Electromagnetic Acoustic Test of the Artificial Defects for a Plate-type Nuclear Fuel

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1. Introduction

Most research and test reactors use the nuclear fuel plates which are consisted of a fuel meat in aluminum alloy. Last year, 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 the plate-type 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 under immersion condition, 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 is a non-ferromagnetic material such as aluminum with a good acousto-elastic property, which requires 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 Electromagnetic Acoustic Transducer (EMAT) technology for an automated inspection of a nuclear fuel without water.

2. Design and Fabrication of the EMAT

The popular shape of permanent magnet is the round type. The magnetic field from the permanent magnet has the normal components, which induce the Lorentz forces along the radial directions. [2]

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 and photograph of fabricated sensor was shown in Figure 1.

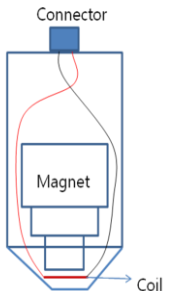


Fig. 1 Sketch and Photograph of EMAT

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. For the Ultrasonic C-scan data acquisition, three-axis ultrasonic system including motion control box and an acquisition computer with A/D board and motion control board controlled by Winspect software were used. [3]

An EMAT transducer used for this experiment is a self fabricated sensor having an exciting and sensing coil diameter of 12 mm and 32 turns. For the enhanced sensitivity, a frequency matching of 3.5 MHz were used.

Fig. 2 Experimental setup for an EMAT

3.2 Test Results

A plate type nuclear fuel was simulated with 2mm Al sheet. Three aluminum plates were used for evaluation of the defect size and depth effect shown in Figure 3.

An EMAT which generated a shear horizontal (SH) waves was applied to the target material through surface movement for detection of Flat Bottom Holes (FBH) of an aluminum plate.

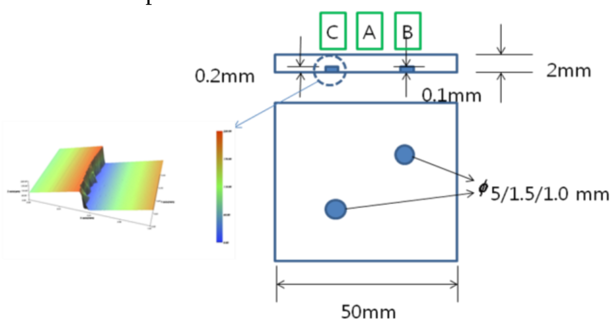
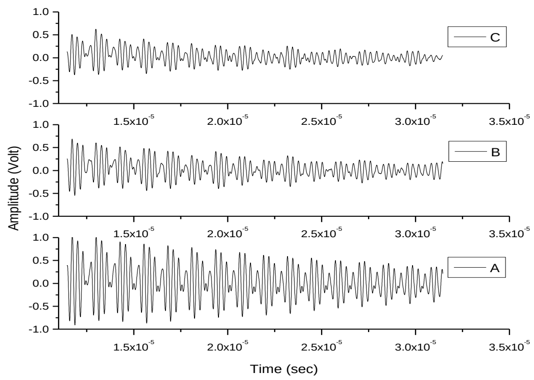


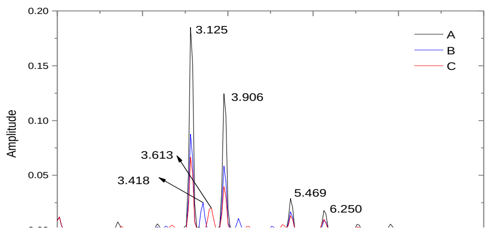
Fig. 3 Typical specimen with artificial defects

Figure 4(a) showed that an EMAT ultrasonic signal and a zoomed signal which was averaged 100 times from the back wall of 2mm were characterized with repetitive amplitudes of 1.28 μs intervals. Signal patterns were changed depending on the different position of EMAT sensor. Position A is on the defect-free surface and Position B is above the 0.1mm deep FBH and Position C is above the 0.2mm deep FBH as shown in Fig.3. Ultrasonic signals at the deeper defect position showed the lower amplitude and the worse regularity.

For the further evaluation, the magnitude fast Fourier transform (FFT) was applied for assessing the bond quality of plate-type nuclear fuel with 2mm thick.[2] Figure 4(b) showed a fundamental resonant peak and a few successive resonances in the frequency domain from the back wall. The frequency interval of 0.78 MHz seemed to be related to the wall thickness and the peak spectrums have lower amplitude and in addition, a tiny higher frequency signal after a fundamental peak occurred due to FBH.



(a)



(b)

Fig. 4 (a) Ultrasonic signal waveform and (b) frequency spectrum from the back wall (black) and artificial defect (blue and red) of Al plate of 2mm thick

EMAT ultrasonic C-scan data were acquired with non-contact configuration. A motion driver made noises which prevent the signal acquisition. After solving the noise problem, EMAT non-contact scanning was performed and C-scan image was obtained as shown in Fig. 5. Minimum size of detection is 1.5mm dia. FBH based on the C-scan image with this system. The size of 5mm and 1.5mm FBH defects appeared to be a size of coil (12mm). And the deeper size of defect was tested, the lower amplitude of ultrasonic signal was shown due to scattering of an artificial defect.

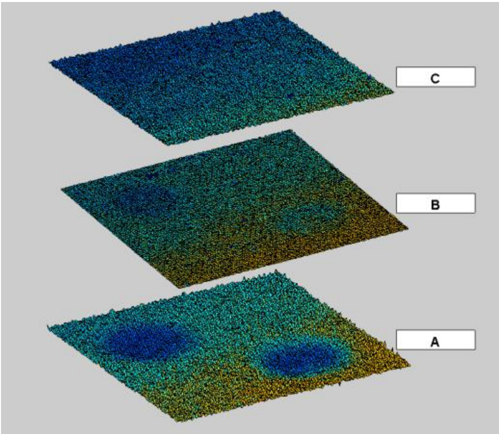


Fig. 5 Ultrasonic C-scan of Al plates with (a) FBH of Φ 5mm (b) FBH of Φ 1.5mm (c)FBH of Φ 1.0mm.

4. Conclusions

The EMAT SH wave showed a different signal pattern from Al plate with several defects for the measurement of a bond quality of plate-type nuclear fuel without water in spite of lower conversion efficiency. It also provides a better resolution from magnitude fast Fourier transform of a back wall signal. The non-contact EMAT scanning was applied to a plate type aluminum material for automation with sensitivity of 1.5mm dia. defect. EMAT is also needed to develop the high resolution sensor and instrument for automated inspection process of nuclear fuel.

Acknowledgements

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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, Y. S. Lee, Y. M. Cheong, “Feasibility of Electromagnetic Acoustic Evaluation fro Quality Test of a Plate-type Nuclear Fuel,” Autumn Conference of Korean Nuclear Society, 2010.