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Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 75-76
20-22 November, 2013

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-

適切な周波数のガイド波でのエルボ部高感度欠陥検出 1
-欠陥反射波の特徴と検出感度-

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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

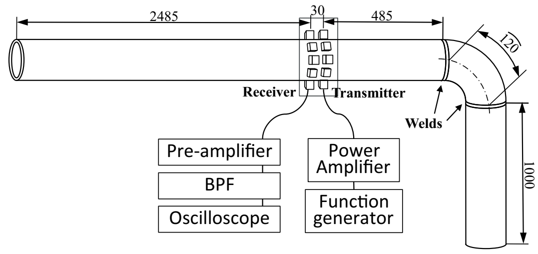

Fig. 1 Experimental setup

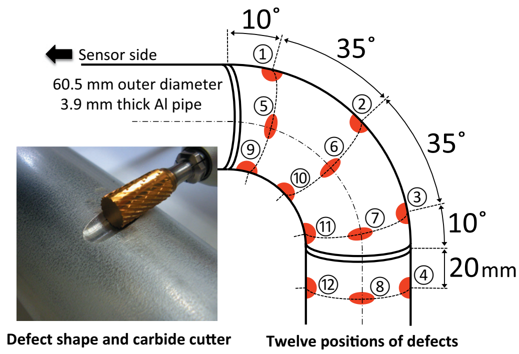

Fig. 2 Twelve defect locations and shape

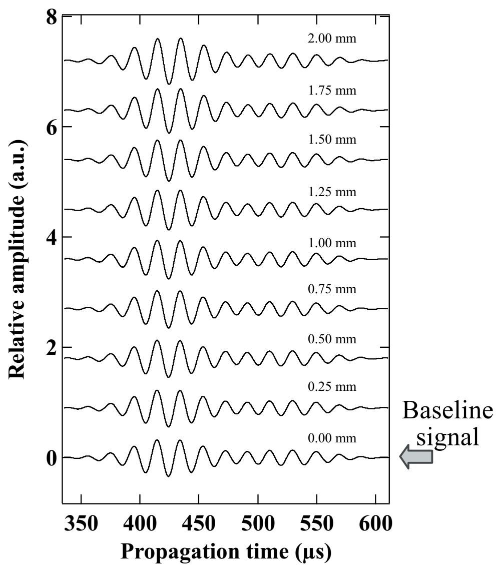

Fig. 3 Variation of waveforms at defect location ⑤ for different defect depths

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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 φ between the two signals takes 90˚ < |φ| < 180˚. Conversely, the signal increases if |φ| < 90˚ (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 Al 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.

Acknowledgment

This work was supported by Enhancement of Ageing Management and Maintenance of Nuclear Power plant 2010 by NISA of METI.

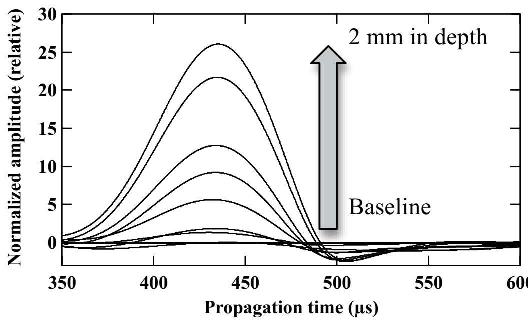

Fig. 4 Relative enveloped signals. The amplitude that increases monotonically with depth could be observed.

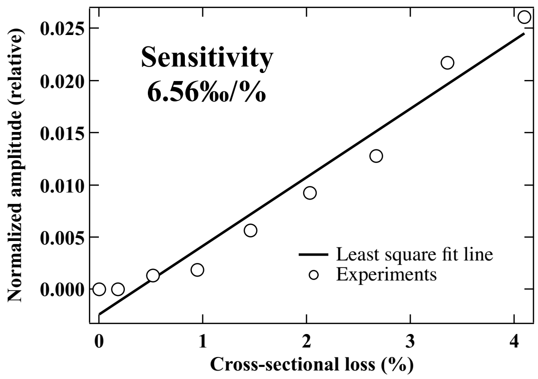

Fig. 5 Amplitude vs. cross sectional loss (location ①)

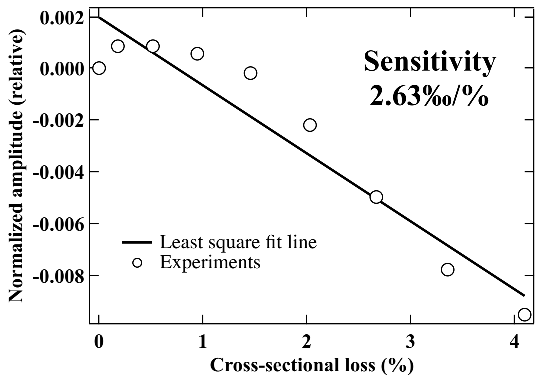

Fig. 6 Amplitude vs. cross sectional loss (location ⑤)

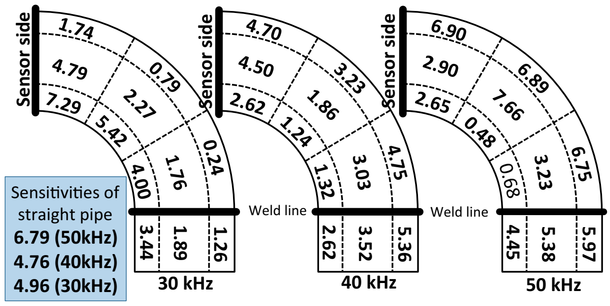

Fig. 7 Sensitivities at all the defect locations (see Fig. 2) for 30, 40 and 50 kHz. Sensitivities of the defect created on a straight pipe (same dimension) were also shown in lower left for comparison.

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