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Mode Identification of Guided Waves in a Curved Pipe

Heung-Seop Eom, Sa-Hoe Lim, Jae-Hee Kim
Korea Atomic Energy Research Institute, Integrated Safety Assessment Div., P.O.Box 105, Yuseong Daejeon,,ehs@kaeri.re.kr

1. Introduction

Ultrasonic guided wave technique has been widely employed for the long range inspection of structures such as plates and pipes because it has the ability to propagate over long distances [1]. In the nuclear power field, there recently appeared a need for on-line nondestructive monitoring which can be employed during the operation stage of power plants [2]. As ultrasonic guided waves have shown promise for on-line monitoring of power plants, a lot of work has been done in the institutes and universities on this matter [3,4]. In the case of detecting defects in simple straight pipes, the dispersion curves obtained from the modeling processes are closely akin to the experimental results. But the modeling of wave propagation in some structures, such as an elbow region of a pipe, is not practical due to elbow echo and unpredictable interface conditions [5]. This paper presents an experimental approach to identify the most dominant modes of guided waves in a curved region of a pipe, which is a key factor in detecting flaws in a pipe..

2. Specimen and Dispersion Curves

The specimen used for this study was a sus304 seamless stainless steel pipe which is commonly used in nuclear power plants. Table 1 shows the specifications of the specimen. Figure 1 is the group velocity dispersion curves of the specimen.

Table 1. Specification of seamless stainless steel pipe

Materials	SUS304
Longitudinal wave	5,800 m/s
Transverse wave velocity	3,100 m/s
Density	7.83 g/cm^3
Outer diameter	60.325 mm
Thickness	5.55 mm

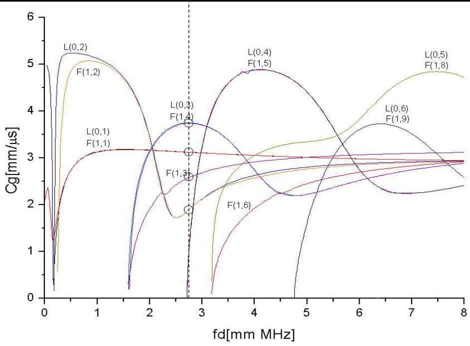

Figure 1. Group velocity dispersion curves of the specimen

3. Experiments

3.1 Experimental Setup

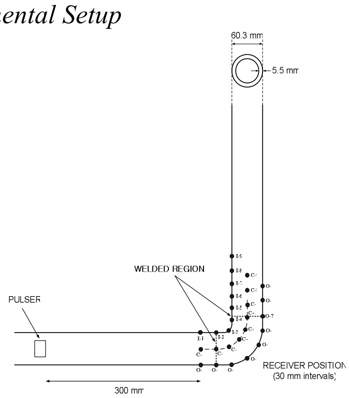

Figure 2. Top view of the specimen and the experimental setup for the mode identification in the curved part of a pipe

Figure 2 is a schematic diagram of the experimental setup. Tests were performed using a pulser/receiver, two 0.5 MHz transducers, and a digital oscilloscope. A through transmission test was setup by using 30, 45, and 60 deg. wedges. The curved region of the specimen was made with a SUS304 elbow. The transmitter was placed at 33cm from the starting point of the curved region. RF signals were captured at 18 points (Center region of the elbow - C1 through C9 and Outer region of the elbow - O1 through O9). The receiver position was shifted away from the transmitter by a step of 3cm.

3.2 Group Velocity Measurement

Group velocity measurement is one of the methods to identify the mode of guided waves. This can be calculated from the time of flight (TOF) and the distance between the transmitter and the receiver. Figure 3 shows the measured group velocities of the major modes which could be derived from three incident angle – 30, 45, and 60 degree.

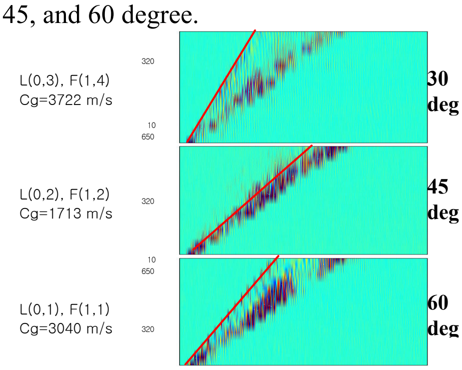

Figure 3. Measured group velocity and cumulated signals to calculate the group velocity

3.3 Mode Identification in the Curved Region of a Pipe

The objective of this study was to identify the most suitable modes for the inspection of a curved pipe. From the various sample case experiments, L(0,2) mode was the most identifiable one in the center part (C1 through C9) of the curved region of the pipe and L(0,1) mode was the most identifiable one in the outer region. But both of these two modes had problems when they were passed over the two welds.

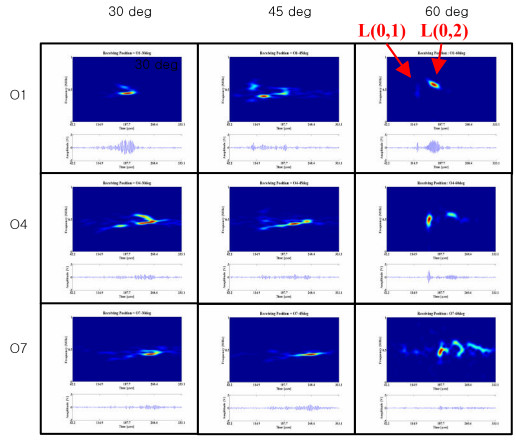

Figure 4. RF signals and its STFT results: Left label: receiver position. Head label: incident angle of the transmitter

Figure 4 shows RF signals and their short time Fourier Transform results from the through-transmission test at the position O1 with an incident angle of 30 deg., the position O4 with an incident angle of 30 deg., and so on. In the incident angle of 60 deg., L(0,1) mode and L(0,2) mode were most identifiable. On the other hand the identification of the specific modes was difficult in the incident angles of 30 and 45 deg.

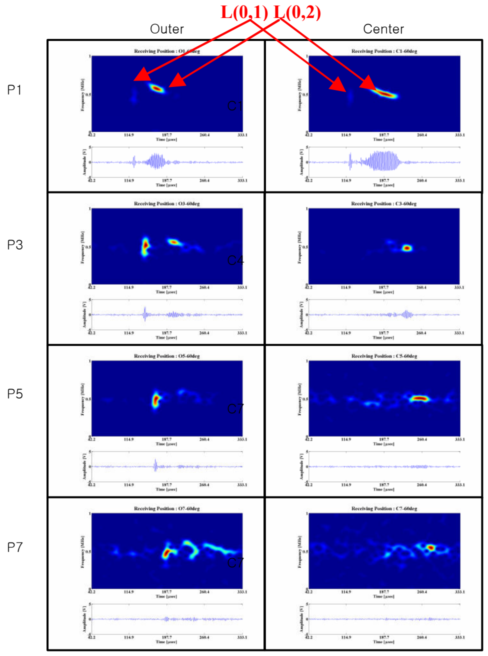

Figure 5. RF signals and its STFT results at incident angle 60 deg. Head label: the position on the circumference of the pipe. Left label (P1~P7): location of the receiver.

Figure 5 shows RF signals and their STFT results from the through-transmission test at the center position (C1, C3, C5, C7) and the outer position (O1, O3, O5, O7). L(0,2) mode clearly appeared at the starting point of the outer region (O1). Then it gradually disappeared from the O3 position and L(0,1) mode became the main mode after that point. In the center region, L(0,2) mode was identified as the strongest mode through the entire receiving position (C1 through C9). Therefore it seems that L(0,2) mode is suitable for the inspection of the center region of the curved pipe, and L(0,1) mode is suitable for the inspection of the outer region.

4. Summary

This paper presents an experimental approach to identity the suitable modes for the inspection of a curved pipe being used in nuclear power plants. Group velocity dispersion curves of the specimen were provided as guidance for a practical use. Sample case mode identification of guided waves in the curved region of the specimen pipe was experimented. The results showed that the main propagation modes were different in the center and outer parts of the curved region of the pipe. The results will be used as baseline data for a study on detecting flaws in the curved part of pipes.

Acknowledgements

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REFERENCES

[1] P. Cawley, Practical Long Range Guided Wave Inspection – Managing Complexity, in Review of Progress in Quantitative NDE, eds. D. O. Thompson and D. E. Chimenti (AIP, New York, 2003), Vol. 22, pp. 22-37.
[2] N. Nakagawa, F. Inanc, R. B. Thompson, W. R. Junker, F. H. Ruddy, J. M. Beatty, and N. G. Arlia, On-line NDE for Advanced Reactor Design, in Review of Progress in Quantitative NDE, eds. D. O. Thompson and D. E. Chimenti (AIP, New York, 2003), Vol. 22, pp. 1728-1734.
[3] Cheong, Y.-M., Lee, D.-H., Jung, H.-K., Ultrasonic guided wave parameters for detection of axial cracks in feeder pipes of PHWR nuclear power plants, Ultrasonics, Vol. 42 (1-9), pp. 883-888,2004
[4] Eom, H.-S., Kim, J.H., Kim, Y.H., and Song, S.-J., Experimental studies on guided waves for the on-line inspection of steam generator tubes, Key Engineering Materials, Vol. 270, pp. 416-421, 2004
[5] Joseph L. Rose, Li Zhang, Michael J. Avioli, and Peter J. Mudge, A natural Focusing Low Frequency Guided Wave Experiment for the Detection of Defects Beyond Elbows, Transactions of the ASME, Vol. 127, pp. 310-316, 2005