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An Analysis of the Guided Wave Patterns in a Small-bore Titanium Tube by a Magnetostirctive Sensor Technique

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1. Introduction

The presence of damage or defects in pipes or tubes is one of the major problems in nuclear power plants. However, in many cases, it is difficult to inspect all of them by the conventional ultrasonic methods, because of their geometrical complexity and inaccessibility. The magnetostrictive guided wave technique has several advantages for practical applications, such as a 100-percent volumetric coverage of a long segment of a structure, a reduced inspection time and its cost effectiveness, as well as its' relatively simple structure.

One promising feature of the magnetostrictive sensor technique is that the wave patterns are relatively clear and simple compared to the conventional piezoelectric ultrasonic transducer. If we can characterize the evolution of the defect signals, it can be a promising tool for a structural health monitoring of pipes for a long period as well as the identification of flaws [1].

An in-bore guided wave probe was developed for an application to small bore heat exchanger tubes [2]. The magnetostrictive probe installed on the hollow cylindrical waveguide generates and detects torsional waves in the waveguide. This waveguide is expanded by the drawbar to create an intimate mechanical contact between the waveguide and the inside surface of the tube being tested.

In this paper, we analyzed the wave patterns reflected from various artificial holes in a titanium tube, which is used in the condenser in a nuclear power plant. The torsional guided waves were generated and received by a coil and a DC magnetized nickel strip as well as an in-bore guided wave probe. The wave patterns from various defects were compared with two different sensor techniques and a detectable limit of the defected was estimated.

2. Experimental methods

2.1 Preparation of Specimen

The titanium tubes, similar to the tubes in the condenser in a nuclear power plant are used for the specimen. The dimensions of the tubes are an outer diameter of 22.25 mm, thickness of 0.7 mm, and length of 6 m, which are used for the specimen. Several holes with a diameter of 1 mm were fabricated at a distance of 3.5 m from the tube end. A hole is equivalent to 1.5% CSA (cross sectional area) of the tube). A Ni strip width of 25.4 mm was wrapped and bonded along the circumference of the tube with an epoxy.

2.2 DC bias magnetization along the circumference for a small bore tube

A DC bias magnetization along the circumference of a tube is required for a generation of a torsional vibration mode, T(0,1). Generally, a circumferential magnetization of a magnetostictive strip can be achieved by moving a permanent magnet along a circumference. Practically, however, it is not easy for a tube with a small diameter. Alternatively a high DC current along the axial direction can generate a circumferential magnetization. An automotive battery charger that can supply more than 50 Amperes was used for a DC electric current source. In order to obtain a clear signal in the time domain, one cycle of the 128 kHz sinusoidal excitation was applied.

3. Results and discussion

Fig. 1 shows the ultrasonic waveforms obtained from the various holes in the titanium tube by a Ni strip sensor. Because of the strip sensor location from the tube end, multiple beam paths are possible, as shown in Fig. 1. There is no change or distortion in the waveform structure, except for a variation of the amplitude. The signal amplitude increases, as the number of holes increases from 0 ~ 5, i. e. as the defect size increases and a linear relationship is proposed, as shown in Fig. 2. Based on the signal amplitude by three times the nose level, the detectabiliby of this experimental condition was determined as approximately 0.5% CSA.

Fig. 3 shows that ultrasonic waveforms correspond to Fig. 1, but from an in-bore guided wave probe. The waveform structure is more complicated. We believe the complicated waveform is due to the multiple array structure of the probe.

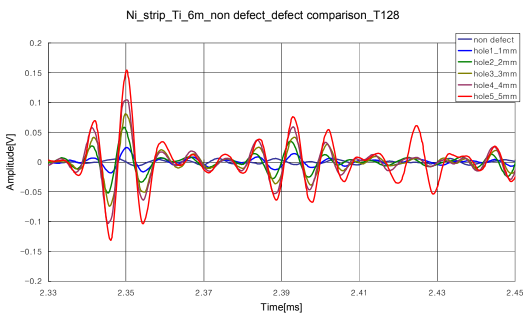

Fig. 1 Comparison of waveform of various defect sizes with Ni strip sensor. The number of holes is from 0 to 5 at the distance of 3.5 m from the tube end.

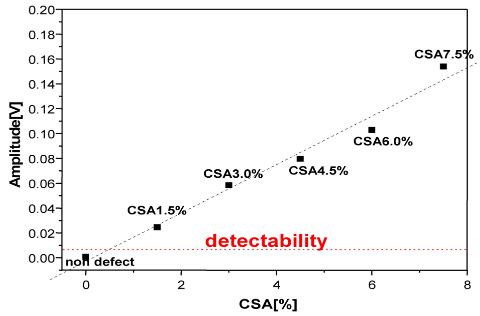

Fig. 2 Amplitude of various defect sizes with a Ni strip sensor. Detectability was determined based on the three times of the noise level.

It is also noted that there is no change or distortion of the waveform structure, except for a variation of the amplitude. The signal amplitude increases, as the number of holes increases from 0 ~ 5, i. e. as the defect size increases and a linear relationship was proposed, as shown in Fig. 2. The detectabiliby is estimated based on a signal amplitude by three times the nose level and determined as below 0.5% CSA. Because the Fe-Co-V alloy strip is used in the in-bore guided wave probe, a higher amplitude is estimated compared to the Ni strip sensor, which results in a good signal-to-noise ratio.

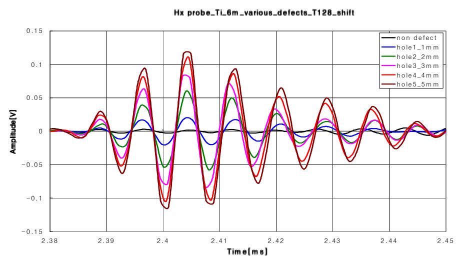

Fig. 3 Comparison of the waveform of various defect sizes with an in-bore guided wave probe. The number of holes is from 0 to 5 at the distance of 3.5 m from the tube end.

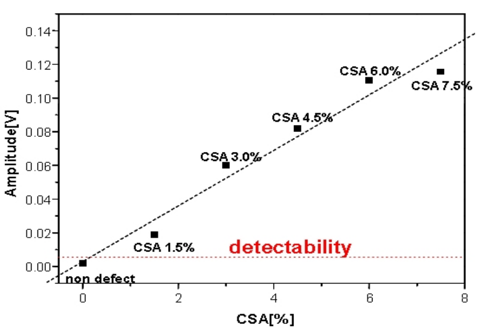

Fig. 4 A Plot of the wave amplitude of various defect sizes with an in-bore guided wave probe. Detectability was determined based on the three times the noise level.

Figs. 5 and 6 show a typical wave pattern by a Ni strip sensor and an in-bore guided wave probe respectively. As mentioned earlier, the signal pattern in Fig. 5 from the Ni strip sensor is very clear and simple. These signal characteristics can be a potential indicator for a structural health monitoring in a pipe experiencing a degradation and the evolution of a defect or aging.

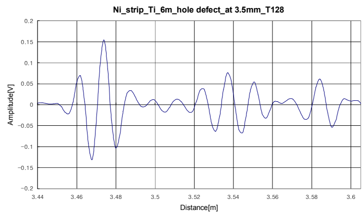

Fig. 5 Typical waveform by a Ni strip sensor.

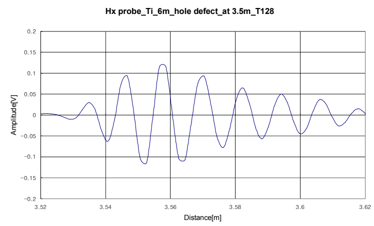

Fig. 6 Typical waveform by an in-bore guided wave probe.

Acknowledgements

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