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ABSTRACT

Standard NDT techniques, such as radiographic, magnetic particle or ultrasonic inspection, are used routinely to assess the fitness for service of operating equipment. However, access to suspect areas can be limited and render standard NDT methods ineffective. Examples of such areas are simple pipe supports and pressure vessel full penetration welds under repads. In these cases, extensive operational disruptions are required to perform standard NDT techniques and determine if in-service damage is present.

This paper presents two cases where ultrasonic guided wave technology has been used to inspect areas of limited access. The guided waves described in these applications are generated and received on plate, in both through transmission and in pulse echo modes. Results will be presented for both simple pipe supports and pressure vessel full penetration welds under repads.

Keywords: Inspection, simple pipe supports, repad welds, guided waves.

INTRODUCTION

Guided wave inspection techniques have been used to inspect pressurized equipment for some time now; they have gained much acceptance in the area of piping inspection[1]. For piping, the standard inspection entails sending guided waves axially down the pipe to inspect for corrosion wall loss. This provides a long range screening tool for wall loss, and can effectively reduce the amount of surface area requiring localized NDT inspections.

Guided waves differ from conventional ultrasonic waves, in that they are bulk vibrations that utilize the medium that they propagate in as a wave-guide. Typically, they have lower frequencies, longer wavelengths, much longer propagation distances and different interaction rules with flaws when compared to conventional ultrasonic waves[2]. In general, the guided wave modes are dispersive, meaning that both the group velocity and the phase velocity will in general be dependent on the product of the wall thickness and frequency (or proportional to the ratio of the wall thickness and wavelength)[2]. This is in sharp contrast to conventional ultrasonic theory where the velocity is independent of wall thickness and wavelength. Figure 1 shows an example of the group velocity dispersion curves for EMAT (electromagnetic acoustic transducer) generated guided waves with a wavelength of 1 inch for several lower order modes. There will also be corresponding phase velocity dispersion curves.

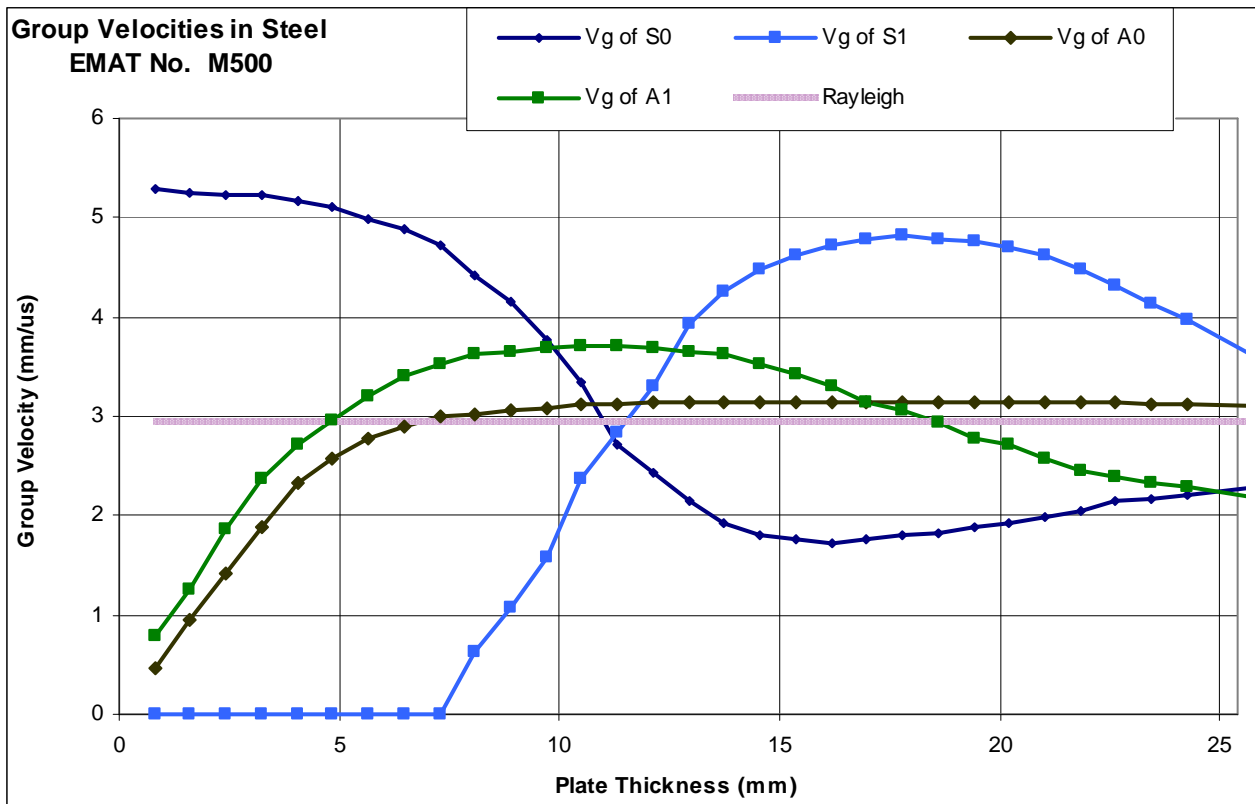


FIGURE 1 – Group Velocity Dispersion Curves for EMAT Generated Lower Order Guided Waves

Although the most common form of guided wave inspection directs a guided wave axially down piping, guided waves can also be generated on plate. Plate waves will have different properties than axially generated guided waves in piping, in terms of their propagation velocities, dispersion characteristics and particle motions. On plate, guided waves can either be used in pulse-echo or in through transmission modes. In pulse-echo mode, the inspection relies on reflected echoes from flaws to be measured at the probe, and in through transmission mode relies on changes induced in the through transmission signal resulting from corrosion. The application of plate waves for inspections is illustrated with the two examples presented here.

EXPERIMENTAL PROCEDURE

Two applications of guided waves on plate are summarized:

- The first is the inspection of corrosion under simple pipe supports, as shown in Figure 2.
- The second involves inspection of welds under repads on compressor bottles.

Pipe supported sections are prone to corrosion since moisture is often trapped where the pipe and support contact[3]. Standard NDT techniques require that pipe coatings are removed and surfaces are prepared; this can leave the pipe more susceptible to corrosion. Additionally, many other techniques, such as conventional ultrasonic testing and visual

inspection, are hampered by lack of access directly under the pipe support. EMAT generated guided waves travelling circumferentially around the pipe can access this area effectively. In this configuration, guided waves are directed circumferentially around the pipe in through transmission mode using a guided wave transmitter and receiver physically separated on the pipe.



FIGURE 2 – Simple Pipe Supports

The inspection of welds under repads on compressor bottles using standard NDT techniques are challenging. Typically, compressor stations have multiple compressor bottles in several stages; as the stage number increases, so does the compression, pressure and temperature of the gas. Due to compressor bottle vibration, residual and applied stresses at the welds and HAZ, the predominant damage mechanism of compressor bottles is fatigue cracking[4]. It is possible to inspect accessible welds on compressor bottles with standard NDT techniques, but the full penetration welds under repads have proven difficult to inspect in the past due to the lack of access[4]. It is often these welds under the repads that are susceptible to in-service cracking, as shown in Figure 3.

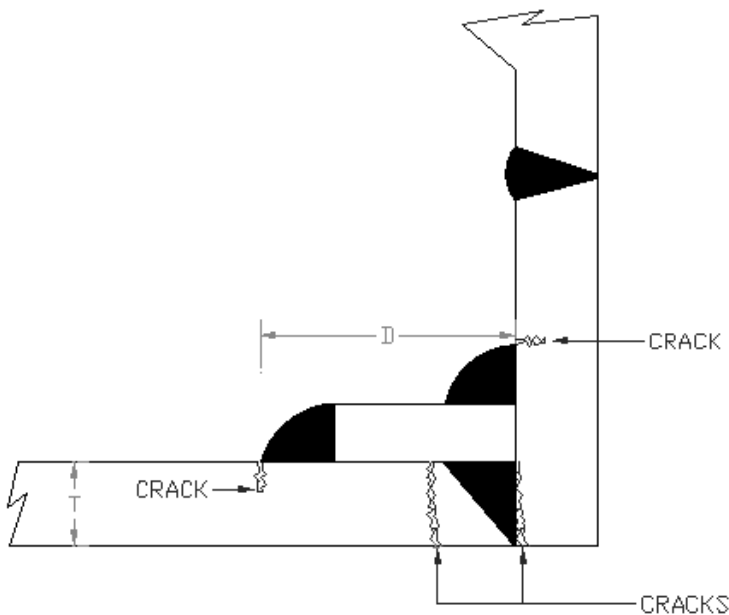


FIGURE 3 – Schematic of Cracking in Full Penetration Welds Under Repads

In order to inspect these welds, Matrix Inspection has developed a guided wave inspection technique called RPAT™ (Repad Access Technology). This inspection technique generates a guided wave on the shell of the bottle, which is directed under the repad towards the full penetration weld. This gets sound intensity into the area of interest for in-service cracking. When performing compressor bottle inspection, it is important to properly calibrate the system and choose an appropriate guided wave mode. Inspection is then done by interpreting the reflections from under the repad in order to identify areas with cracking.

RESULTS

Simple Pipe Support Inspection

For simple pipe support inspection, the transmitter and receiver are scanned along the top of the pipe, that is, perpendicular to the acoustic wave path. The transmitter generates a guided wave that propagates in both directions around the pipe circumference. There will therefore be two main signals measured at the receiver; one will be the signal from the wave propagating across the top of the pipe, and the other will be from the wave travelling around the bottom of the pipe. The output of the receiver will therefore show both direct signals at times equal to the separation distances divided by the group velocity of the guided wave. Figure 4 shows an EMAT scan of a section of pipe with three areas of corrosion, and Figure 5 shows the corresponding line graph of arrival time. The corrosion appears in these figures as a variation in the amplitude of the wave travelling around the bottom of the pipe as shown in Figure 4, and as a variation in time of arrival of the same guided wave as shown in Figure 5. The wave travelling across the top of the pipe is unchanged, as shown in the figures.

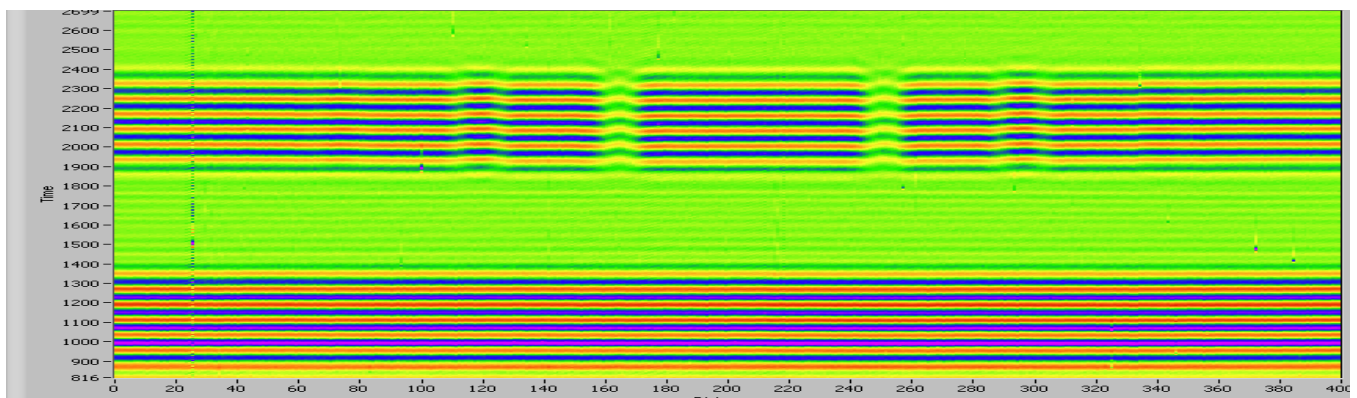


FIGURE 4 – B-scan of Three Areas of Wall Loss

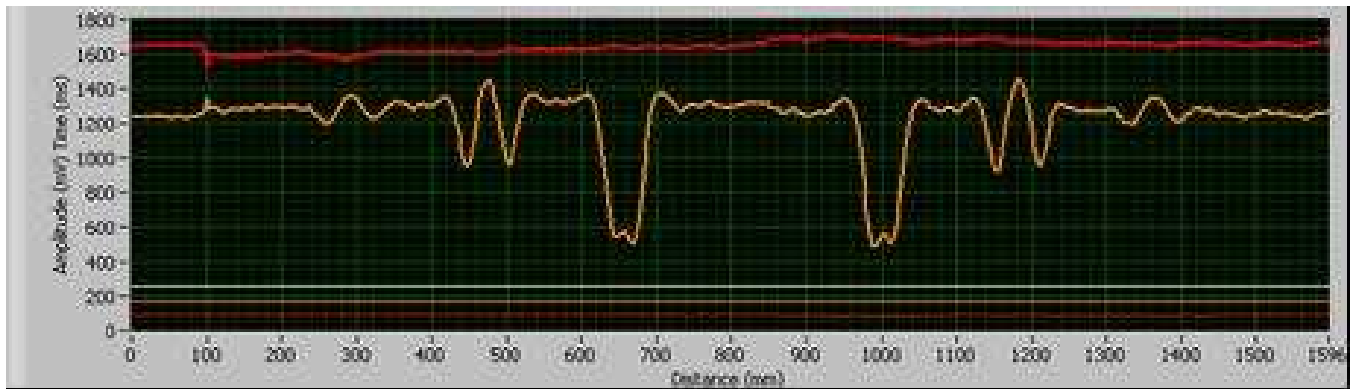


FIGURE 5 – Line Graph of Arrival Time for Same Scan Area as Shown in Figure 4

Depending on the guided wave mode used and the wall thickness of the material, the group velocity and phase velocity will increase or decrease as a result of the wall loss. The amount of wall loss can be estimated from the change in the arrival time measured in the line graph. Matrix Inspection has parameterized the time delays for a variety of guided wave modes over different wall losses and has been using this inspection technique successfully in the field for some time.

RPAT™ Inspection

Matrix Inspection developed the RPAT™ procedure through a set of trials to be able to detect weld cracking under repads. Initially, these trials started with working on compressor bottles that were provided by customers. Sample flaws were machined into these bottles at a variety of locations under the repads to simulate cracking in the area of the full penetration weld.

Inspection of these bottles revealed signals that varied in amplitude depending on the specific characteristics of the repad and weld geometry. Figure 6 shows a typical A-scan of a compressor bottle inspection with no flaws present. When the guided wave travels underneath the repad fillet weld, a signal is reflected early in time, as shown at position 54 mm. The full penetration shell to nozzle weld also generates a signal shown at position 102 mm. This signal can vary quite significantly in amplitude and position around the circumference of the nozzle. It also varies quite significantly when comparing signals from different compressor bottles. The inside surface of the nozzle also generates a signal as shown at position 122 mm; this represents the end of the inspection range.

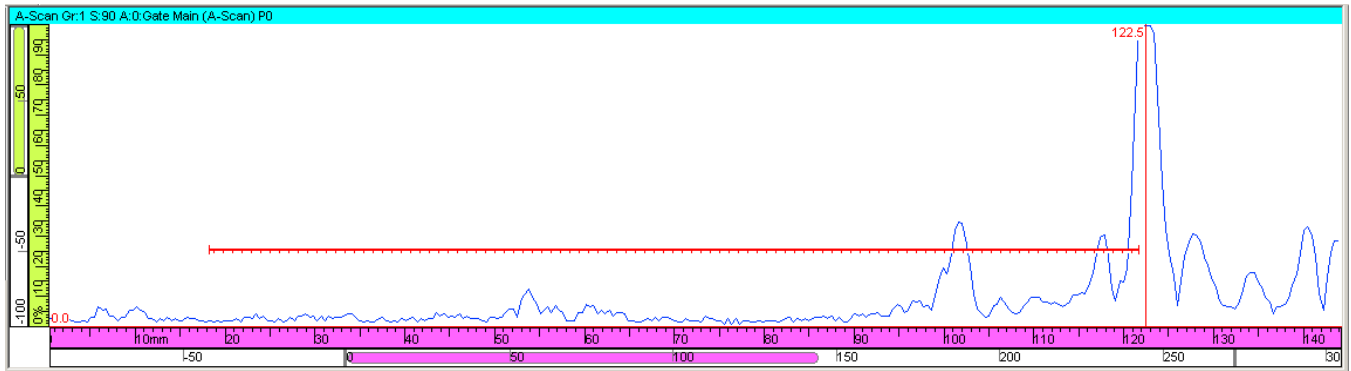


FIGURE 6 – RPAT™ Signal with No Flaws Present

CONCLUSIONS

Guided waves are currently being used in many inspections of operating equipment. They have significant advantages when compared to standard ultrasonic inspection in inspecting equipment with suspect areas with difficult access. Guided waves have more complex behaviour in terms of their many modes and dispersive nature than standard ultrasonic waves. However, this also provides advantages in terms of being able to engineer the guided waves for specific inspection tasks.

This paper has presented two successful applications of guided waves. In both cases, it is the long range propagation capabilities coupled with ability to propagate guided waves into areas where standard inspection techniques cannot handle that make these techniques successful. In the future, RPAT™ will be further refined and be used for crack detection under repads. It is also expected that both of these techniques will be applicable to other inspection applications with similar requirements.

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