Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

Feasibility of Electromagnetic Acoustic Evaluation for Quality Test of a Plate-type Nuclear Fuel

Hyun-Kyu Jung *, Yoon-Sang Lee, 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

Most research and test reactors use the nuclear fuel plates which are consisted of a fuel core in aluminum alloy. Recently KAERI signed a deal with the Jordan Atomic Energy Commission to build the research reactor and have to supply the plate-type nuclear fuels. For the demands of world market, KAERI started the research and development of the plate-type fuel elements and endeavored to achieve a localization of fuel fabrication.

For the inspection of plate-type fuel elements to be used in Research Reactors, an immersion pulse-echo ultrasonic technique was applied. [1] This inspection was done with water, so a nuclear fuel was immersed to be prone to corrosion and needed to have time and cost due to an additional process.

The sample that will be examined within this paper is a non-ferromagnetic material such as aluminum which has a good acousto-elastic property, for an effective inspection of a bond quality for a nuclear fuel under a manufacturing environment.

The purpose of this study is to investigate the feasibility of an EMAT technology for an automated inspection of a nuclear fuel without water.

2. Design and Fabrication of the 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 Aluminum plate, the Lorentz force(F_L) occur alone as there is no magneto-elastic contribution which is happen in steel. The shear wave along the radial direction can generate and detect ultrasound effectively. A sketch of EMAT was shown in Figure 1.

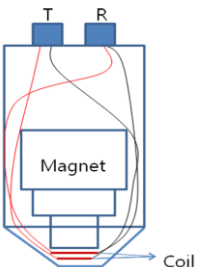


Fig. 1 A sketch of EMAT

A photograph of fabricated sensor was shown in Figure 2.

Fig. 2 Photograph of the transmit-receive EMAT sensor

3. EMAT measurement of the Aluminum plate

3.1 Experimental system of EMAT

This EMAT consisted of a permanent magnet with 3400 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 on Al plates shown in Figure3.

An EMAT transducer used for this experiment is a self fabricated sensor having a exciting coil diameter of 12 mm and a sensing coil of 8 mm diameter and 20 turns. For the enhanced sensitivity, an impedance matching of 6.9 nF and a frequency matching of 1.5 MHz were used as shown in Figure 3.

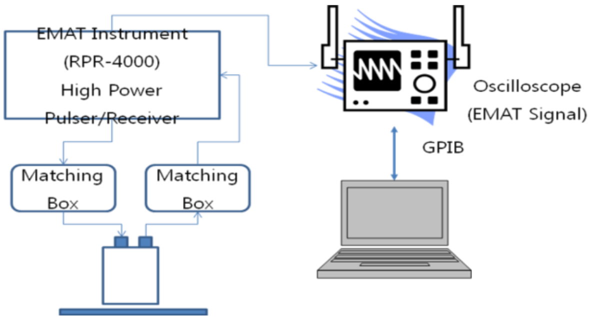


Fig. 3 Experimental setup for an EMAT

3.2 Test Results

Some aluminum plates which have various thicknesses of 10 mm and 5mm and 2mm were used for evaluation of the thickness effect. A plate type nuclear fuel was simulated with 2mm Al sheet which are shown in Figure 4,

An 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 aluminum plate.

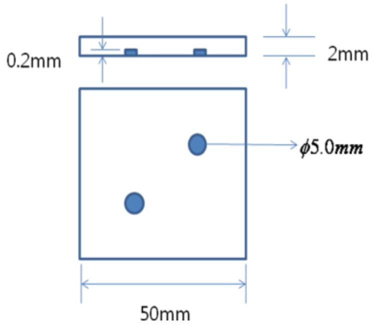
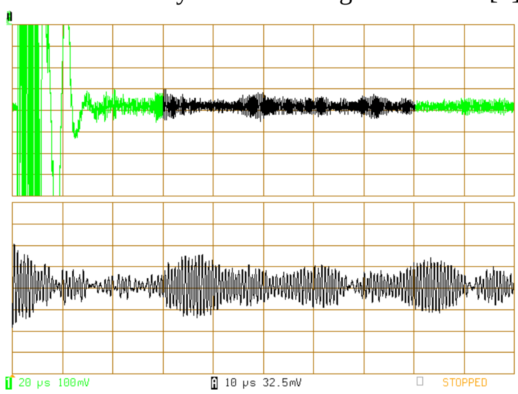


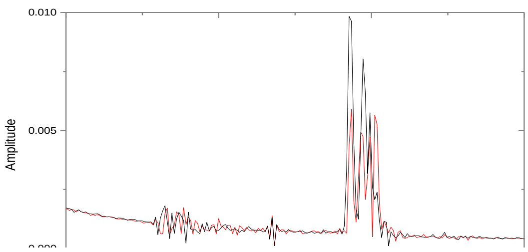
Fig. 4 Aluminum specimen with artificial defects

Figure 5a shows that an EMAT ultrasonic signal and a zoomed signal which is averaged 100 times from the back wall of 2mm were characterized with repetitious amplitudes of around 1.0 to 1.2 μs intervals. The EMAT system paralyzes times of approximately less than 1 μs . This means that the first back wall of ultrasonic shear wave echo can only be observed for aluminum plates that are thicker than 2mm. From this difficulty, the magnitude fast Fourier transform (FFT) is needed for evaluation of bond quality of plate-type nuclear fuel with 2mm thick. [2]

The frequency feature of the EMAT signals showed a few peak in the frequency domain from the back wall. This shows the peak splitting in around 1.5 MHz which is corresponded to a difference in the two shear wave velocities due to the anisotropy of rolled Al sheet 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. [3]



(a)



(b)

Fig. 5 Ultrasonic signal waveform (a) and frequency spectrum (b) from the back wall (black) and artificial defect (red) of Al plate of 2mm thick

4. Conclusions

The EMAT technique show the difficulty of time resolution of 2mm Al sheet, however it provides a better resolution from magnitude fast Fourier transform of a back wall signal and needs no water for generating the ultrasound on a contact surface, could be a convenient inspection method for the measurement of a bond quality of plate-type nuclear fuel in spite of a lower conversion efficiency. The enhanced EMAT can be applied to a plate type aluminum material for an automated scanning without immersion. EMAT is also needed to develop the high resolution instrument for automated inspection process of nuclear fuel.

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] P. Katchadjian, C. Desimone, C. Ziobrowski, A. Garcia, “Detection of Delamination Defects in Plate Type Fuel Elements Applying an Automated C-Scan Ultrasonic System,” 2002 International Meeting on Reduced Enrichment for Research and Test Reactors, Argentina, Nov. 3-8, 2002

[2] S. Dixon, C. Edwards, S.B. Palmer, “High accuracy non-contact thickness gauging of aluminum sheet using EMATs,” Ultrasonics 39 pp 445-453, 2001

[3] 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.