ABSTRACT

Corrosion mapping usually uses ultrasonics with a standard single or dual element piezoelectric probe. Normally, manual inspection is low cost, fairly reliable and fast to do on small areas. The main limitations of manual ultrasonics are no permanent record, and limited coverage on larger areas. The advantages of automated ultrasonic (AUT) corrosion monitoring are that there is a permanent record of the work and it can be relatively fast on large areas. The main limitation of AUT is the cost of the inspection and access requirements. Semi-automated thickness B-Scans fit into the niche between manual ultrasonics and AUT. With the arrival of portable phased array systems, it is now possible to acquire thickness data in a rapid and cost effective manner.

B-scan phased array inspections were used to inspect a contactor in a gas plant. The vessel was made from carbon steel 105 mm thick (4.00 in.). Wet H₂S cracking (also termed lamellar blistering) and wall loss were all anticipated damage mechanisms. Shear wave inspections were performed to detect any step wise cracking present from wet H₂S cracking.

INTRODUCTION

A common ultrasonic application is to use longitudinal wave inspection to monitor a component for thickness. There are a variety of damage mechanisms that affect components that can cause thinning of the material, and a subsequent loss in its ability to contain pressure or fulfill its design function. Examination for this damage mechanism is normally done using ultrasonic inspection with a standard single or dual element piezoelectric probe. This can be done either manually or with an automated ultrasonic system. Much of the corrosion monitoring on smaller equipment is done using manual techniques, and the corrosion monitoring on larger more critical equipment is done using automated techniques.

Typically, the advantages of manual inspection are low cost, fairly high degree of reliability and it is fast to perform on small areas. The main limitations are that there is no permanent record of the work that was done and coverage is limited on larger areas. The advantages of automated ultrasonic corrosion monitoring are that there is a permanent record of the work and it can be relatively fast on large areas. The main limitation is the cost of the inspection and the accessibility requirements. The technique chosen is normally dictated by the customer requirements for a particular inspection.

INSPECTION APPROACH

To fit into the niche between these two techniques, it is fairly common to perform a semi-automated thickness B-Scan inspection. In many cases, this involves using manually operated scanners with computerized data acquisition. With the advent of portable phased array systems, it is now possible to acquire phased array thickness data in
a rapid and cost effective manner [1]. It is also fairly easy to acquire thickness data along with shear wave data augmenting the inspection.

This inspection configuration was used to inspect a contactor in a gas plant. The vessel is made from carbon steel 105 mm thick (4.00 in.), but varying in some locations. The damage mechanisms that were expected are wall loss due to internal corrosion, wall loss due to blistering at the ID surface and wet H2S cracking. When wet H2S cracking is detected, it is normally important to determine if there is associated through step-wise cracking in the through wall direction of the vessel. With the phased array configuration, it is a fairly simple extension of the thickness inspection to perform a shear wave inspection to determine if there is any step wise cracking present.

The inspection area was divided into two inch wide (50 mm) grid bands, which was the width of the phased array probe. Figure 1 shows a schematic of one such inspection area. Phased array inspections were done from both the outside and inside of the vessel.

**FIGURE 1:** Schematic diagram of inspection area.

**EQUIPMENT USED**

A 16:128 OmniScan and a 5L64-A2 64 element probe with a 0.59 mm pitch and a normal incident wedge were used for this inspection. This technique has been used on a number of components with a variety of different wall thickness values. On thicker materials, it is useful to use a 32:128 instrument with a larger aperture to allow better depth focusing. Calibration of this system was done using a standard IIW block and 16 elements of the probe were used to produce a sound beam that had a width of roughly 13
mm at the ID of the vessel. Electronically scanning the sound beam along the width of the probe, and moving the probe along the length of the scan, allowed a 50 mm wide area to be inspected. Due to space limitations in the inspection area, a simple encoder that attached directly to the phased array probe was used.

The sensitivity of the system was determined using a dynamic calibration block that has a series of flat bottomed holes at different depths and diameters. This block was scanned at different focusing configurations and ultrasonic grid sizes to determine inspection sensitivity. This allows a minimum idealized sensitivity to be determined, with field sensitivity being less due to less ideal reflection from pitting.

APPLICATION EXAMPLE

Figure 2 shows a phased array thickness scan. The bottom pane is a B-Scan at one position in the C-Scan, with the corresponding A-Scan in the pane above. The distance along the B-Scan is from the left to right, with the total length of roughly 290 mm (11.5 in.). The depth of the material is displayed from top to bottom, with the nominal thickness in this location being roughly 97 mm (3.8 in.). The back wall echo can be seen at the bottom of the B-Scan, where colour denotes signal amplitude. The signal at the top of the display is probe surface noise.

Figure 2 also shows a wet H$_2$S crack present between positions 152 mm and 178 mm (6 in and 7 in.) The back wall echo is still present beneath the wet H$_2$S crack, indicating it was not reflecting all of the sound. There are a number of signals in the area between a depth of 25 and 50 mm (1 in and 2 in), which are the result of small inclusions in the steel. The red and green cursors display a flaw that is close to the ID of the vessel.
Analysis of this flaw using a second phased array shear wave scan indicated that the flaw was an ID connected flaw at a depth of 86.9 mm (3.42 in.).

Figure 3 shows a scan taken from the ID surface of the vessel in a region where there was wet H₂S cracking. The OD surface of the vessel can be seen at a position of roughly 100 mm (4 in.), and is intermittent due to the wet H₂S cracking blocking the ultrasonic signals in some areas and internal pitting causing poor surface coupling. There is more surface noise in this scan than in Figure 2 due to surface roughness and curvature of the ID surface. Figure 4 shows a zoomed in area from Figure 3. The wet H₂S cracking can be clearly seen from position 55.0 mm to 166.0 mm (2.17 in to 6.54 in.). This is a concentrated series of wet H₂S cracks that vary in depth, but are located closer to the ID surface.
Figure 5 shows a compilation C-Scan taken from the ID of the vessel from many individual C-Scans to reproduce the entire inspection area. In the C-Scan, the white areas correspond to no data being taken (usually because of surface roughness preventing proper coupling), the blue colour represents full thickness and the other colours represent the sound reflecting before the full thickness (usually indicative of wet H$_2$S cracking).
In areas of wet H₂S cracking, shear wave inspection between the angles of -30° to 30° was done to determine if there was any step wise cracking present. Figure 6 shows a scan in an area with a number of wet H₂S cracks at different depths. The cracks that are closest to having the sound impinge on them at normal incidence show the highest amplitudes, and the cracks which are off-angle show lower amplitudes. In this case, there is no step wise cracking associated with any of these wet H₂S cracks. In all of these scans, mode converted signals can be seen that mirror the wet H₂S cracking at higher depths.
CONCLUSIONS
1. Phased array inspection of components for H\(_2\)S cracking works well as shown.
2. Encoded phased arrays are a viable alternative to manual inspections (unauditable) and full automated inspections (AUT).
3. Encoded phased arrays offer many of the benefits of manual UT (simple, relatively economical, flexible) while also offering many of the benefits of AUT (recordable and reproducible results, fast scanning).
4. Phased arrays also permit the use of angled beam inspections to detect step-wise cracking with wet H\(_2\)S cracking.

REFERENCE