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Detecting pipe wall reduction using air-coupled MHz range ultrasonic wave

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Abstract: Air-coupled ultrasonic waves in the megahertz range are applied for noncontact detection in a pipe wall reduction model. Various widths and depths of pipe wall reductions were used, and the pipes were irradiated with 1.2 MHz air-coupled ultrasonic waves. F-mode guide waves were used to detect the defects in the pipe walls. The experimental results confirmed that ultrasonic waves reflecting from areas of wall reduction in the pipes could be detected. A wall reduction of about 10 mm could be deduced from the reflected waveforms. A clear correlation between the depth of the wall reduction and the amplitude of the reflected waves was found.

Keywords: air-coupled ultrasonic wave, megahertz range, wall reduction, nondestructive evaluation

Classification: Ultrasonic electronics

References

[1] H. Nishino, "Fundamentals and Applications of Ultrasonic Guided waves for Nondestructive Inspection," *J. JSNDI*, vol. 52, no. 12, pp. 654–661, 2003. [in Japanese].

[2] T. Hayashi, "Guided Wave Theory for Pipe Inspection and Prospective Technology," *J. JSNDI*, vol. 54, no. 11, pp. 590–594, 2005. [in Japanese].

[3] K. Imano and M. Kondou, "Possibilities of nondestructive evaluation of a pipe using air-coupled ultrasonic wave in the MHz range," *IEICE Electron. Express*, vol. 5, no. 17, pp. 668–671, 2008.

[4] [Online] http://www.ultrangroup.com/Transducers/NonContact/Planar.aspx

1 Introduction

The material reduction of a huge number of pipes due to aging has become an important social issue, and there is concern regarding accidents involving explosions and leakages in industries such as the petrochemical industry and nuclear power generation [1]. To confirm the safety and reliability of units in such industries, a speedy and exhaustive inspection technique is

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required. Although the use of ultrasound is a valuable technique for non-destructive evaluation (NDE), most of such measurements involve point to point inspections, which require much labor and time for maintenance or health monitoring.

Recently, a promising method using guided waves has been introduced [1, 2]. Guided waves have inherent properties of long distance propagation and low attenuation. Conventional coupling agent type inspection methods that use many ring-type transducers fixed around pipes or use a wedge as the phase matching transformer are regularly applied. Where the contact method uses a coupling agent, the placing of transducers around the pipes is a cumbersome process and so high speed scanning inspections cannot be realized. Thus a simple and noncontact method would be a welcome technique in the NDE of pipes. One possible method is the use of air-coupled ultrasonic waves. Although this method is essentially noncontact, the potential problems of the huge acoustical mismatch between transducers and air and the large frequency-dependent attenuation of sound have limited the applications in NDE.

Recently, the possibility of using air-coupled ultrasonic waves in the megahertz range for NDE has been demonstrated [3]. The flexural mode of guided waves in the megahertz range can be clearly transmitted and detected without the use of coupling agents.

In this paper, an experiment was conducted using air-coupled ultrasonic waves in the megahertz range to detect wall reduction and demonstrate the potential use of this method.

2 Experiments for detection of wall reduction

2.1 Localize the wall reduction defect

Localized convection and collision of fluid or powder in pipe is one cause of wall reduction damage. To model wall reduction, several grooves were ground into the surface of aluminum pipes as shown in Fig. 1. Guided waves (here we used F mode waves) are sensitive to defects on both the outer and inner surfaces of pipes [3]. The aluminum pipes used in the experiments were 30 mm in diameter with 2 mm thick. A sample with four types of grooves (widths of 3, 10, 20, and 30 mm and depths of 1 mm) were prepared. Another sample with four types of grooves (depths of 0.34, 0.65, 1.0, and 1.2 mm and widths of 6 mm) was also made.

Figure 2 shows the measurement system. An exciting signal was generated from a function generator at 1.2 MHz and with 10 cycles of sine burst waves of 10 $V_{\text{p-p}}$, and amplified to 190 $V_{\text{p-p}}$ and applied to the transducer via a matching circuit. Transducers used as the transmitter and receiver were a specialized piezoelectric-type for air-coupled ultrasound (Ultran NCT-1.5D-13) [4], which have the resonance frequency of 1.2 MHz Ultrasonic waves launched from the transducer were radiated at an incident angle θ_c of 7.5 degrees. At this angle, four modes of guided waves, F(1,1), L(0,1), T(0,1) and T(1,1) would be excited. In our previous paper [3], the most easily excited

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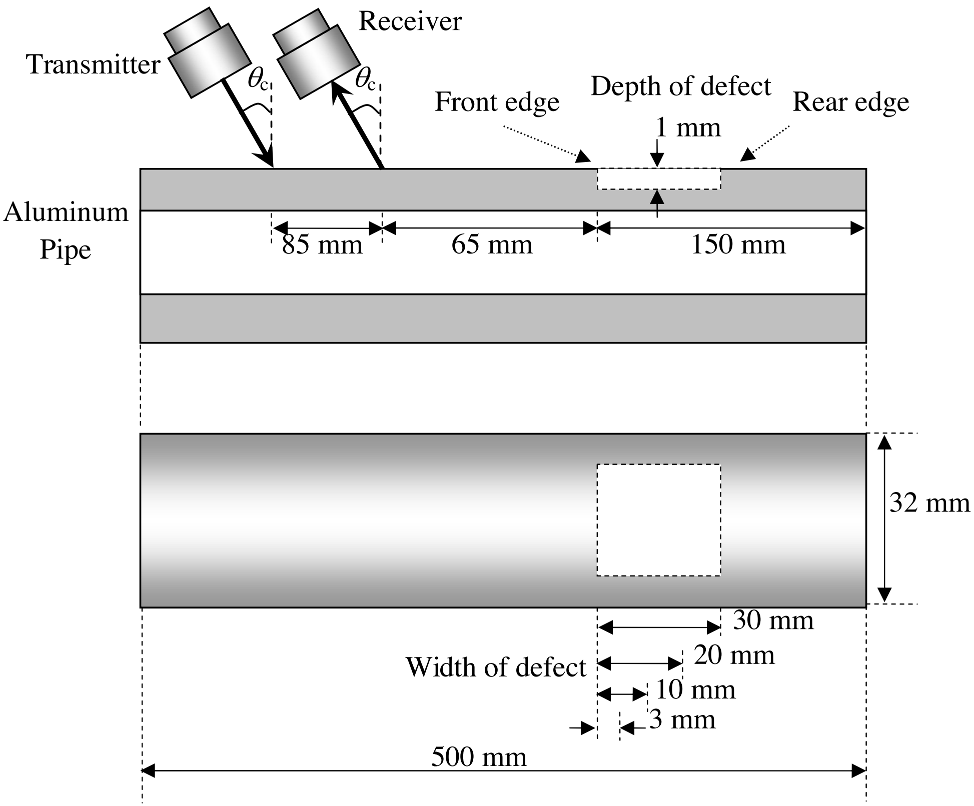

Fig. 1. Geometry of aluminum pipe with various defect widths

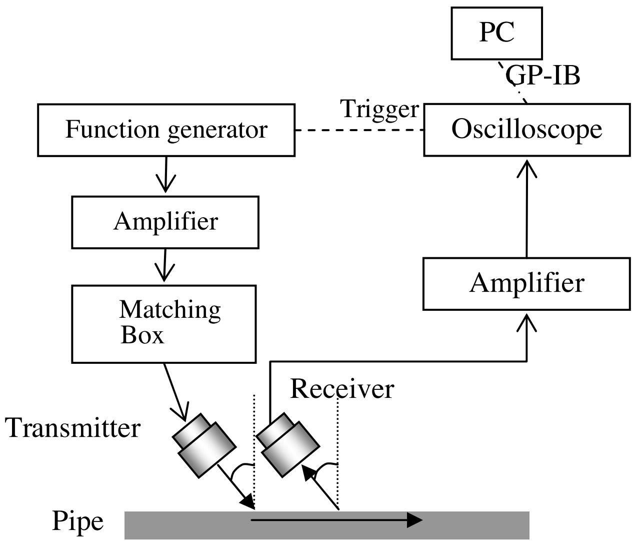

Fig. 2. Measurement set-up

and dominant mode, F(1,1), was used for the guided probing waves. Guided waves generated in the aluminum pipe propagated and were then received after reflection at the front and rear edges of a groove. The reflected waves from both edges were received by the same type of receiving transducer after collecting information relating to the conditions.

The received signal was observed by an oscilloscope and fed to a computer via the GP-IB. We could identify the position of defects from the wave

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velocity and propagation time.

Fig. 3 shows the experimental results. As described above, S/N of signal are very poor because of huge acoustic mismatch between transducers and air, and large frequency dependent attenuation of sound in air [3]. The signal reflected from the defect (i.e. the grooves) is observed around 65 μs, which coincides with the calculated values $(((85 + 65) + 65)\,\mathrm{mm}/3300\,\mathrm{m/s} = 65\,\mu\mathrm{s}$, where the incident path is 85 + 65 mm and return path is 65 mm and the velocity of the F(1,1) mode in the aluminum pipe is 3300 m/s [3]. As the width of the defects increases, the reflected waves from the front and rear edges split into two wave groups. Time lags of the second wave group correspond to the width.

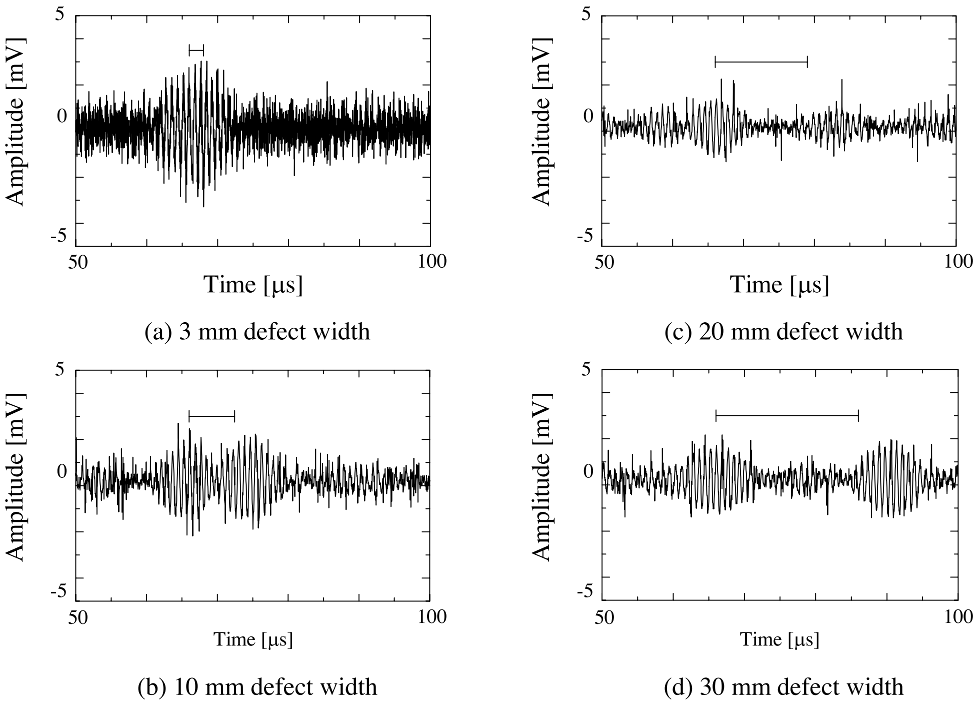

Fig. 3. Experimental results for various defects widths

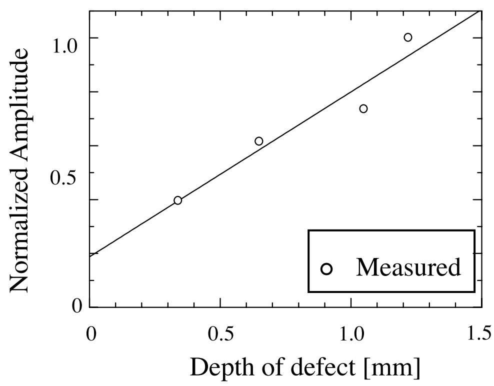

Fig. 4. Experimental results for various defect depths

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2.2 Effect of depth of wall reduction

Figure 4 shows the effect of the depth of the grooves. The horizontal axis is normalized by the value of the amplitude for a depth of 1.2 mm. The received amplitude is linearly proportional to the depth of the defect; thus the wall reduction can be roughly estimated from our experimental results.

3 Conclusion

The experiments demonstrated the transmitting/detection abilities of MHz range air-coupled ultrasonic waves. The possibility to detect wall reductions shows the usefulness of this method, which has the potential to become a powerful tool for NDE. The detection of other types of defects such as holes and cracks is our next experimental work.

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