**Efficient defect detections in an elbow part of piping by guided waves using appropriate frequency 1**

-Reflection phenomena at defects and sensitivities of defect detections-

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**1. Introduction**

Guided wave technique [1-3] is an efficient screening method for health monitoring of piping. Straight parts of piping can be applied simply by the technique because the propagation phenomena are relatively simple. In elbow parts of piping, however, defect detections are much more difficult due to the complex wave structures, although the two typical types of wall thinnings (corrosion of Liquid Droplet Impingement; LDI and Flow Accelerated Corrosion: FAC) are frequently occurred.

This paper shows an experimental approach to reveal the sensitivities of defect detections at several locations in an elbow part of piping. Experimental phenomena regarding the gradual increasing artificial defects were shown. The results show that the sensitivities at outer side of the elbow were relatively higher for 40 and 50 kHz and those at inner side were higher for 30 kHz. Important experimental phenomena of the guided wave propagating in the elbow part were also shown.

**2. Experiments**

Straight-elbow-straight configuration pipes were employed as specimens, as shown in Fig. 1. 60.5 mm outer diameter and 3.9 mm thick Al pipes were used. Both ends of the elbow (JIS Long elbow) were welded to the two straight pipes. The dry-coupled piezoelectric ring-shaped sensor was used for generating and detecting the T(0,1) mode guided waves. Twelve locations of artificial defects were shown in Fig. 2. Depth of each defect was gradually increased up to 2 mm with 0.25 mm step. All the experimental investigations were carried out with three different frequencies 30, 40 and 50 kHz to reveal the differences due to the frequencies.

**3. Results and discussions**

Figure 3 shows the variations of 50 kHz for different defect depths.

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**Fig. 1** Experimental setup

**Fig. 2** Twelve defect locations and shape

**Fig. 3** Variation of waveforms at defect location #5
signals for different depths of the incremental defect at the location ①. The signal without defect (bottom) shows the baseline signal that was emerged from the structural complexity of the elbow part. Comparing the baseline signal with the other signals, the defect signals were very small and were always buried in the baseline signal. Therefore, subtracting the baseline signal from any observed signal is an essential procedure [4,5] to obtain the defect signals. The relative enveloped signals to which was applied the baseline subtractions for various defect depths were shown in Fig. 4. The relative reflection coefficient as a function of cross sectional loss was shown in Fig. 5. The circles and line indicate the experiments and their least square fit line, respectively. We defined the slope of the line as the sensitivity (%/%) of defect detection.

Another example at the location ⑤ was also shown in Fig. 6. In this case, the reflection coefficient decreases with an increase of cross sectional loss. This interesting phenomenon can be explained simply as follows: First, the defect signal is always on the large baseline signal. Then the observed signal monotonically decreases if the phase difference $\phi$ between the two signals takes $90^\circ < |\phi| < 180^\circ$. Conversely, the signal increases if $|\phi| < 90^\circ$ (see Fig. 5). Here, the sensitivity (%/%) was redefined as the absolute slope of the reflection coefficient as a function of cross sectional loss.

The sensitivities at all the defect locations were summarized in Fig. 7. The sensitivities at outer side of the elbow were relatively higher for 40 and 50 kHz than those for 30 kHz. Conversely, the sensitivity at inner side of the elbow was relatively higher for 30 kHz. A main reason of the phenomena is due to the wave energy concentrations and is revealed in our 2nd report of “FEM analyses and a method for efficient defect detections”.

4. Conclusion

It was confirmed experimentally that the sensitivities of defect detections at outer side of the elbow of the 50A Sch. 40 A1 pipe were relatively high for 40 and 50 kHz and those at inner side were high for 30 kHz. It was shown that the subtracting the baseline signal from the observed signal is an essential procedure and is inevitable to extract the defect signal buried in the spurious baseline signal.

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References

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