Feasibility Study on the Guided Wave Technique for Condenser Tube in NPP

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1. Introduction

The condenser tube is examined by the eddy current test (ECT) method to identify the integrity of the nuclear power plant. Because ECT probe is moved through the tube inside to identify flaws, the ECT probe should be exchanged periodically due to the wear of probe surface in order to remove the noise form the ECT signal. Moreover, it is impossible to examine the tube by ECT method because the ECT probe can not move through the inside due to the deformation such as dent.

Recently, the theory of guided wave was established and the equipment applying the theory has been actively developed so as to overcome the limitation of ECT method for the tube inspection of heater exchanger in nuclear power plant.

The object of this study is to know the feasibility of applying the guided wave technique to condenser tube in NPP.

2. Methods and Results

2.1 Guided Waves Technology and Instruments

Guided waves refer to elastic waves in ultrasonic and sonic frequencies that propagate in a bounded medium (such as pipe, plate, rod and so on) parallel to the plane of its boundary. The waves termed "guided" because it travels along the medium guided by the geometric boundaries of the wave. The velocity of the guided waves varies significantly with wave frequency and the geometry of the medium.

The magnetostrictive sensor developed by the Southwest Research Institute is a sensor that generates and detects guided waves electromagnetically in the material under non-destructive testing.

The magnetostrictive sensor is directly operable on structure made of ferrous materials and of non-ferrous materials by bounding a thin nickel to the structure under testing.

A schematic diagram of the magnetostrictive sensor and associated instruments (MsSR 2020D) for the generation and detection of guided waves is illustrated in Figure 1. The sensor is configured to apply a time varying magnetic field to the structure be under test and to pick up magnetic induction changes in the material caused by the guided wave.

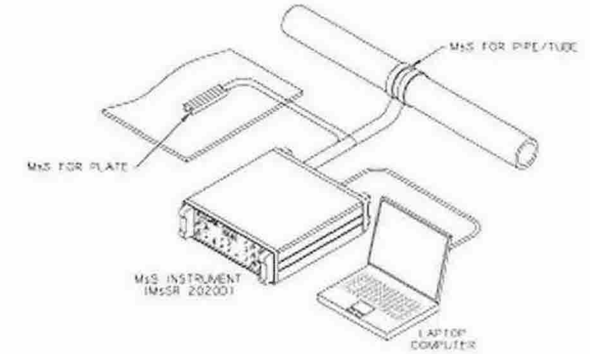

Figure 1. Schematic diagram of the magnetostrictive sensor and associated instruments

2.2 Torsional Guided Wave Mode

The guided wave mode is controlled by the relative alignment between the direct current bias magnetic field and the time varying magnetic field produced by the magnetostrictive sensor.

For torsional guided wave mode in tube, the alignment is perpendicular. The guided wave propagate in the direction parallel to the direction of time varying magnetic field produced by the magnetostrictive sensor

The fundamental torsional guided wave mode is not dispersed and does not interact with liquid inside the tube.

The disadvantage of the torsional guided wave magnetostrictive sensor is the requirement for direct physical access to the tube surface for bonding of the thin ferromagnetic layer. [1]

The velocity of torsional guided wave is 3,100 m/s in condenser tube material.

2.3 Guided Wave Mode Analysis

To show the magnetostrictive sensor system (MsSR 2020) capability, the artificial flaws placed at the twelve locations along the condenser tube in Figure 2.

The tube made of Titanium Gr. 2 was 24 mm outside diameter with 0.7 mm wall and was 3 m long.

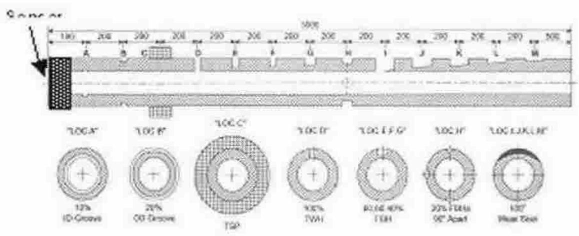

Figure 2. Flawed Condenser Tube

The data were acquired with the magnetostrictive sensor positioned at the tube left end in figure 2.

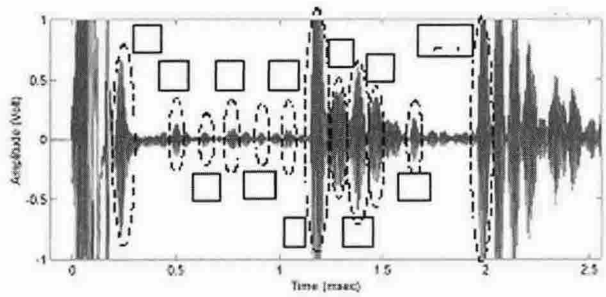

Figure 3. 128 kHz Torsional Mode guided wave data obtained from condenser tube specimen

The data in figure 3 demonstrate the guided wave's ability to inspect the entire condenser tube circumference from a single sensor location. Even though, the "A" flaw in Figure 2 was not detected because of the magnetostrictive sensor dead zone with about 250 mm.

The guided waves are very useful for inspecting condenser tube for various shape and depth flaws.

3. Conclusion

The ECT method for condenser tube inspection is very tedious work and takes about two weeks during the overhaul in NPP. The cost and time of condenser tube inspection is continuously required to be decreased without reducing integrity of the condenser tube.

Guided wave technique using magnetostrictive sensor is possible quickly and economically for inspecting condenser tube with 18 m long for defects from a single test location. But this experiment was conducted the outer of the condenser tube. In site use, it is recommended that in-core type magnetostrictive sensor and examination procedure be developed to inspect the condenser tube.

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