FLEXURAL TORSIONAL GUIDED WAVE PIPE INSPECTION

Z. Sun[1], L. Zhang[2], and J.L. Rose[2]

[1] GE Global Research Center, Niskayuna, NY 12309, USA
[2] 212 Earth and Engineering Science building,
The Pennsylvania State University, University Park, PA 16802, USA

ABSTRACT. Based on the flexural torsional guided wave theory and its focusing technique, this paper demonstrates the defect detection capability of flexural torsional guided waves on multiple defects with different shapes and axial, circumferential locations in pipe.

Keywords: flexural torsional guided waves, pipe inspection, focusing, multiple defects.
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INTRODUCTION

Flexural torsional guided wave theory and its focusing technique have been developed and applied to pipe inspection recently [1, 2]. Single defect in pipe has been successfully detected by flexural torsional guided waves with largely improved signal-to-noise ratio (SNR) compared to the axisymmetric guided wave technique. To further demonstrate defect detection capability of flexural torsional guided waves, this paper presented the multiple defects detection of the flexural torsional guided waves in a pipe. All defects were detected with accurate axial and circumferential locations. This new flexural torsional guided wave focusing technique has great potential to improve the possibility of detection (POD) of various kinds of defects in pipelines at critical but inaccessible areas.

EXPERIMENTAL SETUP

Figure 1 showed the axial distribution of three defects in a 16in Schedule 30 steel pipe: a through-wall round hole at 13 feet away from the left edge of the pipe with 1.5% cross sectional area (CSA), a saw cut at 17 feet with 3% CSA, and another saw cut at 19 feet with 3%CSA. The center of the left-most ring in the mounted 3-ring transducer was 3 feet apart from the left edge. Each ring had 44 elements equally spaced, which were grouped into four channels with 11 elements in each. Total 12 independent channels can be controlled by different time delays and amplitudes. Ring spacing and axial time delays controlled the excitation of specific family of guided wave modes. Circumferential time

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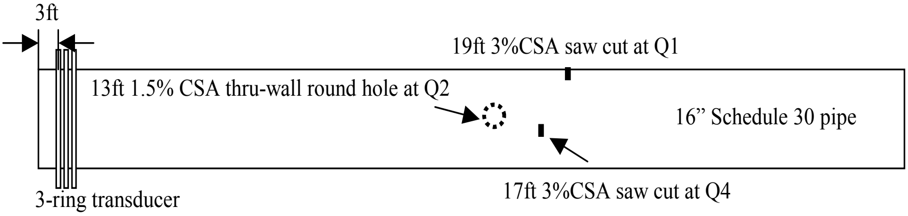


FIGURE 1. Schematic of axial distributions of defects in 16” pipe.

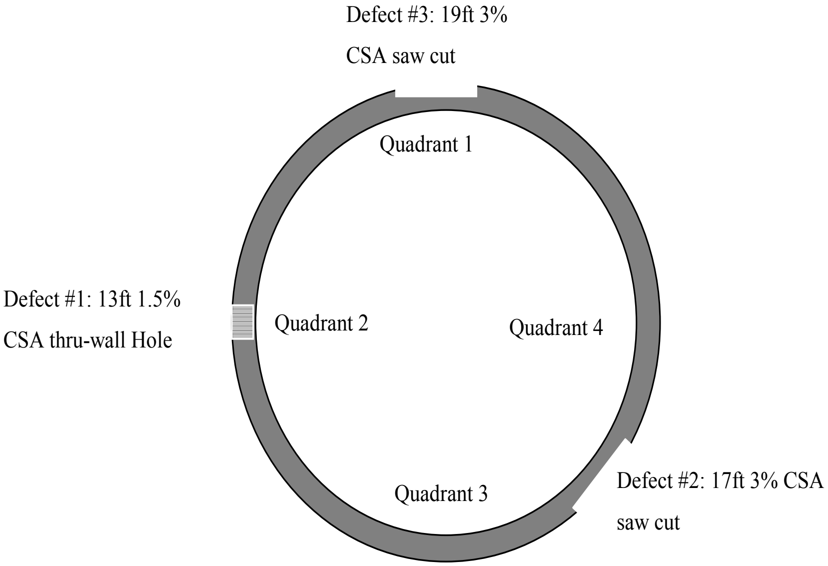


FIGURE 2. Cross section view of the 16in pipe with three defects locations.

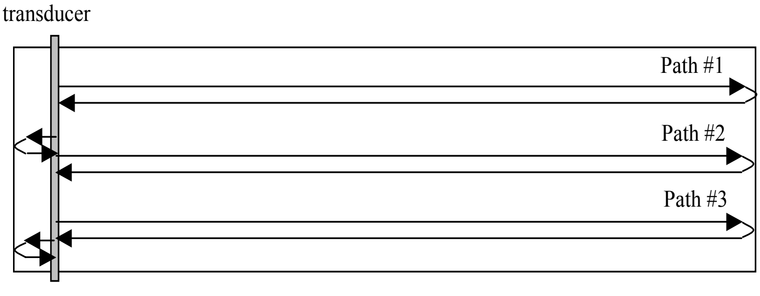


FIGURE 3. Schematic of three wave propagation paths in the 16in. pipe for back wall signals

delays were used to control the focusing of wave energy in the circumferential direction, which helped to locate defect on the pipe circumference. Figure 2 showed the circumferential locations of the three defects.

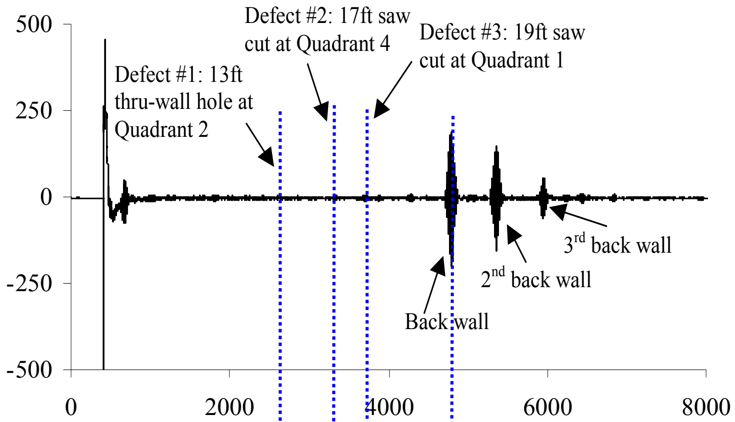
MULTIPLE DEFECT DETECTION

First, the 3-ring transducer mounting position was selected experimentally. When the transducer was mounted exactly at the left edge of the pipe, longitudinal modes L(0,2) and the corresponding higher order modes were excited besides T(0,1) group of modes, even though shear vibrations were predominantly generated by the transducer elements. When the 3-ring transducer was moved 3 inch apart from the left edge of the pipe, the longitudinal modes excitation was greatly reduced. However, the experimental data interpretation needed more attention because of multiple propagation paths for each wave mode. Figure 3 gave an example of the three propagation paths of the back wall signals (reflecting signal from the right edge of the pipe) of the 1st family of torsional modes, e.g., T(0,1) and the corresponding high order flexural modes. Similarly, there were three propagation paths for the reflecting waves from each defect. With transducer position selection of 3 inch apart from left edge, echoes from each defect were separated.

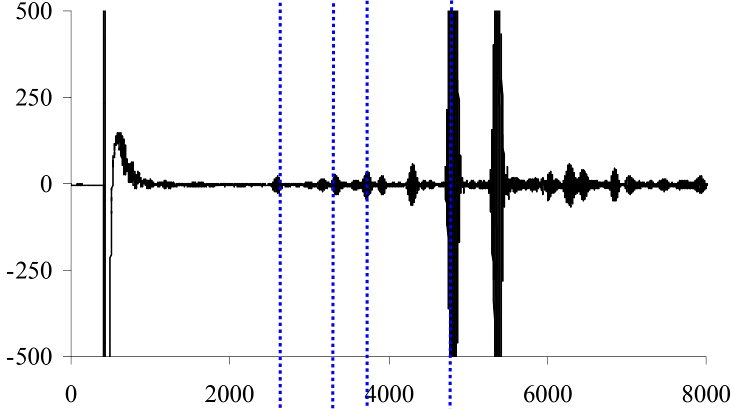
Figure 4(a)-(f) showed the flexural torsional guided wave inspection results on a 16 inch Schedule 30 steel pipe. The echo arrival time for each defect was marked by dash lines only from the shortest propagation path. The time delays of flexural torsional wave focusing for both transmitting and receiving were calculated from the shortest path for each defect. Figure 4(a) displayed the axisymmetric inspection result at 65kHz. Except three back wall echoes, there was no clear indication for any defect. Figure 4(b) gave the axisymmetric inspection result at 50kHz. Obviously the back wall signals were increased and small echoes appeared around defect locations. But the result was still marginal to make reliable defect calls because of the low SNR. Compared to Figure 4(a), figure 4(b) showed the advantage of frequency tuning – optimal frequency selection. From Figure 4(c) to 4(f) flexural torsional focusing technique was applied to the inspections to focus at four different quadrants in the pipe circumference. When the wave energy was focused at quadrant 1 and 19 feet, which was the location of defect #3, the echo and SNR of defect #3 was greatly increase as shown in Figure 4(c). Figure 4(d) gave the inspection result with focusing at defect #1 and as expected, the echo of defect #1 was increased by focusing. Figure 4(e) showed the inspection result focusing at quadrant 3 and 17 feet, where no defect was located. Figure 4(f) showed the result with the focusing point at quadrant 4 and 17 feet - the defect #2 location. Signal amplitude and SNR were largely improved for all three defects by applying the flexural torsional focusing technique. With the aid of electronic controls of excitation and receiving, sweeping of the focal point of flexural torsional guided waves can be carried out with high efficiency. Hence, defects at different circumferential directions and distances can be located accurately with improved SNR and POD.

CONCLUDING REMARKS

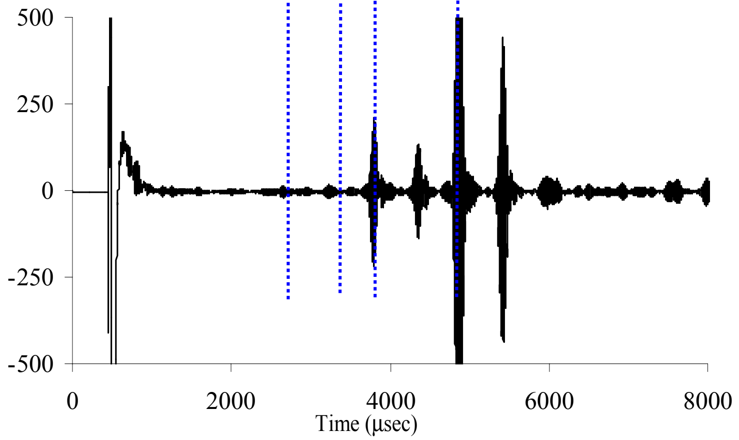
The pipe inspection results clearly showed the advantages of the flexural torsional guided wave focusing technique for defect detection in pipe with greatly improved SNR and POD. Both circumferential and axial locations of defects can be accurately detected. This technique has great potential for pipeline monitoring at many critical but inaccessible areas, such as highway, bridges and road crossings.



(a). Axisymmetric excitation at a random frequency 65 kHz. (Poor results)

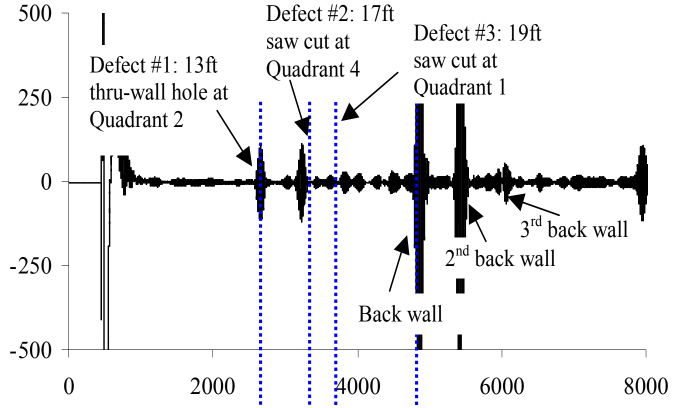


(b). Axisymmetric excitation at a tuned frequency 50 kHz (marginal results)

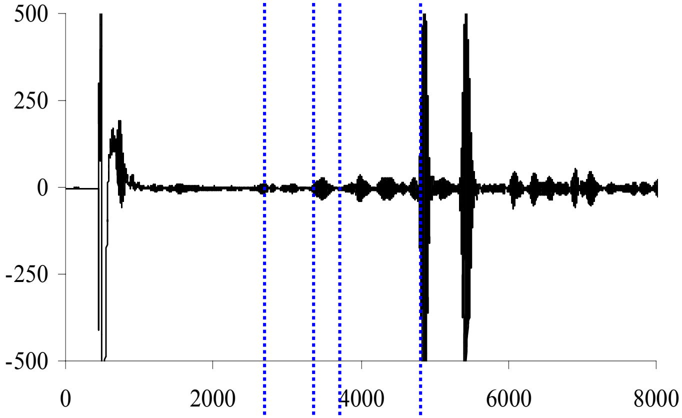


(c). Focusing at Quadrant 1 and 19 ft (defect #3), 50 kHz (SNR increase of defect #3)

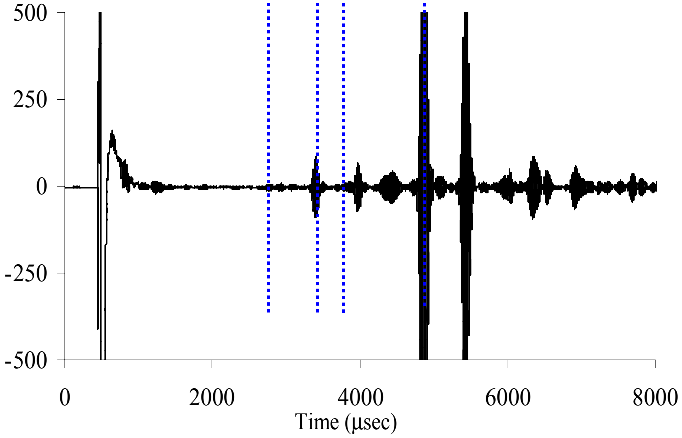
FIGURE 4. T(0,1) group of modes focusing inspection results on a 16” Schedule 30 steel pipe with three defects (cont’d);



(d). focusing at Q2 and 13ft (defect #1), 50 kHz (SNR increase of defect #2)



(e). focusing at Q3 17ft (no defect), 50 kHz (no defect indication)



(f). focusing at Q4 17ft (close to defect #2), 50 kHz (SNR increase of defect #2)

FIGURE 4. T(0,1) group of modes focusing inspection results on a 16” Schedule 30 steel pipe with three defects.

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