**Phased Array UT application on in service Heavy wall Reactors**

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**ABSTRACT**

Phased Array UT application for high thick Reactors can be effectively used to find out corrosion, Hydrogen induced damages, Step wise cracking, Stress corrosion cracking or Fatigue cracking. Phased Array UT especially is good tool to size the indications and to monitor the same frequently. This abstracts is presented on specific application of stress corrosion cracking detection, sizing by using Phased Array UT and comparing the results between PA and TOFD on heavy wall Reactor welds.

**INTRODUCTION**

Stress Corrosion cracking is a type of crack expands in corrosion environments. It can be a lead thread to equipments as it may cause sudden failures under tensile stress. It is more common in alloy than pure metal. There are many challenges always exists to find out stress corrosion cracking especially in heavy wall reactors by using conventional NDT techniques and by TOFD due to complex orientation of crack. However this has been overcome in past few years by using advanced ultrasonic techniques such as Phased Array UT. In our sample, we used Phased Array UT and TOFD to detect and size the crack indications on Cr Mo reactors with thickness over 100 mm and analysis the same for effective technique and concluded PA UT more effective tool than TOFD.

**THE TOOLS USED**

Phased Array UT/TOFD equipment with 16:128 modules is used along with 64 elements probes, frequency 2.25 Mhz. Low frequencies selected due to the penetration requirements considering high thickness. Manuel encoder selected for encoding the length dimension of cracks along with probe instead of scanners due to the crack complex orientation and for sizing.

**CALIBRATION**

Calibration block selected from the same material and the same thickens as per code requirements such as ASME Sec V. A study has been performed to find out the effective calibration block of Side Drill Holes (SDH) and notches of different sizes. By using various reference of those, a trial out performed to detect 1 mm size artificial notch on the same thickness and same material. Finally it has been concluded the below simple calibration block as in figure 1 is more effectively suited for our application.
The calibration has been performed by using 6 mm SDH as in above figure. Once the calibration completed, gain has been raised up to 10 dB to theoretically compensate 1 mm SDH (approximation). Further 6 dB increased for scanning dB purpose. With the above set up, 1 mm notch has been successfully detected.

**TYPE OF SCANNING/TECHNIQUE**

The scanning has been performed for PA as per the below details with all combinations:
1. Non parallel scan perpendicular to the weld
2. Parallel scan on the weld itself
3. Parallel scan across the weld
4. Angulations scan to the weld for better crack orientation manually without encoder

Details of scans listed out in the below figure 2:

![Figure 2](image-url)

However for TOFD simple non-parallel and parallel scans are performed.
DETECTION AND SIZING

In general as the Stress Corrosion Cracking starts from inside wall, a set of beams created to focus especially the inside wall. Another set of beams created to cover the whole volume of weld. There is no further set of beam were necessary to cover the fusion surface or other indications. However depends on orientation of cracks, further focus scans with high angular resolution may be necessary to better sizing.

TOFD images:

A typical TOFD image of crack indications specified in below figure 3 by using 2 M Hz TOFD probe.

![FIGURE 3](image)

As we can witness from this image, crack indications are missed out totally and it could be due to size and tightness of indication. That is 2 MHz probe sensitivity may not sufficient to detect such crack indications.

A typical TOFD image of crack indications specified in below figure 4 by using 5M Hz TOFD probe.

![FIGURE 4](image)
As we can witness in above image, crack indications are visible hardly despite of lot of noises due to high frequency as well as material.

From both above TOFD images, it is not viable either to size and plot the orientation of crack indication.

**PA images:**

The orientation of cracks has been plotted by using normal scan without encoder by either parallel scan, angular scan or non-parallel scan as necessary. The sizing of cracks has been specially performed by Crack Tip Diffraction methods. dB drop method may used to measure the length and height of crack as supplement to Crack Tip Diffraction. A typical Phased Array indication is specified as in below figure 4.

![PA images](image_url)

**FIGURE 5**

From the above PA images, it is clearly identified both longitudinal and transverse cracks. Also we can plot the orientation and sizing of the indications by analyzing different scan images such as A, B, C, S & E scans.
EVALUATION

The cracks have been evaluated for length, size, propagation and orientation were plotted in simple software by referring all the scanning techniques. Few samples have been cut out to verify the above findings by using other NDT methods such as conventional visual examination as well Penetrant Testing. All the samples were conformed to the findings of Phased Array results. A typical plotting of crack indications is specified below figure 6.

![Typical Crack Plotting](image)

**Fig:** A typical crack plotted in Auto CAD from phased array data

CONCLUSION

The Phased Array UT is effective method to detect Stress Corrosion Cracking on heavy wall reactors compare to TOFD or any other conventional NDT techniques and however the challenges always remain on sizing and plotting the orientation. This can be overcome by additional focused scans as well as effective evaluation and plotting the orientation.

REFERENCES

1. P. Ciorau: A Contribution to Detecting and Sizing Linear Defects by Phased Array Ultrasonic Techniques, 4th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components, London, 6-8 December 2004


4. ASME Sec V, article 4, ASME code case 2235.