Development of Under-Sodium Visualization Program for In-Service Inspection of In-Vessel Structures in a Sodium-cooled Fast Reactor

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1. Introduction

For the periodic safety assurance of a sodium-cooled fast reactor (SFR), the in-service inspection (ISI) of a SFR should be applied according to the ASME code rules and guidelines [1]. As the liquid sodium of a sodium-cooled fast reactor (SFR) is not transparent to light, a conventional visual examination cannot be used for the inspection of in-vessel structures under a sodium level in a reactor vessel. Ultrasonic inspection technique is a unique method to inspect the in-vessel structures submersed in 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 [2, 3]. Recently a novel plate-type ultrasonic waveguide sensor using the A_0 mode leaky Lamb has been developed [4~6]. The ultrasonic waveguide sensor modules are installed into the ISI access ports in the reactor head and the ultrasonic waves transmit through the waveguide plate in the hot sodium, as shown in Fig. 1. In this study, the visualization inspection program which is named as Under-Sodium MultiView have been developed for the application of the waveguide sensor module to the in-service inspection of in-vessel structures in a SFR.

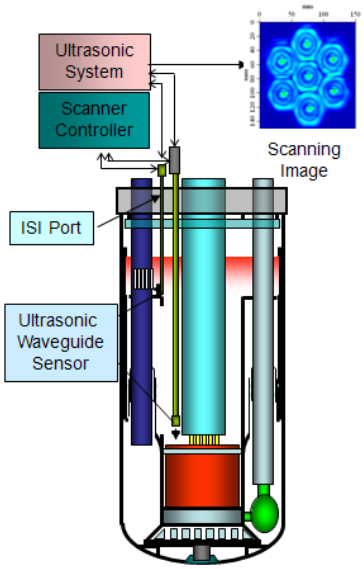

Fig. 1. In-service inspection of in-vessel structures in SFR by using ultrasonic waveguide sensor.

2. Ultrasonic Waveguide Sensor Module

The ultrasonic waveguide sensor module have been designed and manufactured for the application to the in-service inspection of in-vessel structures in sodium. The ultrasonic waveguide sensor modules consist of the ultrasonic waveguide senor device, the multistage guide tube and the upper head unit for the double rotation and vertical movement (raising and lowering) of the ultrasonic waveguide sensor unit. Ultrasonic waveguide sensor device is made up of an ultrasonic transducer (commercial PZT sensor), a wedge, a waveguide strip plate, and an acoustical shielding tube. The wedge is designed to produce A_0 mode Lamb wave in a low frequency range. The experimental facility has been designed and constructed to verify the performance of the prototype ultrasonic waveguide sensor module, as shown in Fig. 2. The experimental facility is composed of a 13 m long H-beam frame, a scanner driving module, and ultrasonic system. The ultrasonic 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, a personal computer and under-sodium visualization program.

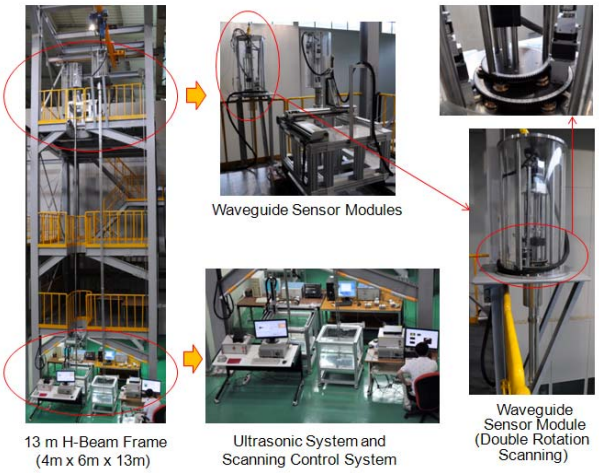

Fig. 2. Ultrasonic waveguide sensor modules and experimental facility.

3. Under-Sodium Visualization Program

The under-sodium visualization program which is named as Under-Sodium MultiView (US-MultiView) has been developed to control the double rotation scanner, the acquisition of ultrasonic signals and the mapping of the scanning images by using LabVIEW software. LabVIEW is a language developed by National Instruments for the control of instruments and a data acquisition. VI (Virtual Instrument) is for an instrument control, data acquisition and data processing [7].

US-MultiView program organizes a scanner control and scanning visualization mapping. Ultrasonic scanning image can be obtained from the ultrasonic signal and position information. Figure 3 shows a front panel of the US-MultiView program. The program is composed of several control and display sections. 'A-scan graph/control' section contains A-scan display, scale setting and DAQ board setting. 'Gate configuration' section contains a setting such as a delay time, range, threshold and so forth for the gate. In the 'scanner control and positioning' section, the movement controls of the waveguide sensor module and the setting of the scanning range and resolution are contained. The sections for B-scan, C-scan and 3D-scan are display the image mapping results.

The performance verification of the under-sodium visualization program has been evaluated by a C-scan mapping test of the ultrasonic waveguide sensor module in water. The test targets were a loose part pin and a reactor core mock-up. Figure 3 shows the A-scan signals and C-scan mapping result of a loose part pin by the internal double rotation scanning in the ultrasonic waveguide sensor module at the localized area. The loose part pin can be detected and clearly identified, as shown in Fig. 3. Figures 4 and 5 show the C-scan image and 3D visualization image of the reactor core mock-up obtained by double rotation scanning of the ultrasonic waveguide sensor module. The reactor core mockup were clearly identified and resolved in the image.

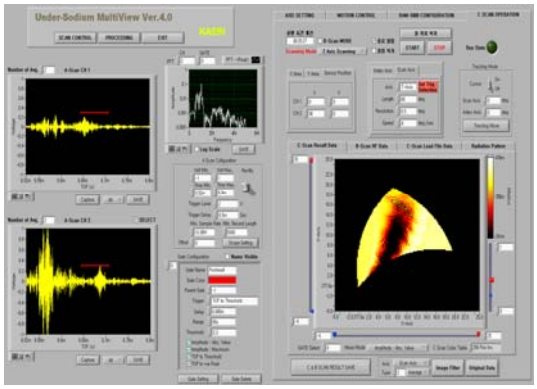

Fig. 3. US-MultiView program and C-scan mapping of loose part pin by the double rotation scanning of waveguide sensor module.

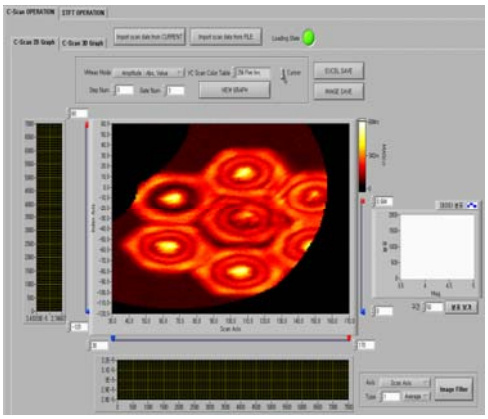

Fig. 4. C-scan visualization image of reactor core mock-up

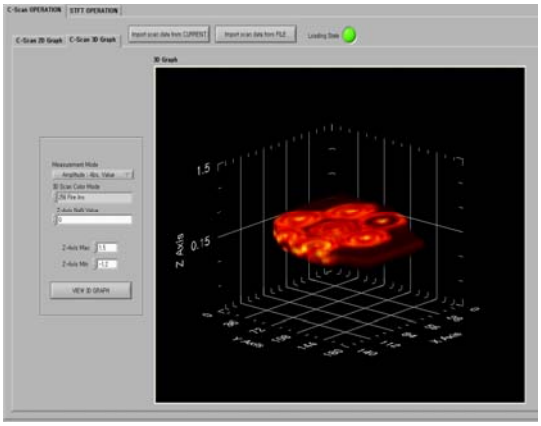

Fig. 5. 3D visualization image of reactor core mock-up

4. Summary

The under-sodium visualization program (US-MultiView) has been developed for the in-service inspection of a reactor core and in-vessel structures in a sodium-cooled fast reactor by using a LabVIEW graphical programming language. The US-MultiView program has a function of the scanning control of ultrasonic waveguide sensor module, the ultrasonic signal processing and the C-scan imaging visualization. The visualization performance of the US-MultiView program has been successfully demonstrated in water environment condition.

ACKNOWLEDGEMENT

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