Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

Prototype Ultrasonic Waveguide Sensor Modules for Under-Sodium Inspection of Sodium-cooled Fast Reactor

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1. Introduction

As the liquid sodium of a sodium-cooled fast reactor (SFR) is not transparent to light, a conventional visual inspection can not be used for observing the in-vessel structures under a sodium level in a reactor vessel. Ultrasonic inspection technique is a unique method to inspect inside sodium. Under-sodium viewing 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 novel plate-type ultrasonic waveguide sensor using the A_0 mode leaky Lamb has been developed [3~5]. The ultrasonic waveguide sensor 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 10 m long prototype ultrasonic waveguide sensor modules have been designed and manufactured for the application of the ultrasonic waveguide sensor to the under-sodium inspection of in-vessel structures in a SFR. The experimental facility has been designed and constructed to verify the feasibility and performance of the prototype ultrasonic waveguide sensor modules. And the Under-Sodium MultiView (US-MultiView) program is developed for the control of ultrasonic waveguide sensor modules and the C-scan imaging visualization by using a LabVIEW graphical programming language.

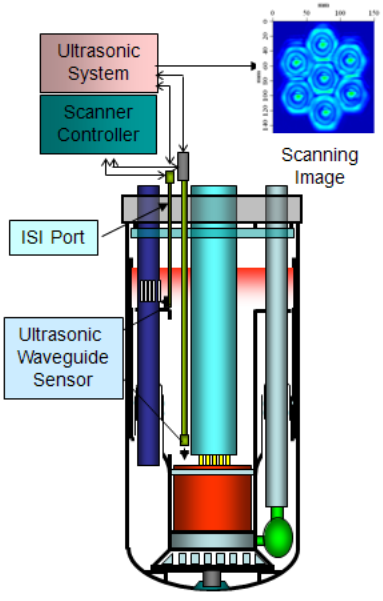

Fig. 1. Under-sodium inspection of in-vessel structures in SFR using ultrasonic waveguide sensor.

2. Prototype Ultrasonic Waveguide Sensor Modules

The single waveguide sensor module and the double waveguide sensor module have been designed and manufactured for the application to the under-sodium viewing and the detection of loose parts, respectively. Figure 2 shows the schematic design drawing of a manufactured 10 m long waveguide sensor module. The ultrasonic waveguide sensor modules consist of the ultrasonic waveguide senor device, the multistage guide tube and the upper head unit for the rotation and vertical movement (raising and lowering) of the ultrasonic waveguide sensor unit. Ultrasonic waveguide sensor unit is made up of an ultrasonic transducer, a Teflon wedge, a waveguide strip plate, and an acoustical shielding tube. The ultrasonic transducer is a commercial PZT sensor. A Teflon wedge is designed to produce A_0 mode Lamb wave in a low frequency range.

A real-scale experimental facility has been designed and constructed to verify the feasibility and performance of the 10 m long prototype ultrasonic waveguide sensor modules. Figure 3 shows the manufactured the 10 m long waveguide sensor modules and the real-scale experimental facility. The real-scale experimental facility is composed of a 13 m long H-beam frame, a XYZ scanner, a scanner driving module, and ultrasonic C-scan system. The ultrasonic C-scan system is composed of a scanning driver module, a high power ultrasonic pulser/receiver (RITEC RAM-5000), a digital oscilloscope, an A/D convert board and a personal computer.

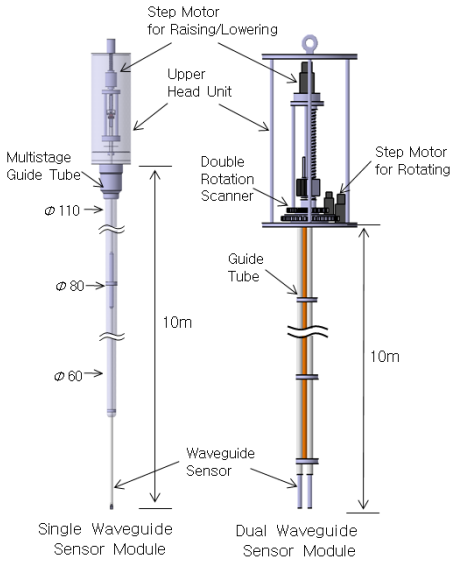

Fig. 2. Schematic drawing of prototype waveguide sensor modules.

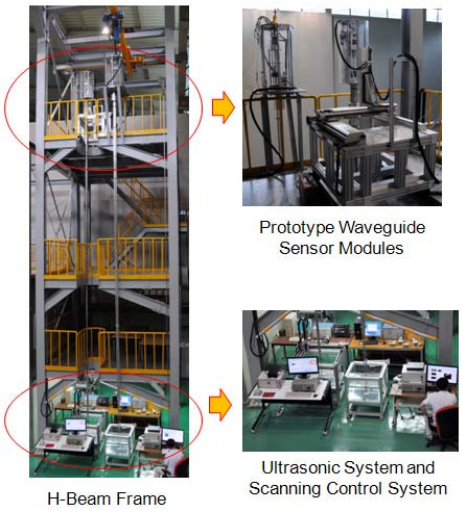

Fig. 3. Experimental facility for performance test of single and dual waveguide sensor modules.

3. Performance Tests

3.1 Single Waveguide Sensor Module

The performance for the visualization imaging resolution using a 10 m long single waveguide sensor module is evaluated by a C-scan test in water. The test targets were a reactor core mock-up, loose part pins and surface slit flaws on the block. The reactor core mockup and loose part pins were clearly identified and 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 flaw is about 0.8 mm.

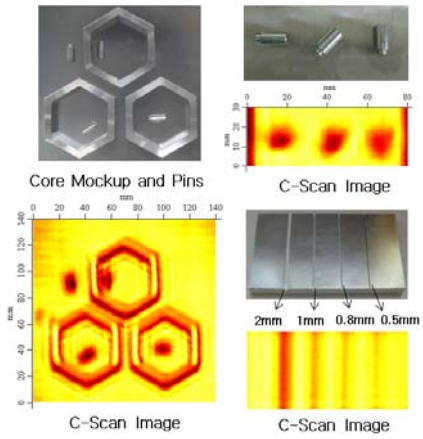

Fig. 4. C-scan visualization image of reactor core mock-up, loose parts and slits by the single waveguide sensor module.

3.2 Dual Waveguide Sensor Module

The dual waveguide sensor module which has the 2 channel waveguide sensor devices and the double rotation scanner in the upper head unit was developed for the loose part detection and identification in the fixed local area. The 2 channel waveguide sensor devices provide the 0 degree vertical beam and the 45 degree angle beam. The US-MultiView ver. 4 program has been developed for the double rotation C-scan imaging using the dual waveguide senor module. Figure 5 shows the A-scan signals and C-scan mapping result of a loose part pin by the internal double rotation scanning in the dual waveguide sensor module at the fixed local area. The loose part pin can be detected and clearly identified, as shown in Fig. 5.

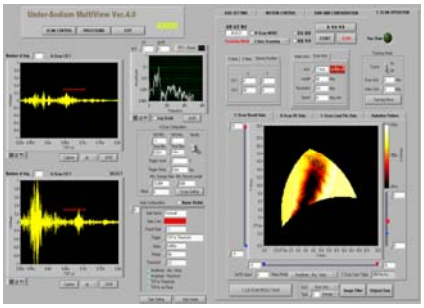

Fig. 5. US-MultiView ver. 4 program for loose part detection using the dual waveguide sensor module.

4. Summary

The 10 m long prototype ultrasonic waveguide sensor modules have been developed for the under-sodium inspection of a reactor core and in-vessel structures in a sodium-cooled fast reactor. The real-scale test facility with a 13 m H-beam structure was designed and constructed for the feasibility and performance tests of the prototype ultrasonic waveguide sensor modules. The US-MultiView ver. 4 program has been developed for the under-sodium inspection using the ultrasonic waveguide sensor modules. The performance of the ultrasonic waveguide sensor modules has been successfully demonstrated in water environment condition.

ACKNOWLEDGEMENT

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

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