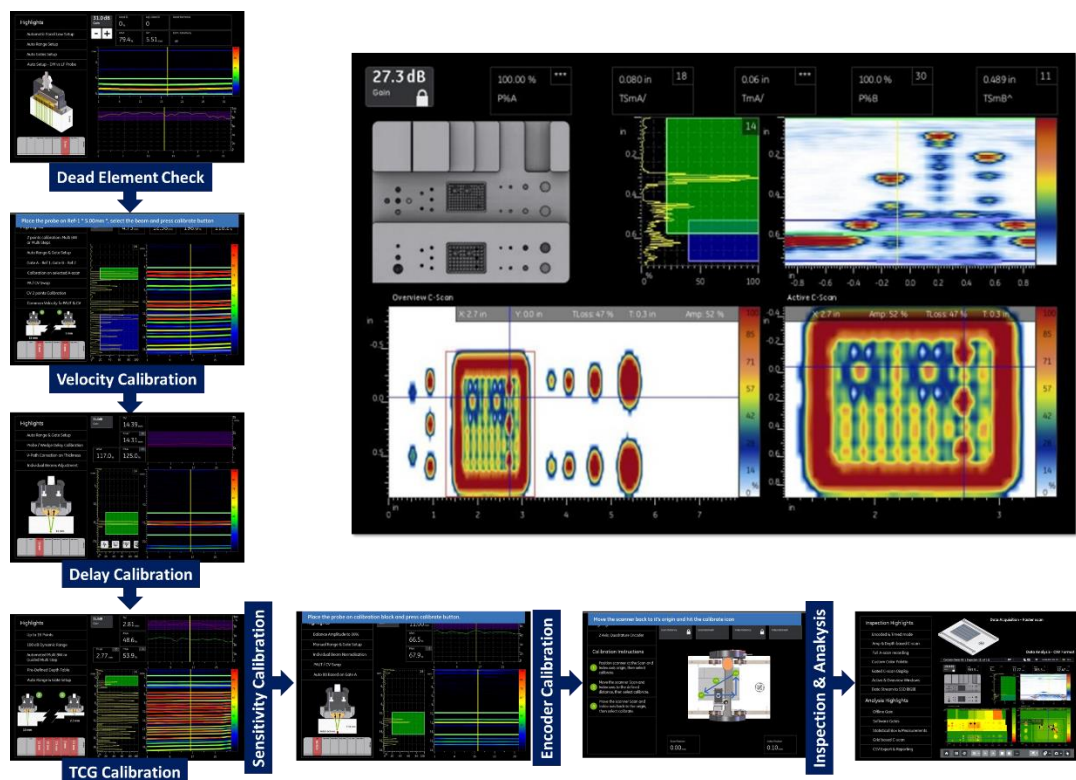


Figure 4. Procedure of UTPA calibration, inspection and remaining thickness analysis

The projected C-scan image or corrosion mapping from the UTPA is converted to CSV format as shown in Figure. 5. The result revealed a high-density of measurement point given of grid size of 1 mm \times 1 mm using UTPA comparing to single point assessment capability using UTTG. Detection of true T-min generated by corrosion mapping is possible and applicable to determine and calculate the remaining life assessment of engineering structure.

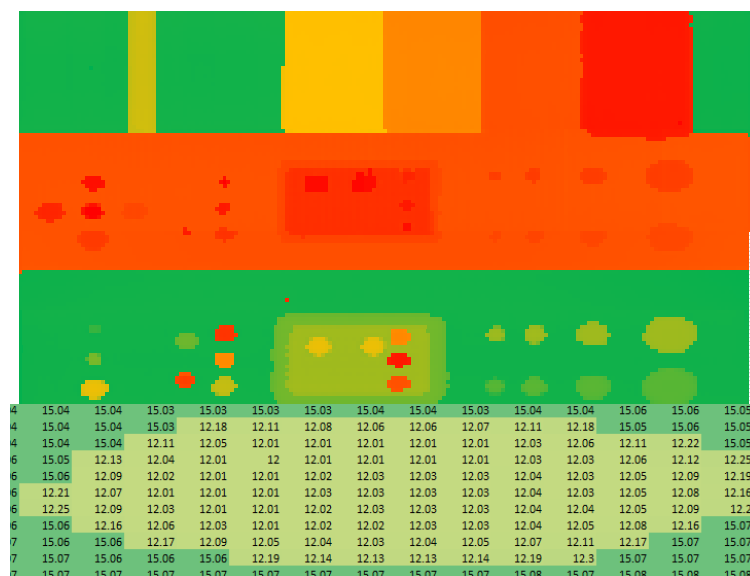


Figure 5. Converted C-scan display into CSV format

Projection of 3D image as shown in Figure. 6 was used to enhance the corrosion mapping from the C-scan display to analyse the profile and condition of internal corrosion of tested product. The result also reveal the minimum thickness of the sample is 1.27 mm.

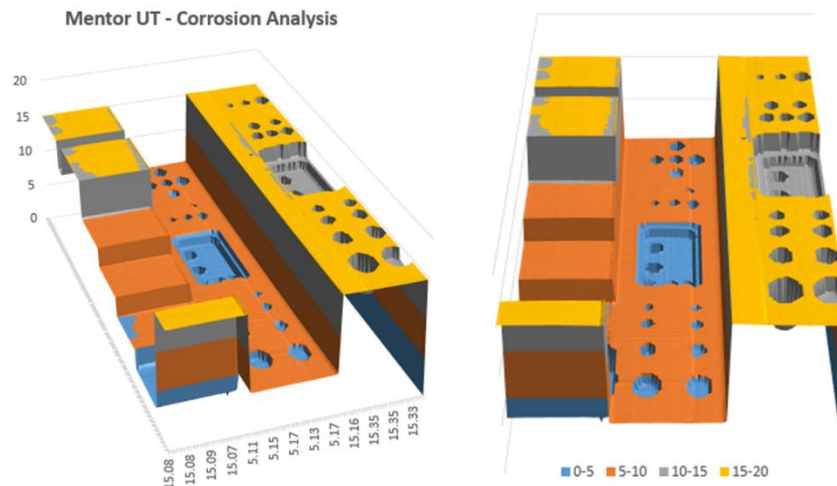


Figure 6. Projection of 3D images to identify the corrosion profile and thickness.

3. Conclusion

UTPA is an advanced technique to improve the POD of defect to avoid catastrophic disaster due to erosion and corrosion take places within the engineering product. Projected multiple displays such as A, B, and C-scans improves the detecting, locating and characterizing of defects which is essential for remaining life assessment of engineering product.

Acknowledgments

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