Feasibility Test of Ultrasonic Waveguide Sensor Assembly for Under-Sodium Viewing in Sodium-cooled Fast Reactor

Young-Sang Joo, Sa-Hoe Lim, Chang-Gyu Park, Jae-Han Lee
KAERI, 150 DukJin-Dong, YuSeong, Daejeon, Korea, ysjoo@kaeri.re.kr

1. Introduction

The visual inspection of reactor internal structures should be applied in accordance with the ASME XI Division 3 which contains the rules and guidelines for an in-service inspection (ISI) of a sodium-cooled fast reactor (SFR) [1]. As liquid sodium is opaque to light, a conventional visual inspection can not be used for observing the internal structures under a sodium level. Under-sodium ultrasonic inspection has been widely developed for an in-service inspection of the reactor internal components and structures of SFR [2, 3]. Recently a new ultrasonic waveguide sensor has been developed [4, 5]. The waveguide sensor visualization technology is to have an ultrasonic transducer over the reactor head and a transmission of the ultrasonic waves using some specific waveguides still in the hot sodium, as shown in Fig. 1. In this study, the ultrasonic waveguide sensor assembly has been designed and manufactured. Propagation characteristics of the ultrasonic wave in the waveguide sensor are evaluated. Under-water C-scan imaging tests are carried out to confirm the feasibility of the ultrasonic waveguide sensor.

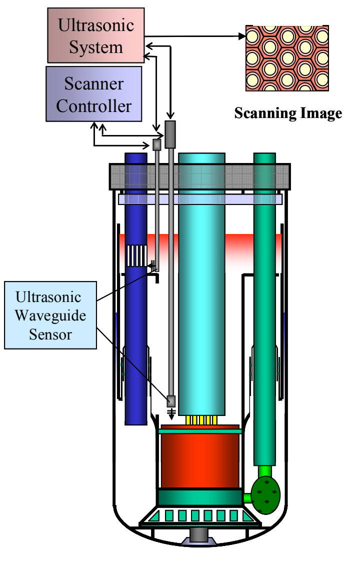
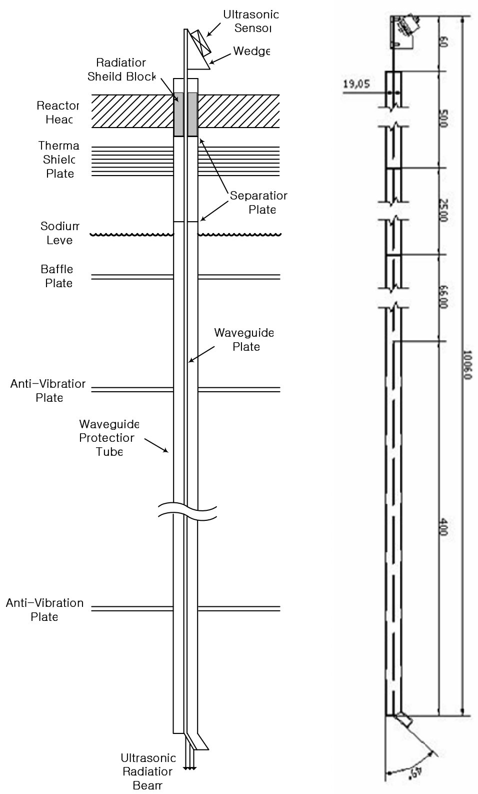


Figure 1. Visual inspection of reactor internals using ultrasonic waveguide sensor

2. Design and Manufacture of Ultrasonic Waveguide Sensor Assembly

Waveguide sensor assembly was designed for an actual application to an under-sodium visualization of the reactor internal structures of SFR. Figure 2 shows a schematic design of the waveguide sensor assembly and a detailed drawing of a mock-up waveguide sensor. Waveguide sensor has a slender cylindrical structure, and it is vertically supported at the rotating plug of the reactor head, and horizontal anti-vibration support plates are installed outside the tube to support the tube from the horizontal vibration induced by the sodium flow. Waveguide sensor assembly is made up of an ultrasonic transducer, a wedge, a waveguide strip plate, an acoustical shielding tube, a steel radiation shielding block, and a separation pad. Waveguide strip plate guides the A_0 Lamb wave. To prevent an energy loss taking place due to a liquid contact, the waveguide strip plate is enclosed within an acoustical shielding tube until the point of a radiation beam emission is reached. The used ultrasonic transducer is a commercial PZT sensor. Variable angle liquid wedge is designed to produce A_0 mode Lamb wave in a low frequency range.



(a) Schematic design (b) Drawing
Figure 2. Waveguide sensor assembly

3. Experimental Feasibility Test

An experimental facility was setup for the feasibility test of the waveguide sensor technology, as shown in Fig. 3. It consists of a 3-axis scanner, a high power ultrasonic system (RITEC RAM-10000), a computer, a

Lecroy oscilloscope and a waveguide sensor assembly. High power pulse generation is necessary to send the ultrasonic signal to the end plate of the waveguide sensor with a 10m distance. The transducers use a commercial PZT sensor (0.5 inch diameter and 1 MHz). The Winspect^{TM} software was used for the C-scan imaging.

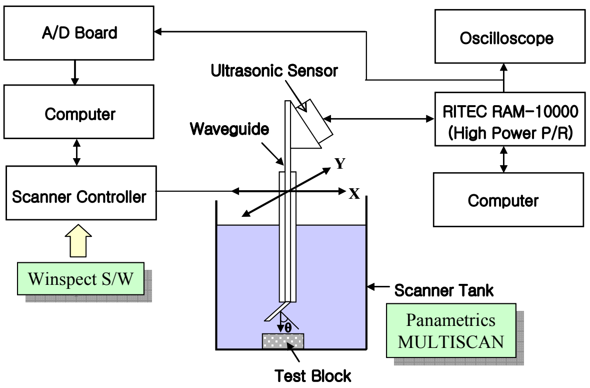
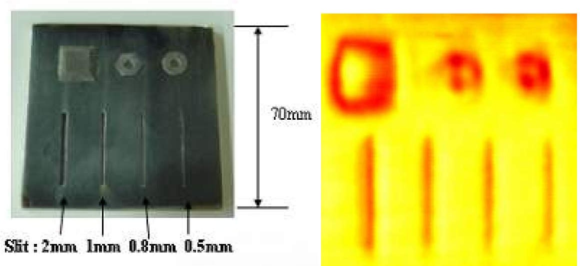
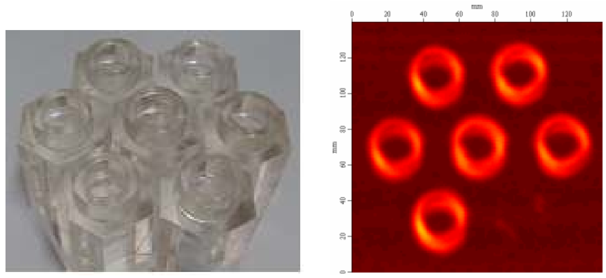


Figure 3. Experimental setup

The feasibility for the under-sodium visualization using a waveguide sensor is evaluated by a C-scan imaging test with a blind target under water. A 10 m long mock-up waveguide sensor assembly with a shield tube was manufactured for a comparison of the C-scanning resolution. The test targets were used for the blind test. The first target was a rectangular plate with four slits of different widths (2 mm, 1 mm, 0.8 mm and 0.5 mm) and three loose parts (stepped plate, small nut and washer) on the surface. The second target was a mock-up of a reactor core. The loose part reflectors were partially identified and also the slits were clearly resolved in the image, as shown in Fig. 4. It was verified that a spatial resolution of the C-scan image for the detection of a surface defect was less than 2 mm. In the second verification test, a C-scan experiment for the mock-up of a reactor core was performed. A bottom right sub-assembly in the core mock-up target was intentionally deformed to check on the detection ability of a distortion of the reactor core. Figure 5 shows the C-scan image for the upper part of the core mock-up. This result demonstrates the visualization mapping ability of a reactor core and the detection ability of a deformed sub-assembly for a reactor core at a 10m distance by using the developed waveguide sensor technology.



(a) test target (b) C-Scan image
Figure 4. Visualization image of test target with slits and loose parts


(a) core mock-up (b) C-scan image
Figure 5. Visualization image of reactor core mock-up using waveguide sensor

4. Conclusion

A plate-type ultrasonic waveguide sensor and ultrasonic visualization technique has been developed for an under-sodium visualization of a sodium-cooled fast reactor. An ultrasonic waveguide sensor assembly has been designed and manufactured. The possibility of the ultrasonic waveguide sensor has been verified by C-scanning experiments in water. As the C-scanning resolution result of the blind test, a precision of less than 2 mm was achieved. The feasibility of the waveguide sensor technique was successfully demonstrated for a visual inspection of reactor internals.

ACKNOWLEDGEMENT

This study was supported by the Korean Ministry of Education, Science & Technology (MEST) through its National Nuclear Technology Program.

REFERENCES

[1] ASME B&PV Code, Section XI, Division 3, “Rules for In-service Inspection of Nuclear Power Plant Component,” 1992.
[2] G. Seed, “In-Service Inspection and Monitoring of CDFR,” Nucl. Energy, Vol. 25, No.2 Apr., pp. 129-135, 1986.
[3] J.A. McKnight, et al., “Recent Advanced in the Technology of Under-Sodium Inspection in LMFBRs,” Liquid Metal Engineering and Technology, BNES, London, pp 423-430. 1984.
[4] Y.S. Joo and J.H. Lee, “Beam Steering Technique of Ultrasonic Waveguide Sensor for Under-Sodium Inspection of Sodium Fast Reactor,” ICONE 13-50340, 2005.
[5] Y.S. Joo, S.H. Kim and J.H. Lee, “Under-Sodium Inspection Techniques for Reactor Internals of KALIMER-600 using Ultrasonic Waveguide Sensor,” Proceedings of 2005 Autumn Conference on the Korean Nuclear Society, 2005.