EMAT Technology for a Wall Thickness Measurement of an Oxide Scaled Carbon Steel Piping

H.K. Jung [a], Y.M. Cheong [a]
[a] Korea Atomic Energy Research Institute (KAERI), PO Box 105, Yusong, Daejon 305-600, Korea

1. Introduction

EMAT(Electro-Magnetic Acoustic Transducer) uses a combination of static and dynamic magnetic fields to convert electrical energy into acoustic energy. The static magnetic field is induced by permanent magnet and the dynamic magnetic field is produced by the electrical coil.

There are two contributions from an EMAT transducer that generate an ultrasonic signal. The first contribution is the Lorentz Force which is the most commonly utilized contribution within the NDT industry. The second contribution from an EMAT transducer utilizes the magnetostrictive force, which is less well-known.

The sample that will be examined within this paper involves the presence of a high temperature oxide scale that is commonly found on the external walls of boiler tubes. The high temperatures, in excess of 500°C or 1000°F, can cause the steam and flue gas constituents to react with steel to form a brittle iron oxide called magnetite on the inside and outside surfaces of a steel boiler tubing. The magnetostrictive EMAT can produce ultrasonic signals under a specific condition, such as, the presence of magnetic conductive materials.

Hence, the objective of this study is to investigate the feasibility of a magnetostrictive EMAT for an effective inspection of material loss for a nuclear power piping system.

2. Design of the EMAT

Figure 1 illustrates the difference in a signal amplitude of the magnetostrictive EMAT and Lorentz EMAT at the same lower strength magnetic field level. At lower level magnetic fields, the magnetostrictive contribution has a greater amplitude output.

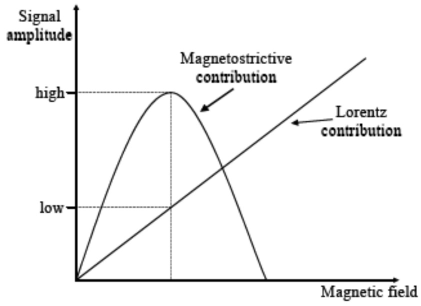

Figure 1 Comparison of the magnetostrictive and Lorentz contributions.

This magnetostrictive EMAT propagates shear horizontal waves into the target part through a high temperature oxide scale. It does this through the combination of static and dynamic magnetic fields produced from the permanent magnet and current induced coil, respectively, as shown in Figure 2. The scale is aligned along the static magnetic field B_s generated by the permanent magnet. The dynamic magnetic field B_d is induced from the current that runs through the flat coil. B_d causes the scale surface to be pulled radial outward and inward as the transducer is pulsed with an alternating electrical current. The dynamic magnetic field B_d pulses the scale, which in turn produces a normal incident SH wave within the pipe.

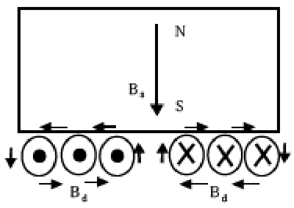

Figure 2 Principle of the SH wave generation

3. Thickness Measurement of the EMAT

Tests performed with a scaled boiler tube sample, the EMAT transducer and ultrasonic pulser/receiver system operated by Winspect S/W indicate that the minimum thickness under ideal test conditions is about 0.2 mm.

Since the scale on a pipe can vary in thickness, the EMAT transducer does not produce a set center frequency. Instead, this frequency varies as the scale thickness varies. The typical center frequency of this EMAT is 5MHz but could range from 2 to 8MHz depending on the scale thickness.

A typical EMAT waveform is shown in Figure 3, representing a shear wave wall thickness measurement of a 7.6 mm boiler tube with a typical ultrasonic pulser/receiver system.

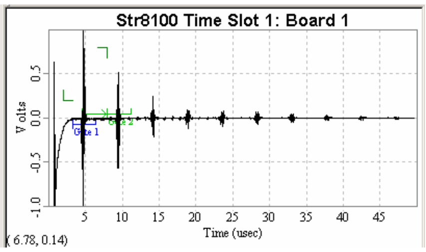

Figure 3 Typical EMAT waveform

For a comparison, Figure 4 shows the waveform obtained from the same pipe sample using a conventional dual element 5 MHz piezoceramic transducer that generates a longitudinal wave.

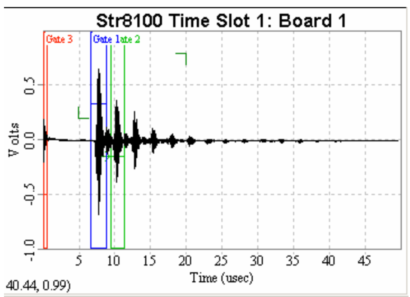

Figure 4 Typical duel-element piezoelectric transducer waveform

The EMAT can produce a SH wave without a mode conversion. The SH waves provide a greater resolution than a longitudinal wave due to a shorter wavelength, and can thus measure a thinner minimum wall at a given frequency.

4. CONCLUSIONS

It is possible to conclude that the magnetostrictive EMAT is a useful inspection tool for a carbon steel piping if the specific coating is provided. The EMAT saves an inspection time because a scale removal is eliminated from the inspection process. Scanning time is also reduced since no couplant is required for an inspection. If an additional precision is required, the EMAT can be used for a full surface coverage to pinpoint areas of concern and further, a spot inspection with an ultrasonic transducer can be performed.

Acknowledgements

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References

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