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Monitoring Pipe Thinning using Accelerometers

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1. Introduction

Pipe thinning is one of the major issues for the structural fracture of pipes of nuclear power plants. Therefore a method to inspect a large area of piping systems quickly and accurately is needed. In this paper, we proposed the method for monitoring pipe thinning using accelerometers. Our basic idea come from that a group velocity of impact wave is different as wall thickness. If the group velocity is measured, wall thickness can be estimated. This is because an arrival time difference can be measured easily in time-frequency domain rather than time domain. To test the performance of this technique, experiments have been performed for a plate and U type pipe. Results show that the proposed technique is quite powerful in the monitoring pipe thinning

2. Monitoring Pipe Thinning

Bending waves, which propagate through a pipe, have different wave speed as pipe thickness. For example, wave speed on thick pipe faster than on thin pipe. In this paper, we study the correlation with group velocity and pipe thickness theoretically and experimentally.

2.1 Basic Theory

Group velocity of a plate can be derived as [1]

$$C_g = \frac{3.6 \cdot hf \cdot C_L^{'2}}{C_{ph} \cdot (C_L^{'} + 9hf)} \tag{1}$$

Where h is the thickness of plate, f is frequency, C_L is longitudinal wave speed, and C_{ph} means a phase velocity. In the low frequency range, eq.(1) can be simplified as

$$C_g \cong 2 \cdot \sqrt{\omega} \left(\frac{D}{\rho h} \right)^{\frac{1}{4}} \tag{2}$$

Where D is

$$D = \frac{Eh^3}{12(1-\nu^2)} \tag{3}$$

E is Young's modulus, and ν means the Poisson's ration. Eq.(2) and (3) show that the group velocity is different as the plate thickness. Therefore, the equations are arranged with regard to plate thickness, then we can obtained the equation as follows

$$h = \frac{\sqrt{3}}{2} \cdot \frac{C_g^2}{\omega} \cdot \sqrt{\frac{\rho(1-\nu^2)}{E}} \tag{4}$$

2.2 Plate Experiment

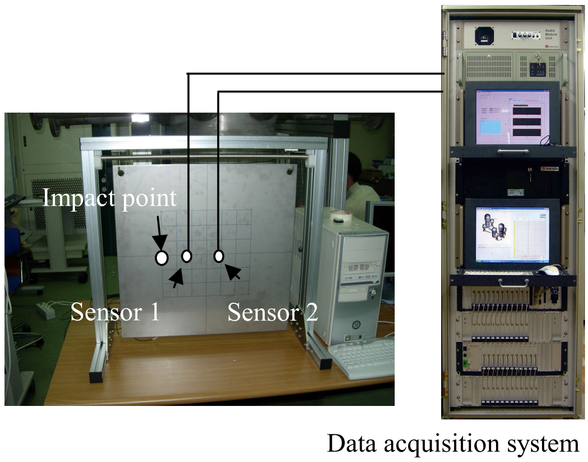


Fig. 1 Experimental setup for plate whose thickness is 2mm. Accelerometers are used for measuring impact response (B&K type 4374).

To verify the proposed method, we have performed plate experiment. Fig. 1 shows the experimental setup. We used accelerometers(B&K Type 4374). Material of plate is SUS304 whose Young's modulus is 205 GPs, poisson's ratio is 0.3 and density is 9780kg/m^3. The plate size is 600mm X 600 mm and thickness is 2mm. Sampling frequency is 200kHz.

After measuring group velocity, we can estimate the pipe thickness by using eq.(4). Estimated plate thickness is 2.01mm. Since true plate thickness is 2mm, the proposed method is very powerful for estimating thickness.

Fig. 2 shows the experimental results. Where dotted line means estimated group velocity and solid line is eq.(2) when thickness is 2mm. As you can see, the experimental result coincides with theory very well.

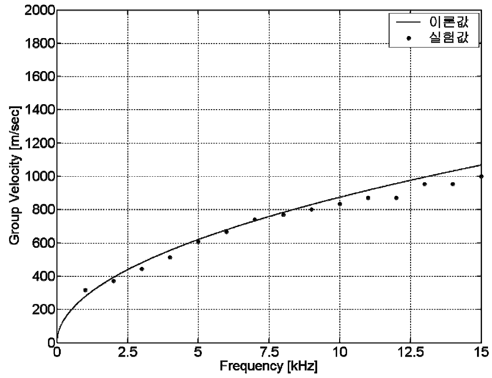
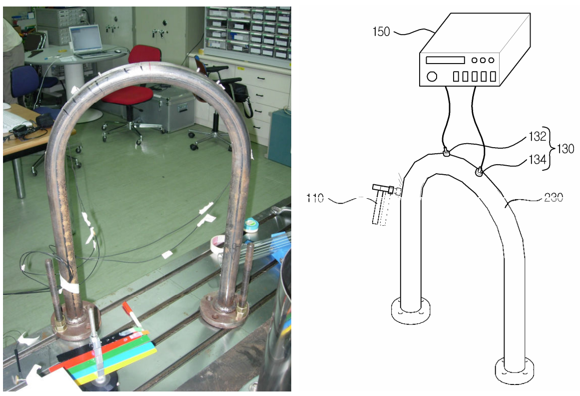


Fig.2 Estimated group velocity. Where solid line is eq. (4) and dotted line means experimental result.

2.3 Pipe Experiment

Fig. 3 shows experimental setup for U type pipe. Experimental condition is the same with plate experiments. We have performed experiment for 2mm, and 4mm thickness pipe.



(a) (b)

Fig. 3 Experimental setup for U pipe. 110 is impact hammer, 150 is data acquisition system, 132 and 134 are accelerometers and 230 is a pipe.

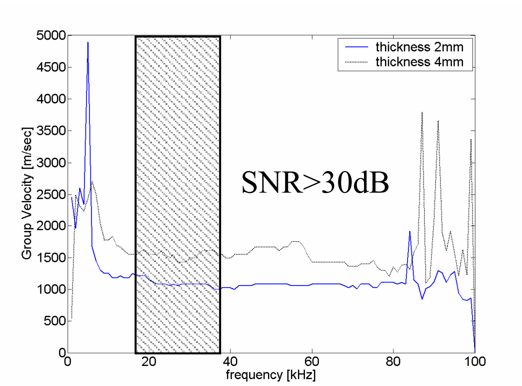


Fig. 4 Estimated group velocity when pipe thicknesses are 2mm and 4mm.

.Fig. 4 shows estimated group velocities when pipe thicknesses are 2mm and 4mm. When pipe thicknesses are 2mm and 4mm, the group velocities are 1200m/sec, and 1600m/sec respectively. Experimental result shows that if we measure group velocity using accelerometers, we can monitor the pipe thinning.

3. Conclusion

We have introduced a method that can effectively estimate the thickness of pipes using accelerometers. To verify theoretical formulation, plate and pipe experiments were carried out. In conclusion, the method in this study is very useful in monitoring pipe thinning.

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