Pulsed Electromagnetic Thickness Evaluation of a Ferro-magnetic Plate

Hyun-Kyu Jung *, Yong-Moo Cheong
Korea Atomic Energy Research Institute (KAERI), PO Box 105., Yuseong, Daejeon, 305-600, Korea
**Corresponding author: hkjung@kaeri.re.kr*

1. Introduction

EMAT (Electro-Magnetic Acoustic Transducer) is a non-contact transducer that generates and detects the ultrasonic waves in electrically conductive materials. EMATs can be designed to generate various wave modes such as a Rayleigh wave, a Lamb wave and a shear horizontal (SH) wave. As the coupling between the EMAT and the sample is electromagnetic, EMAT is relatively insensitive to a surface condition by which a piezoelectric ultrasonic signal can be affected. [1]

EMAT uses a combination of static and dynamic magnetic fields to convert electrical energy into acoustic energy. The dynamic magnetic field is produced by an electrical coil and the static magnetic field is induced by a permanent magnet which makes it difficult to inspect the steel material due to an immobility of magnetic interaction.

The sample that will be examined within this paper is a ferro-magnetic material such as a carbon steel in order to consider the coupling of Lorenz force, Magnetization force and Magnetostriction force for an effective inspection of a metal loss or a corrosion detection for a nuclear component under a high temperature and radiation environment.

The purpose of this study is to investigate the feasibility of a pulsed EMAT technology for an automated inspection of a carbon steel piping with no water.

2. Design of the pulsed EMAT

The popular shape of electromagnet is the solenoid type. The magnetic field from the electromagnet has the radial and the normal components, which induce the Lorentz forces along the normal and radial directions.

In carbon steel, the Magnetization force(F_M) and the Magnetostriction force(F_{MS}) as well as the Lorentz force(F_L) occur together. The normal direction forces (F_M and F_L) cancel out and the shear wave (F_{MS}) along the radial direction can generate and detect ultrasound effectively. [2] Modeling of an electromagnet by Ansoft software was used for simulating the magnitude and the distribution of an induced magnetic field on the core surface of an electromagnet. The result of modeling was shown in Figure 1.

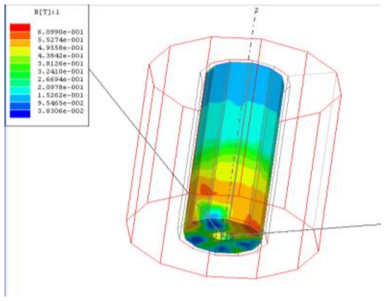


Fig. 1 Modeling of the induced magnetic field (B) on the core surface of an electromagnet

A photograph of fabricated sensor was shown in Figure 2.

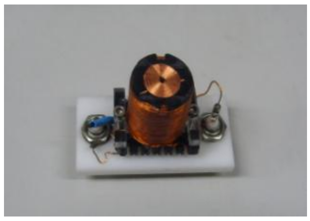


Fig. 2 Photograph of the pulsed EMAT sensor

3. Pulsed EMAT measurement of the steel plate

3.1 Experimental system of Pulsed EMAT

This EMAT consisted of a electromagnet with 300 Gauss of magnetic field and a pan-cake coil was connected to a high power ultrasonic gated amplifier system RPR-4000 with 8 kW tone burst signal to obtain the maximal output power. EMAT measurements were performed with a steel plate shown in Figure3.

A pulsed EMAT transducer used for this experiment is a self fabricated sensor having a sensing coil diameter of 15 mm and a magnetizing coil of 0.6 mm diameter and 400 turns . For the enhanced sensitivity, an impedance matching of 4.7 nF and a frequency matching of 2.3 MHz as well as a frequency filter were used as shown in Figure3. A pulsed magnetization was achieved by the own designed circuit and a delay trigger was applied to match a force interaction between the magnetic field of an electromagnet and the eddy current of a sensing coil.

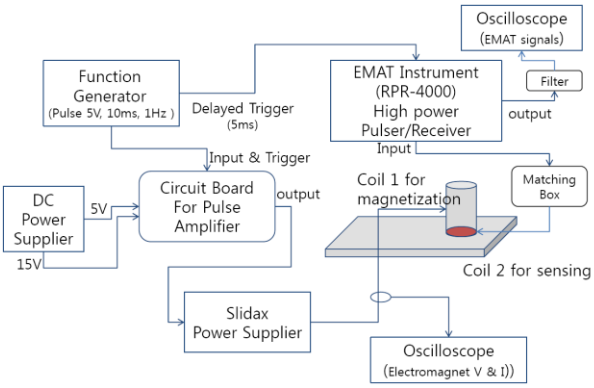


Fig. 3 Experimental setup for a pulsed EMAT

3.2 Test Results

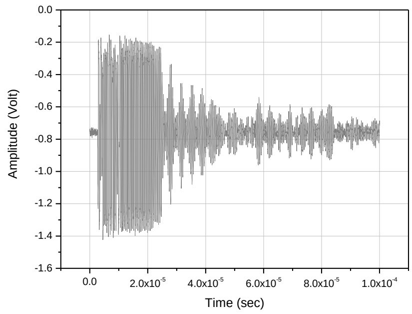
A typical steel plate which has various thicknesses ranging 1 to 10 mm with 1mm of step is shown in Figure 4,

A pulsed EMAT which generated a shear horizontal (SH) waves was applied to the target material through a surface movement for a wall thickness measurement of a steel plate.

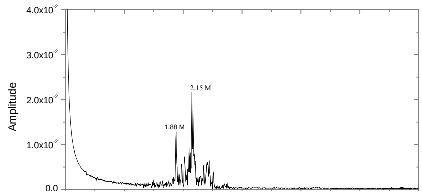
Fig. 4 A step wedge of carbon steel

Figure 5a shows that the EMAT ultrasonic signals from the back wall of 6mm were characterized with repetitious amplitudes of 3.7 μs intervals. This is the SH wave characteristics which show the velocity of 3.24 mm/sec and the better sensitivity than those from a back wall of non-magnetic material.

Another feature of the EMAT signals showed a few peak in the frequency domain from the back wall. This shows the peak resonance with a 2.15 MHz which is related to the excited tone burst signal as shown in figure 5b. A SH wave can provide an accurate tool to detect a wall thickness due to its property of a surface movement by the electromagnetic forces.



(a)



(b)

Fig. 5 Ultrasonic signal waveform (a) and frequency spectrum (b) from the back wall of steel plate

4. Conclusions

The EMAT technique which provides a good resolution from a back wall and needs no couplant for generating the ultrasound on a contact surface, could be a convenient inspection method for the measurement of corrosion and erosion in a carbon steel piping in spite of a lower conversion efficiency. The pulsed EMAT can be applied to a ferromagnetic component for an automated scanning without a strong interaction by a magnetic force. EMAT is also needed to develop the cross interactive instrument between the probe movement and the magnetizing time for automation to the corrosion sensitive component.

Acknowledgements

This work was supported as a part of the long-term nuclear R&D program supported by the Minister of Education, Science and Technology of Korea.

REFERENCES

[1] H. K. Jung, K. C. Heo, Y. M. Cheong, Non-contact Thickness Measurement of a Non-magnetic Plate using EMAT, Spring Conference of Korean Nuclear Society, 2008.
[2] M. Hirao and H. Ogi, EMATS for Science and Industry, Kluwer Academic Publishers, 2003.