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Effect of Alternating Excitation and Application of an In-Bore Magnetostrictive Transducer for a Long-range Guided Wave Inspection

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1. Introduction

There are several incidents regarding a leakage of pipes which are in the category of a safety class as well as a non-safety class in nuclear power plants. However, in many cases, because of their geometrical complexity and inaccessibility, it is difficult to inspect them by the conventional ultrasonic methods. The magnetostrictive transducer 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 relatively simple structure. Recently it has been found that the magnetostrictive properties of Fe-Co-V alloy showed superior to the conventional Ni strip. The guided wave signal amplitudes by the Fe-Co-V alloy strip are much higher than those of the Ni strip. However, the alternating excitation should be kept as low as possible to avoid unwanted vibration modes. In this paper, the effect of an alternating excitation on the DC bias magnetization of the Fe-Co-V alloy strip was investigated. In order to apply a DC magnetization along the circumference of a small bore tube, an automotive battery is used to bring the Ni strip to a saturated magnetization. In addition, an in-bore torsional guided wave probe was applied to an inspection of a heat exchanger or steam generator tubes.

2. Experimental methods and results

2. 1 An Effect of alternating excitation

Because the alternating excitation power should not exceed the DC magnetic bias in the strip there is a limitation for a high power electrical excitation. For the investigation to obtain an optimum parameter, an alternating excitation was varied by a serial connection of a variable potentiometer.

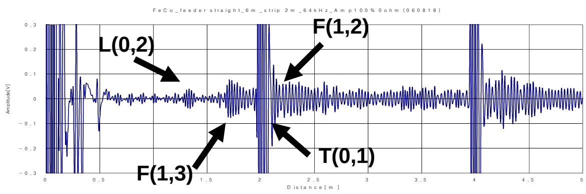
In order to investigate the effect of an alternating current when compared to a DC bias magnetization, a Fe-Co-V alloy strip was bonded to a straight carbon steel pipe with an outer-diameter of 63.5 mm, a wall thickness of 6.5 mm and length of 6 m. The strip was located at 1/3 of the pipe, so reflections from the pipe end appear every 2 m position.

2. 2 DC bias magnetization along the circumference for a small bore tube

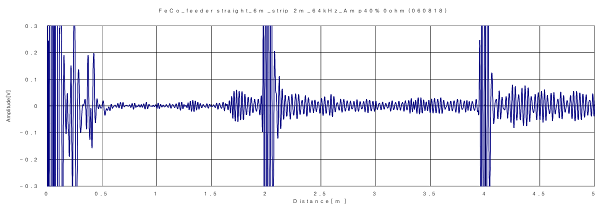
A DC bias magnetization along the circumference of a tube is required for a generation of a torsional vibration mode, T(0,1). Generally, a circumferential magnetization of a magnetostictive strip can be achieved by moving a permanent magnet along the circumference. Practically, however, it is not easy for a tube with a small diameter.

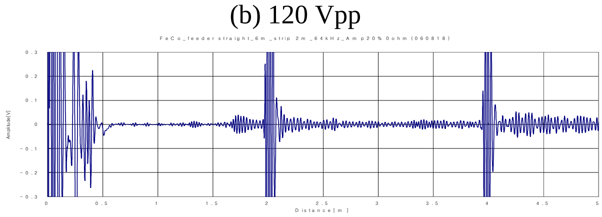
Alternatively a high current along the axial direction can generate a circumferential magnetization. A DC electric current source, such as an automotive battery or a DC power supply that can supply at least 50 Amperes of DC current can be used for this purpose. One should be careful so as to prevent the wires from overheating, thus one should not apply the DC current more than 4 second.

A 304 stainless steel tube for a heat exchanger with dimensions of an outer-diameter of 20.1 mm, wall thickness of 0.7 mm and length of 6 m was used for the experiment. An automotive battery of 200 Amperes was used for the circumferential DC bias magnetization.



(a) 300 Vpp


(b) 120 Vpp


(c) 60 Vpp

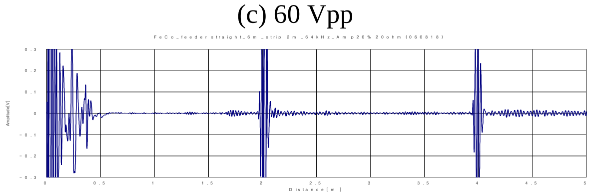

(d) 60 Vpp and 20 Ω attenuator

Fig. 1 Effect of alternating excitation.

The effect of an alternating magnetization is shown in Fig. 4. If the alternating voltage is 300 Vpp with a frequency of 64 kHz, an unwanted vibration mode, L(0,2), F(1,3), and F(1,2) modes are generated in addition to the T(0,1) mode. This can be seen from the group velocity dispersion curve.

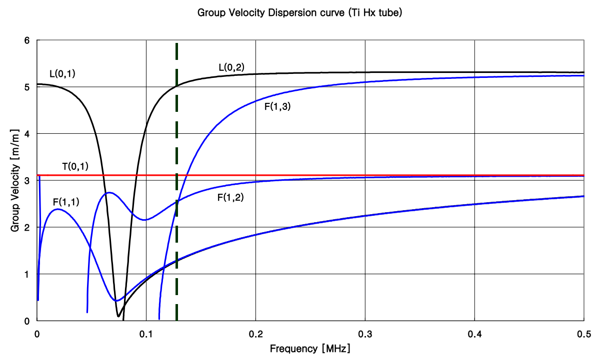


Fig. 2 Group velocity dispersion curves of a heat exchanger tube with an outer-diameter of 20.1mm and a wall thickness of 0.71mm (Material: Stainless Steel 304).

2. 3 In-bore torsional guided wave probe

In order to apply the torsional guided wave from the inside of a heat exchanger tube, a probe consists of a hollow cylinder waveguide, magnetostrictive strip, and drawbar mechanism [7]. 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. To allow for an expansion of the waveguide at the tip, the tip area is longitudinally slit at several orientations around the waveguide circumference. The torsional wave pulse generated by the magnetostrictive strip propagates towards the end of the waveguide inserted into the tube and is coupled to the tube through the mechanical contacts formed at the tip area and then it propagates along the length of the tube. The reflected signals are detected by the magnetostrictive transducer via a inverse process. A damping material is placed on the end of the waveguide opposite the inserted end to minimize the wave reverberations in the waveguide.

Fig. 3 shows the ultrasonic signals obtained from a stainless steel tube using an in-bore torsional guided wave probe. The dimensions of the tube are an outer diameter of 22.23 mm, wall thickness of 1.2 mm, and length of 6 m. The signals at and near the zero distance are those reflected from the probe tip and reverberating in the waveguide of the probe. The signal reflected from the far end of the tube is indicated as the 'tube end'. The dead zone caused by the tip reflected and reverberating signals in the probe was approximately 500 mm.

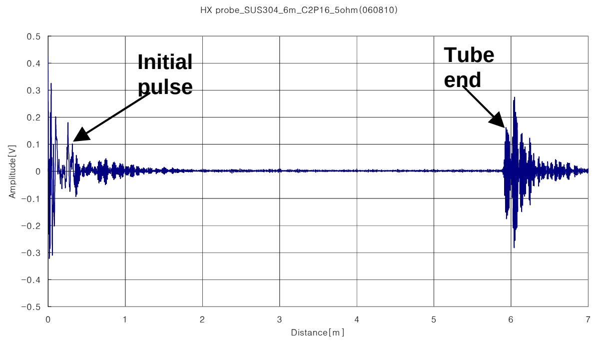


Fig. 3 Signal from stainless steel 304 heat exchanger tube using in-bore torsional guided wave probe.

3. Summary

a) The effect of an alternating excitation when compared to DC bias magnetization was investigated. Even though the Fe-Co-V alloy strip shows much higher signals then the Ni strip, one should be more careful when applying an alternating excitation. It is noted that the alternating excitation should be kept as low as possible to avoid unwanted vibration modes.

b) In-bore torsional guided wave probe was applied to a heat exchanger tube. The signal quality was not good when compared to the case of a DC magnetization along the circumference by using a high power DC supply. However, the in-bore guided wave probe can access the inside of a tube, so it can be used for a screening purpose for a heat exchanger inspection.

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