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Flaw detection in low alloy steels butter welds using advanced technique for productivity improvement

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ABSTRACT

The fast changing economic conditions customer demand for high quality product, product variety and reduced lead–time etc. had a major impact on manufacturing industries to improve the quality performance rate. An analysis being performed using advanced technology Phased Array Ultrasonic Testing on fusion welded low alloy steels to extract flaws from nondestructive testing (NDT). Our goal is to extend the previous study and enable us to detect flaws with images successfully so that the usability of our technique is extended and verified in experiment. A number of defects are being observed in the welding process and can be differentiate very easily. Defects in welding may be found out in two methods, i.e. by Radiographic Tests and by Phased Array Ultrasonic Tests. This paper discusses the feasibility of advanced NDT technique and other related methods.

Keywords: *Low Alloy Steels, Phased Array Ultrasonic Testing, TOFD, NDT*

1. INTRODUCTION

Nondestructive Testing (NDT) refers to a group of analysis techniques to obtain necessary information from a material or a product without damaging its serviceability. Growing needs for those techniques in recent years , there are many available NDT methods such as, ultrasonic testing, Penetrant testing, eddy current testing, leak testing, acoustic emission testing, visual inspection, radiographic testing ,Phased Array UT etc according to the application areas and material types. However, the process of visual inspection often causes subjective decision and relies on the experience of the inspector thus the reliability of such test might be affected and often time-consuming and expensive.

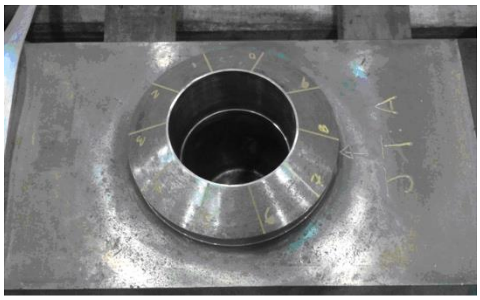
2. DEFINE SCOPE

Arrays using the phase interference resulting from timing of pulses to achieve beam steering or focusing called phased array. Advanced Ultrasonic technique used for flaw detection, sizing, and imaging. This describes the requirements for performing Phased Array Ultrasonic Inspection for quality assessments of pipe to pipe weld ment joints using shear waves. Semi automated examinations are also employing in this procedure. OLYMPUS OMNISCAN MX 2 with Frequency 5MHZ probe is used. There are five types of focusing associated with phased array inspection. Such as Depth Focusing, Sound Path Focusing, Projection Focusing, Focal Plane Focusing and Unfocused. In this context Depth focusing are used.

3. MEASURE

3.1 Calibration block and reference block

Calibrations block V_1 (Stainless Steel or Carbon steel) and reference block used for equipment calibration and standardization. In order to enable the position of defects to be permanently and accurately identified within the component cross section and along its length all locations shall be clearly marked on the component surface prior to examination and all measurements shall be in millimeters. The NDT personnel should specify specific datum reference point.



For the circumferential weld, the scanning datum will be at 0° positions of the pipe and scanning direction toward 360°. The position shall be referring to as per construction drawing. Scanning should be at a speed where the continuous data acquisition is achieved. Interpretation of inspection data shall be performing using TOMOVIEW version 2.9 software. Encoder resolution shall be 32.08pulses/mm.A Scan plan is used to identify the locations of beam path using ES Beam Tool.

Table 1: Beam Path Properties

1	Minimum Angle	40°
2	Maximum Angle	60°
3	Index offset	-20.0 mm(90°) & 20.0 mm(270°)
4	Propagation	Shear Wave
5	Start Element	1
6	Total Element	16
7	Angle Step	1
8	Frequency/Probe	5 MHZ
9	Wedge	AOD 4.5
10	Thickness	11.10mm

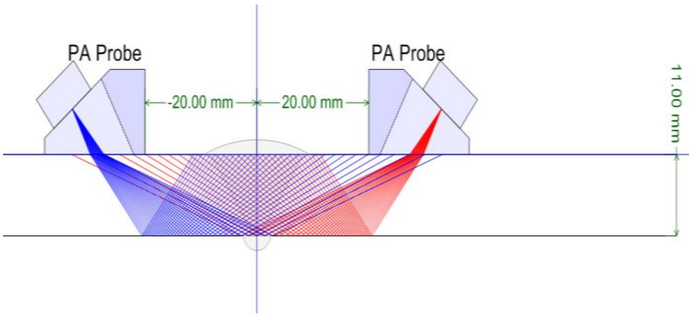
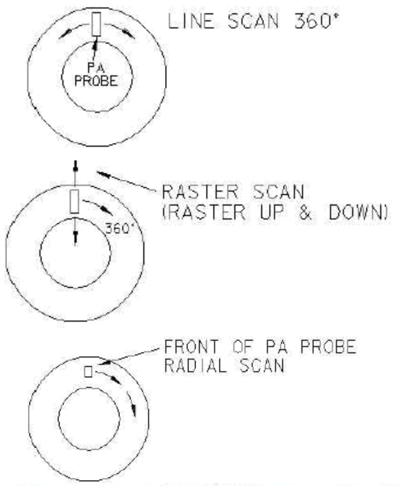
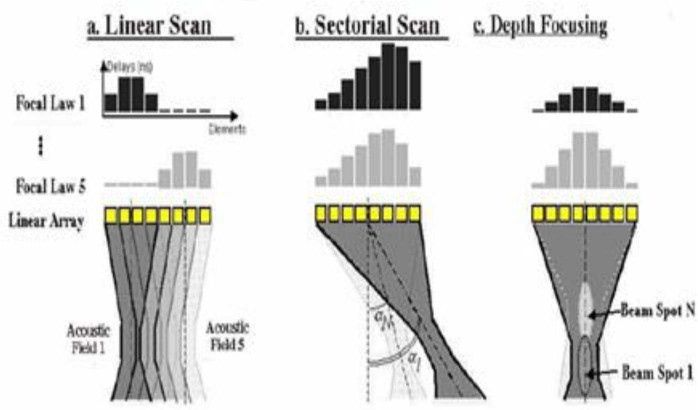


Fig. 1: Scan Plan





3.2 Focus Depth

The maximum distance that the beam can be focused is defined by the near field.

$$\lambda = V/F = 3240\,000/\,5\,000\,000 = 0.648$$

Aperture size (D)= Pitch size x Total element= 0.6 x 16 = 9.6mm

Finally, Near Field = $D^2/4\lambda = 9.6^2 / 4 \times 0.648 = 35.55$mm

3.3 Extracting the Defects

From following figure shows the active data view with 80% reference amplitude.

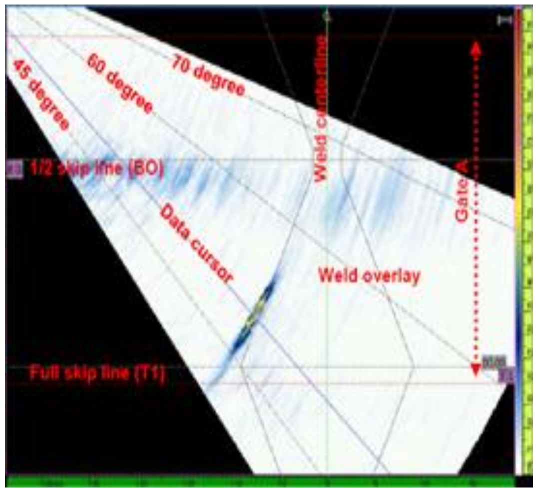


Fig. 2: Sectorial Scanning

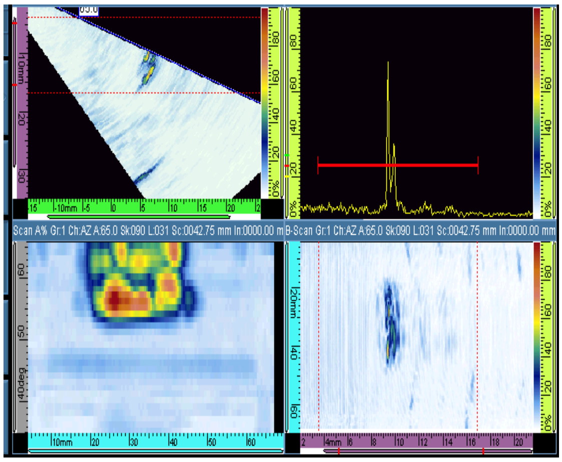


Fig. 3: Root Crack

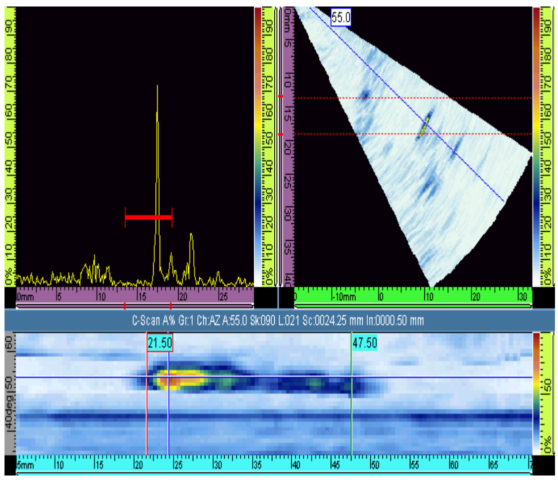


Fig. 4: Porosity

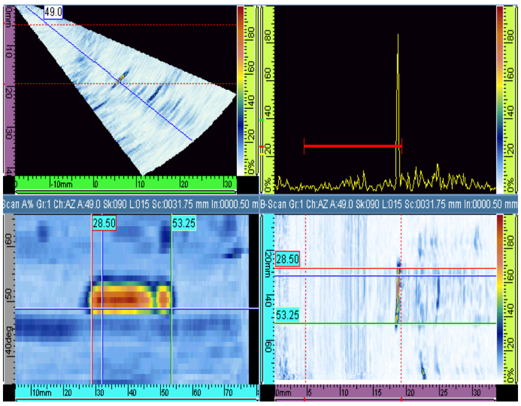


Fig 5: Inclusion

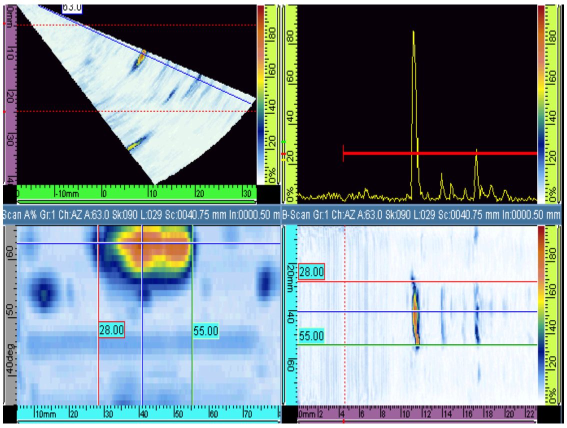


Fig. 6: Lack Of Root Fusion

4. EXPERIMENTS AND ANALYSIS

There is another way of verifying the effect of the proposed method. Following figure compares the Radio graphic Testing result of previous technique.

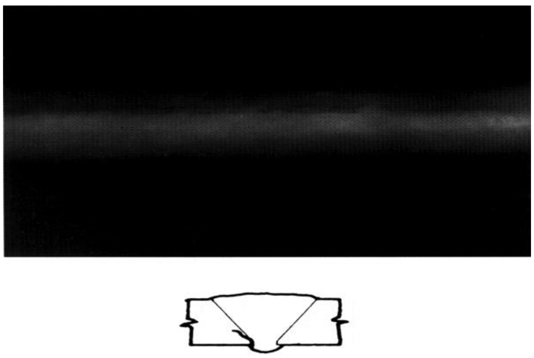


Fig. 7: Root Crack

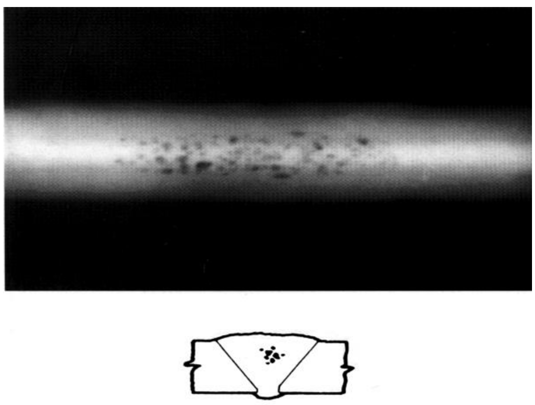


Fig. 8: POROSITY

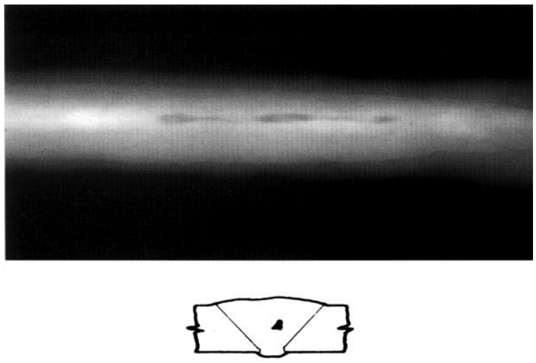


Fig. 9: Inclusion

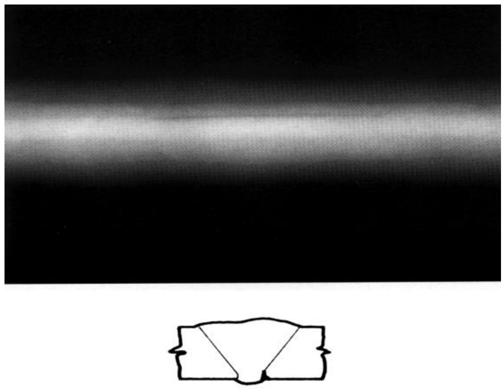


Fig. 10: LACK OF ROOT FUSION

As one can see from Radio graphic figures vulnerable for the input whose brightness distribution is skewed so the image is darker but the proposed method successfully overcomes the problem. Furthermore, the proposed method is successful to obtain defect area for all types.

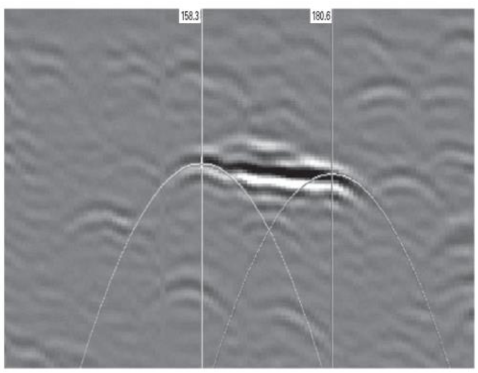
4.1 Discontinuity Verification

TOFD (Time of Flight Diffraction) technique for any discontinuity observed/found during scanning by phased array technique shall be verified by simultaneously as supplementary to confirm the discontinuity. This shall be used only for confirmation purpose for a specific discontinuity detected during PAUT inspection.

4.2 Measuring Flaw Length

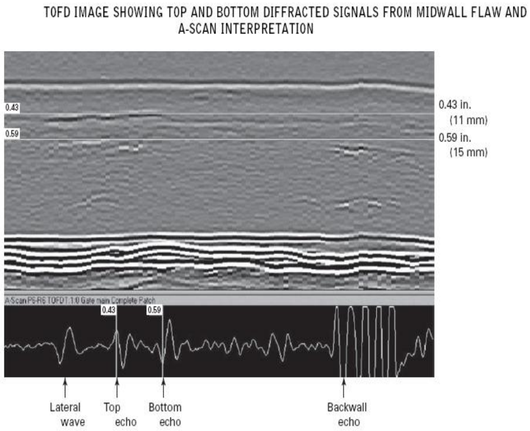
Flaw lengths parallel to the surface can be measured from the TOFD image by fitting hyperbolic cursors to the ends of the flaws.

TOFD IMAGE SHOWING HYPERBOLIC "TAILS" FROM THE ENDS OF A FLAW IMAGE USED TO MEASURE FLAW LENGTH



4.3 Measuring Flaw Height

Flaw height perpendicular to the surface can be measured from the TOFD image by fitting cursors on the top and bottom tip signals. The following are of depth measurements of weld flaws in a 1 in. (25 mm) thick plate. Second is midwall lack of fusion and third is a centerline crack. TOFD signals are not linear, so midwall flaws show in the upper third region of the image. It is possible to linearize the TOFD scans by computer software.



4.4 Flaw Evaluation And Acceptance Criteria

The location, amplitude and extent of all reflectors that produce a response greater than 20% of the reference level shall be investigated.

Acceptance criteria as per ASME B31.3 Process Piping Cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length. Other imperfections are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(a) 1⁄4 in. (6 mm) for *t* up to 3⁄4 in. (19 mm)
(b) 1⁄3*t* for *t* from 3⁄4 in. (19 mm) to 21⁄4 in. (57 mm)
(c) 3⁄4 in. (19 mm) for *t* over 21⁄4 in. (57 mm)
where '*t'* is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, 't' is the thinner of these two thicknesses.

Based on the type of welds and Imperfections Acceptance criteria given in following table

Table 2: Acceptance Criteria for Welds

Acceptance Criteria for Welds

Type of Imperfection	Methods: Visual	Methods: 100% Radiography	Type of Weld: Girth Groove	Type of Weld: Longitudinal Groove	Type of Weld: Fillet	Type of Weld: Branch Connection
	Types of Welds, and for Required Examination Methods					
Crack	X	X	A	A	A	A
Lack of fusion	X	X	A	A	A	A
Incomplete penetration	X	X	A	A	A	A
Internal porosity	...	X	B	B	NA	B
Slag inclusion or elongated indication	...	X	C	C	NA	C
Undercutting	X	X	A	A	A	A
Surface porosity or exposed slag inclusion	X	...	A	A	A	A
Concave root surface (suck-up)	X	X	D	D	NA	D
Surface finish	X	...	E	E	E	E
Reinforcement or internal protrusion	X	...	F	F	F	F

GENERAL NOTE: X = required examination; NA = not applicable; ... = not required.

The standard criterion is given for each type of defects and acceptable value limits.

Table 2: Standard criteria for acceptable value limits

Criterion: Symbol	Criterion: Measure	Acceptable Value Limits	
A	Extent of imperfection	Zero (no evident imperfection)	
B	Size and distribution of internal porosity	Section VIII, Division 1, Appendix 4	
C	Slag inclusion or elongated indication		
	Individual length	$\leq \overline{T}_w/4$ and ≤ 4 mm ($^5/_{32}$ in.)	
	Individual width	$\leq \overline{T}_w/4$ and ≤ 2.5 mm ($^3/_{32}$ in.)	
	Cumulative length	$\leq \overline{T}_w$ in any 12 $\overline{T}_w$ weld length	
D	Depth of surface concavity	Wall Thickness, $\overline{T}_w$, mm (in.)	Depth of Surface Concavity, mm (in.)
		≤ 13 ($^1/_2$)	≤ 1.5 ($^1/_{16}$)
		> 13 ($^1/_2$) and ≤ 51 (2)	≤ 3 ($^1/_8$)
		> 51 (2)	≤ 4 ($^5/_{32}$)
		and total joint thickness including weld reinforcement $\geq \overline{T}_w$	
E	Surface roughness	≤ 12.5 μm (500 μin.) R_a (see ASME B46.1 for definition of roughness average, R_a)	
F	Height of reinforcement or internal protrusion in any plane through the weld shall be within the limits of the applicable height value in the tabulation at the right. Weld metal shall be fused with and merge smoothly into the component surfaces.	Wall Thickness, $\overline{T}_w$, mm (in.)	External Weld Reinforcement or Internal Weld Protrusion, mm (in.)
		≤ 13 ($^1/_2$)	≤ 1.5 ($^1/_{16}$)
		> 13 ($^1/_2$) and ≤ 51 (2)	≤ 3 ($^1/_8$)
		> 51 (2)	≤ 4 ($^5/_{32}$)

5. IMPROVE

Practically, the improvement must investigate necessary knowledge based on brainstorming to create the best solution. Main project implementations by expected benefit are:

Tangible Benefits

• Production efficiency increase by section/day.

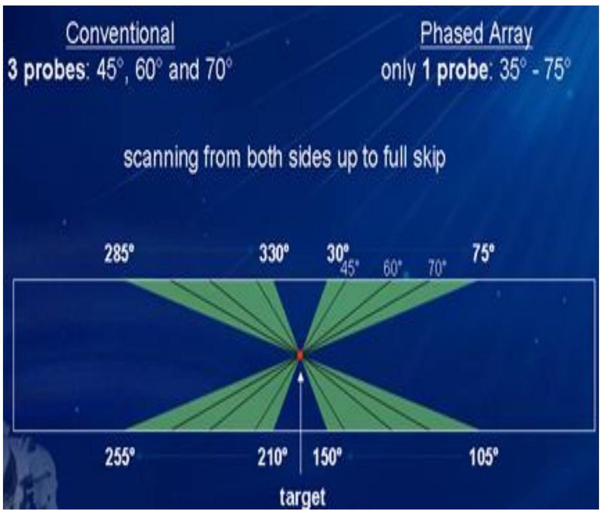
Intangible Benefits

• Customer satisfaction.
• Availability improvement
• Possibility of failure reduced.

Benefits

Electronic scanning (raster) possible without moving probe. Simultaneous inspection with multitude of angles using one probe.
Can better inspect complex geometries or limited access areas. Can replace costly and hazardous radiography applications. Improve the Probability of Detection ,minimize false calls Minimize re verification of discontinuity costs Make it less operator intensive, limited Access inspection
Defect sizing ,Wider inspection area Faster results ,Provide verification of complete inspection

The comparison is made between Conventional and Phased Array technique.Conventional **3 probes**: 45°, 60° and 70° Phased Array **1 probe**: 35° - 75° scanning from both sides up to full skip



Impact on Business Goals

- Electronically Controlled and selectable beam Angles , Focus , Size

- Simultaneous inspection with multiple beams from a single location
- Full color Real time Sector- or Linear- displays with selectable A-Scan
- Fully functional Conventional flaw detector with multiple gates, trigonometric functions, setup and A-Scan memory

6. RESULTS AND DISCUSSION

a) Improvement in productivity – Time saved in reworking is time utilized for effective production of products and services; which is added to the productivity. Higher productivity lead to more production, lower cost of production and better quality and competitiveness in the marketplace
b) Time impact – Considerable time is saved by eliminating non-production (idle) time and by not producing the defective product and by eliminating rework/reprocessing.
c) Cost/benefit impact –A company that reduces its cost of doing business, meets the expectations of its customers more effectively and efficiently, inspires its employees, fosters a culture of dedication and pride, and earns a reputation for quality.
d) Customer satisfaction impact – Customer satisfaction is achieved by providing the products and service of right quality, in the right quantity at the right time, right place and right cost, fulfilling customers'(external as well as internal) stated and implied needs.

7. CONCLUSIONS

Only only those parts of the defect that reflect sound back to the probe produce the image of a reflector. All parts of the defect, which do not reflect parts of the sound beam, will not produce an echo, and therefore give no contribution to the image. In addition the echo shape in the direction of the sound propagation influences the resulting image of the defect. Regretfully, we did not have sufficient NDT images for this study thus this success in experiment might not viewed as a general method to handle PAUT type NDT images but we would like to assert that this method shows sufficient feasibility for it. We would like to extend our efforts to handle more various types of defect extraction from NDT images.

Scope for further improvement

The Six Sigma methodology can improve & new performance standards can be realized. I would like to integrate in this practice effectively in the community of company employees for maintaining & further improving the improved performances.

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