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Performance Tests of Ultrasonic Waveguide Sensor Module for Under-Sodium Visualization of a Sodium-cooled Fast Reactor

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1. Introduction

As liquid sodium of a sodium-cooled fast reactor (SFR) is opaque to light, a conventional visual inspection can not be used for observing the internal structures under a sodium level. Under-sodium visualization techniques using ultrasonic immersion sensors and waveguide sensors have been developed for the inspection of the reactor core and internal components in the SFR [1, 2]. Recently a new ultrasonic waveguide sensor has been developed [3, 4]. The waveguide sensor visualization technology is to have an ultrasonic transducer over the reactor head and a transmission of the ultrasonic waves using some plate waveguide still in the hot sodium, as shown in Fig. 1. In this study, the possibility of applying the ultrasonic waveguide sensor to the under-sodium visual inspection has been investigated by the experimental test. For the application of the waveguide sensor technology to the under-sodium visualization of SFR, the Under-Sodium MultiVIEW imaging program is developed by using a LabVIEW graphical programming language. The sodium test facility with a glove box system and a sodium tank is designed and manufactured to carry out the performance test of ultrasonic waveguide sensor in sodium environment condition.

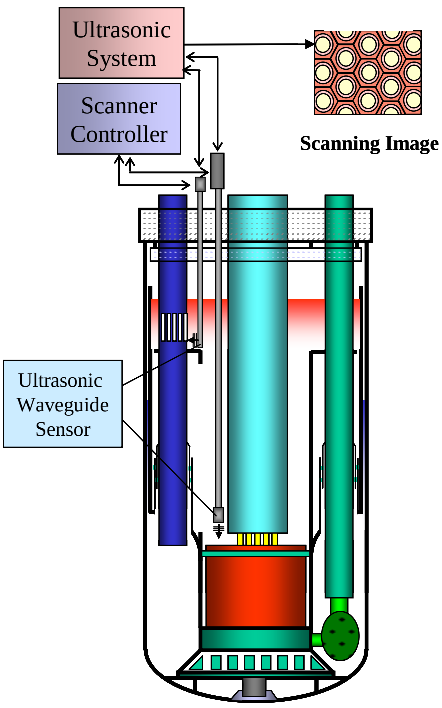


Figure 1. Under-sodium visual inspection of reactor internals using ultrasonic waveguide sensor

2. Ultrasonic Waveguide Sensor Module

Waveguide sensor module was designed for an actual application to an under-sodium visualization of the reactor internal structures of SFR. Figure 2 shows a manufactured 10 m long waveguide sensor module. Waveguide sensor module is made up of an ultrasonic transducer, a wedge, a waveguide strip plate, an acoustical shielding tube. 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. A liquid wedge and a Teflon wedge are designed to produce A_0 mode Lamb wave in a low frequency range.

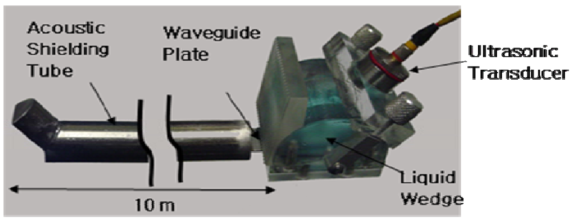
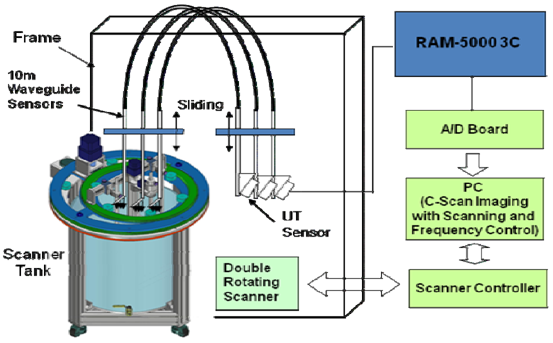


Figure 2. Waveguide sensor modules

3. Experimental Setup and Performance Test

An experimental facility was setup for the performance test of the waveguide sensor modules. The double rotation scanning system with 3 channel 10m waveguide sensors and the frame for performance test of waveguide sensor has been designed and manufactured. Figure 18 shows the ultrasonic C-scan system hardware with a double rotation scanner. The double rotating ultrasonic C-scan system is composed of a double rotation scanner, a scanner driving module, a high power ultrasonic pulser/receiver (RITEC RAM-10000), a LeCroy oscilloscope, a signal processing module and three channel waveguide sensors. A double rotation scanner is to position and control the waveguide sensor by using electric step motors. 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 US-MultiView software has been developed for the C-scan imaging.

The Under-Sodium MultiVIEW C-scan program is developed to control the double rotation scanner, the acquisition of ultrasonic signals and the mapping of C-scan images by using LabVIEW software. LabVIEW is a language developed by National Instruments for the control of instruments and a data acquisition.

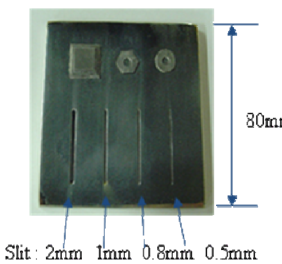


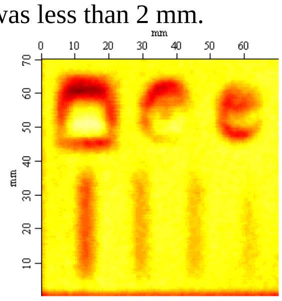
(a) Block diagram

(b) Schematic design (c) Picture

Figure 4. Experimental setup for performance test using waveguide sensor modules

The performance 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 waveguide sensor module 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 and loose parts on the surface. The loose part reflectors were partially identified and also the slits were clearly resolved in the image, as shown in Fig. 5. It was verified that a spatial resolution of the C-scan image for the detection of a surface defect was less than 2 mm.





(a) test target (b) C-Scan image

Figure 5. Visualization image of test target with slits and loose parts by the 10 m long waveguide sensor module

4. Setup of Sodium Test Facility

The sodium test facility with a glove box system and a sodium tank has been designed and manufactured to carry out the performance test of ultrasonic waveguide sensor in sodium environment condition. Figure 6 shows the schematic design drawing of the sodium test facility. The sodium test facility consists of a glove box with an anti-chamber, a sodium test tank with a volume of 30 liters, a sodium drain tank with a volume of around 70 liters, an electric resistance heater, a heater control unit, an Ar circulation and cooling system, a XYZ scanning system and an ultrasonic waveguide sensor.

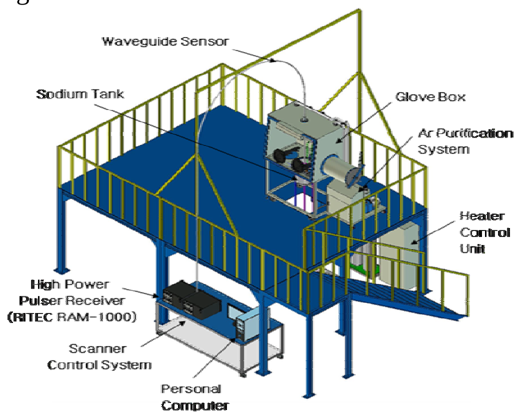


Figure 6. Experimental facility for the performance test in sodium

5. Summary

A novel plate-type ultrasonic waveguide sensor using the A_0 mode leaky Lamb wave has been developed for the under-sodium visual inspection of a reactor core and in-vessel structures in the sodium-cooled fast reactor. The 10 m long ultrasonic waveguide sensor module was designed and manufactured. The C-scan imaging test was carried out in water for evaluating performance of ultrasonic waveguide sensor in water. The double rotation C-scanning program Under-Sodium MultiVIEW has been developed by using a LabVIEW graphical programming language. The sodium test facility with a glove box system and a sodium tank has been designed and manufactured to carry out the performance test of ultrasonic waveguide sensor in sodium environment condition.

ACKNOWLEDGEMENT

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