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Multi Display Scan in Detecting Weld Discontinuity of Thick Carbon Steel Plate using Ultrasonic Testing Phased Array (UTPA) with Comparison to Conventional Ultrasonic Testing (UT)

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ABSTRACT

Non-destructive testing (NDT) is a method of testing and analysis that relies on the application of physical principles to determine the integrity of materials without causing damage. The existence of weld discontinuity can affect the service ability of the structures. Ultrasonic testing Phases Array (UTPA) is advanced ultrasonic testing technology widely practiced in many industries. The multiple ultrasonic elements and electronic time delay will create constructive and destructive interference and steering capability, which could improve detectability compared to a single element of conventional UT. The multi displays presented in A-Scan, S-scan, B-Scan, and C-Scan of UTPA equipment capable of locating, inspecting, and characterise defects within the welded component. Two carbon steel plates with thickness 18 mm and 24 mm were prepared and cut to V-shape configuration and welded using shielded metal arc welding (SMAW) process, labelled as NDE-8826 and NDE-8827 respectively. Both samples were induced with artificial defects of the weld. 16 elements of phased array probe with 0.5 mm pitch and 4 MHz were carried out for this study with encoded scanning to identify weld discontinuity plotted in different types of UT displays. Additional testing was performed using conventional ultrasonic testing (UT) using a 4 MHz probe to compare with the UTPA results and the *acceptability of each defect detections. The length and datum of toe crack, slag, and lack of inter run fusion detected by UTPA in NDE-8826 give the same value as the actual value. However, the localisation of the defect is slightly different at 1.0 mm for UT detection. While the detection value for slag gives the same values for UT and UTPA, which also the same as the actual values. The detection of lack of penetration and lack of fusion in sample NDE-8827 was precisely can be detected by UT and UTPA; hence their datum value has slightly different in the centerline crack and porosity at 2.0 mm for UT measurement, and as for UTPA, it was found that the porosity at 3.0 mm which higher value compared to the actual value, 250 mm. From the result, a relevant indication from the UTPA and conventional UT collected it was found that the UTPA technique is capable of improving the Probability of Detection (POD) of defects compared to the conventional UT.*

Keywords: *multi displays scan, non-destructive testing, ultrasonic testing phased array, UTPA, carbon steel plate*

INTRODUCTION

Non-destructive testing (NDT) is a method of testing and analysis that relies on the application of physical principles to determine the integrity of materials without causing damage to the initial component [1]. The existence of discontinuity or flaws such as lack of penetration, lack of fusion, cracks, etc. can affect the service ability of the engineering component. Misinterpretation and evaluation by the operator can cause a reduction of material strength or catastrophic asset failure in the engineering component and are forced to shut down in the plant. Nowadays, Ultrasonic testing Phases Array (UTPA) is the NDT method most widely practiced in many industries such as oil and gas, power generation, aviation, rail, marine industry, including medical imaging. It is a primary method in generating and receiving ultrasound improved by ultrasonic testing [2]. This technique was already accepted by American Society for Mechanical Engineers (ASME) Section V and American Petroleum Institute (API) RP2X that UTPA capable of improving the Probability of Detection (POD) for in-service inspection and for Structural Health Monitoring (SHM) of operating plant or engineering structure [3]. The transducer of UTPA consist of multiple elements; each of the single elements will able to emitting and receiving ultrasonic waves. The pulsed time of the elements is being controlled and can be focused electronically [4]. The multiple ultrasonic elements and electronic time delay will create constructive and destructive interference, which could a misinterpretation and evaluation of data be happened. Figure 1 shows an example of the A-scan display from a conventional UT machine, which indicates the discontinuity depth and amplitude of signal only, which will lead to the incompetency of the machine to detect the failure. Besides, it will increase the cost, time consumes, and reduce the productivity of detection efficiency [5].

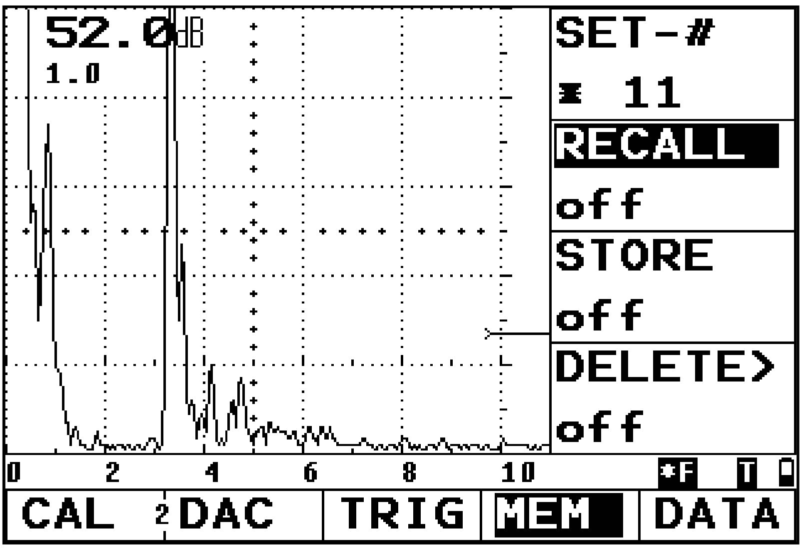


Figure 1: Example of A-Scan Display in Conventional UT Machine

By the way, UTPA is an advanced ultrasonic technique that utilises multiple small elements that pulsed individually with computer-calculated timing, as shown in Figure 2, working principle of UTPA instrument. This technique is capable of inspecting complex geometries that are difficult to access using conventional UT. It is capable of inspecting almost all solid material where traditional UT methods have been practiced and are often used for weld inspections and crack detection [3, 6].

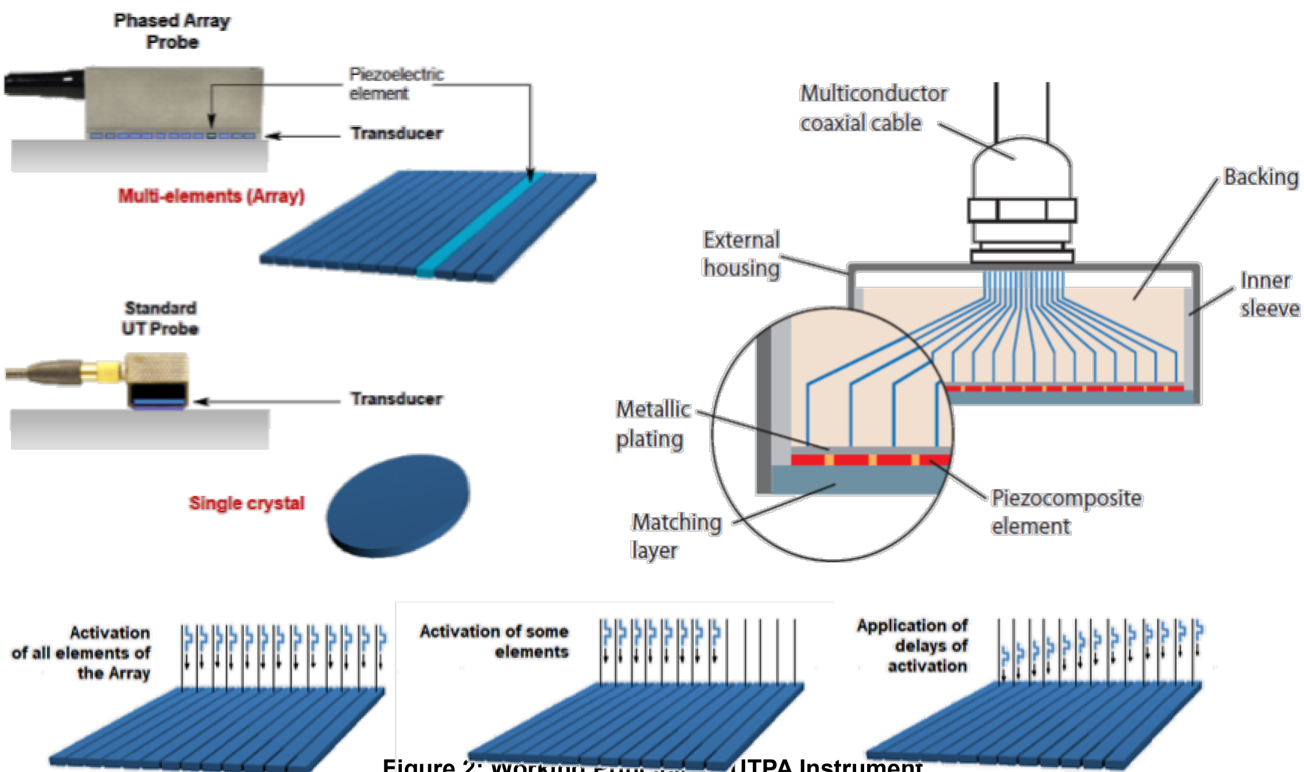


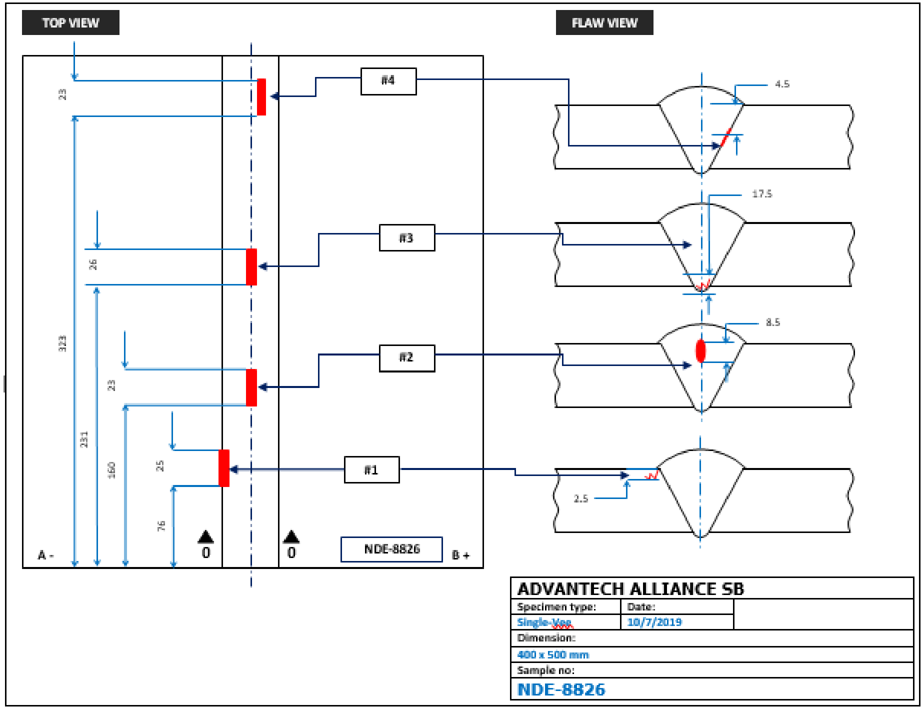
Figure 2: Working Principle of UTPA Instrument

The welding process is also an essential part of building a structure, especially in the metal structure. Shielded metal arc welding (SMAW), also known as manual metal arc welding (MMA or MMAW) is a flux shielded arc welding, manually arc welding process that uses a consumable electrode covered with a flux to lay the weld. Due to the versatility of the process and the simplicity of its equipment and operation, SMAW is one of the world's first and most popular welding processes. It dominates other welding processes in the maintenance and repairing industry. However, it needs an expert operator to weld a V-shape configuration of metal.

EXPERIMENTAL

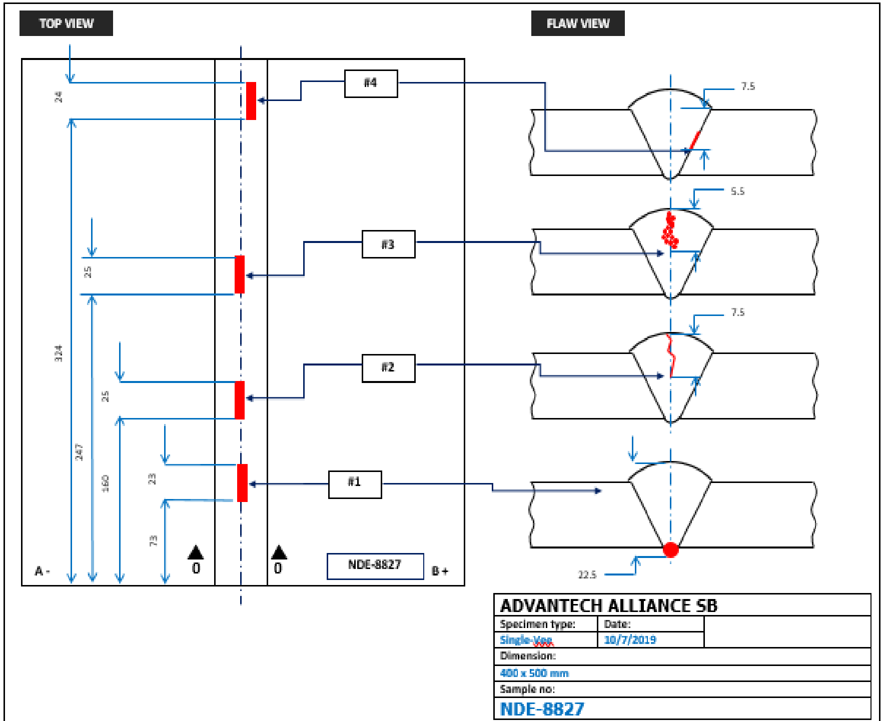
Two carbon steel plates with thickness 18 mm and 24 mm were prepared and cut to V-shape configuration and welded using shielded metal arc welding (SMAW) process and labeled as NDE-8826 and NDE-8827 respectively. Both samples were induced with internal weld discontinuities such as lack of penetration (LOP), lack of fusion (LOF), lack of inter run fusion (LOIRF), slag, and crack. The drawing and the flaw specification of the samples, as shown in Figure 3and Figure 4.

The objective of this study is to verify the accuracy of locating, detecting, characterising, and sizing using UTPA compared to conventional UT. The scanning planning development used ES Beam Tools software as a platform to determine the index offset and the ultrasonic beam coverage of weld volume and heat affected zone, as shown in Figure 5.0. The GE-Phased Array (PA) with 16 elements of phased array probe, 0.5 mm pitch and 4 MHz were carried out for this study with encoded scanning technique. Hence, conventional UT with probe angle of 45^{o}, 60^{o}, and 70^{o} was utilised. Results from conventional UT and UTPA will be compared.



No	Flaw type	Length (mm)	Depth(mm)	Datum (mm)
1	Toe crack	25	2.5	76
2	Slag	23	8.5	160
3	Root crack	26	17.5	231
4	Lack of inter run fusion	23	4.5	323

Figure 3: Specific Information on Welded Samples NDE-8826 with a Thickness of 18 mm



No	Flaw type	Length (mm)	Depth (mm)	Datum (mm)
1	Lack of penetration	23	22.5	73
2	Centre line crack	25	7.5	160
3	Porosity	25	5.5	247
4	Lack of fusion	24	7.5	324

Figure 4: Specific Information on Welded Samples NDE-8827 with a Thickness of 24 mm

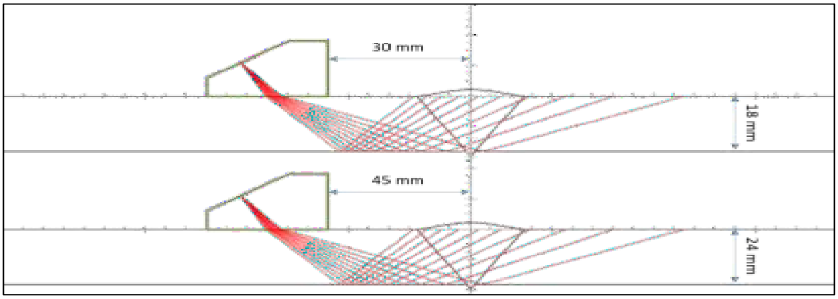


Figure 5: Scan Plan Development for Weld Inspection

RESULTS AND DISCUSSION

Figure 6 and 7 shows the spectra of localising and indication scans of the internal weld discontinuity for booth welded sample NDE-8826 and NDE-8827, respectively.

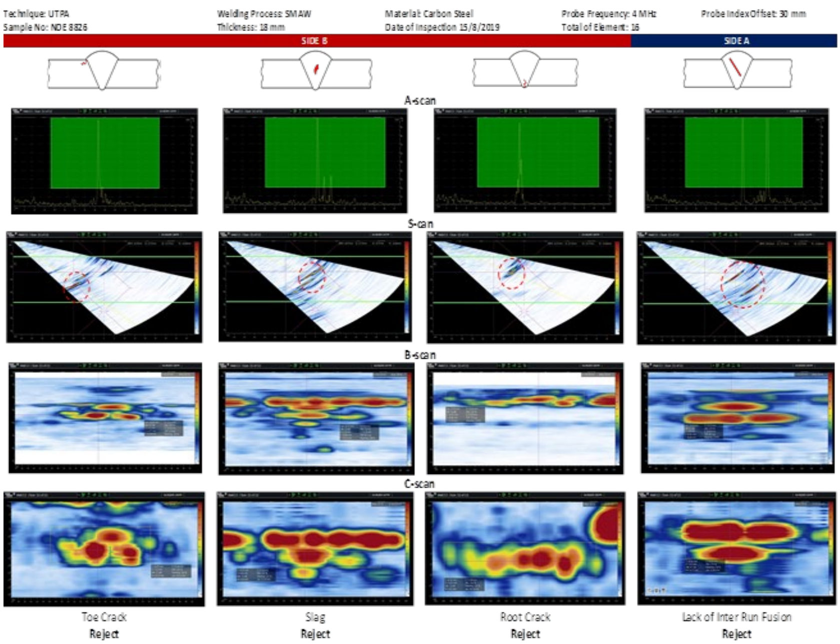


Figure 6: A-Scan, B-Scan, Azimuthal S-Scan and C-Scan of Sample NDE-8826

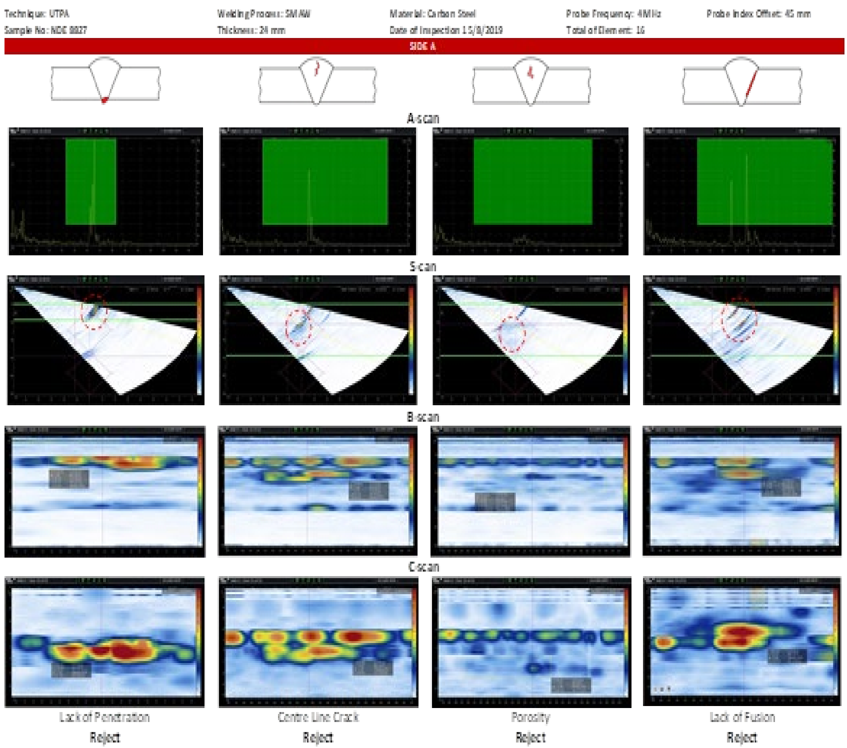


Figure 7: A-Scan, B-Scan, Azimuthal S-Can And C-Scan of Sample NDE-8827

The localisation of the internal weld discontinuity was measured by length, depth, height, and datum. The evaluation data of each defect in both welded samples for using UTPA and conventional UT was shown in Table 1.

Table 1: Data Evaluation of Welds Defect using UTPA with Comparison to Conventional UT

NDE 8826												
Types of Defect	**Toe Crack**			**Slag**			**Root Crack**			**Lack of Inter Run Fusion**		
	Actual	**UT**	**UTPA**	**Actual**	**UT**	**UTPA**	**Actual**	**UT**	**UTPA**	**Actual**	**UT**	**UTPA**
Length (mm)	25	24	25	23	22	23	26	23	25	23	23	23
Depth (mm)	2.5	2	2.4	8.5	8	8.4	17.5	17	17	4.5	4,2	4.4
Height mm)	x	x	3	x	x	3	x	x	3	x	x	33
Datum (mm)	76	74	76	160	160	160	231	230	231	323	323	323
NDE 8827												
Types of Defect	**Lack of Penetration**			**Centre Line Crack**			**Porosity**			**Lack of Fusion**		
	Actual	**UT**	**UTPA**	**Actual**	**UT**	**UTPA**	**Actual**	**UT**	**UTPA**	**Actual**	**UT**	**UTPA**
Length (mm)	23	23	23	25	23	25	25	22	24.5	24	24	24
Depth (mm)	22.5	22	22	7.5	7	7	5.5	5	5	7.5	7	7
Height (mm)	x	x	3	x	x	3	x	x	2.5	x	x	3
Datum(mm)	73	73	73	160	158	160	247	245	250	324	324	324

The length and datum of toe crack, slag, and lack of inter run fusion detected by UTPA in NDE- 8826 have the same value as the actual value. However, the localisation of the defect is slightly different at 1.0 mm for UT detection. At the same time, the detection value for slag gives the same values for UT and UTPA, which also the same as the actual values.

UT and UTPA precisely detected the detection of lack of penetration and lack of fusion in sample NDE-8827; however, their datum value has slightly different in center line crack and porosity at 2.0 mm for UT measurement. As for UTPA, it was found that the porosity measurement gives 3.0 mm higher value compared to actual value at 250 mm.

CONCLUSION

Results of relevant indication from the UTPA and conventional UT collected was found that the UTPA technique is capable of improving the Probability of Detection (POD) of defects compared to the conventional UT. Projected multiple displays such as A-scan, B-scan, S-scan, and C-scan helps the operator to improves the detecting, locating, and characterising and sizing of defects, which is essential in SHM of engineering component in the industry. Limitation from the A-scan of conventional UT could lead to misinterpretation of sizing due to the SNR effect [6]. UTPA accurately detected the locating, detecting, characterising and sizing of the internal weld discontinuities compared to UT.

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