Development of Double Rotation C-Scan Program for the Visualization of a Reactor Core and In-vessel Structures in SFR

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1. Introduction

The in-service inspection (ISI) of in-vessel structures of a sodium-cooled fast reactor (SFR) should be applied for the periodic safety assurance of SFR according to the ASME code rules and guidelines [1]. As the liquid sodium of a sodium-cooled fast reactor (SFR) is opaque to light, a conventional visual inspection is unavailable for the inspection of the reactor core and in-vessel structures under a sodium level. An ultrasonic wave should be applied for an under-sodium viewing (USV) of the in-vessel structures. Under-sodium ultrasonic sensors have been widely developed for an ISI of the reactor core and in-vessel structures of SFR [2-3]. In previous research works, the novel plate waveguide sensor has been developed for the application of remote under-sodium viewing and also the feasibility of the waveguide sensor technique has been successfully demonstrated for an ultrasonic visual inspection of a reactor core and in-vessel structures [4-5].

KALIMER-600 has a double rotating plug in reactor head for the refueling of reactor fuel assemblies as shown in Fig. 1. The waveguide sensors will be permanently installed in the double rotating plug for the mapping of reactor core and in-service inspection of in-vessel structures. In this study, a double rotating scanner system and a C-scan image mapping program Under-Sodium MultiVIEW (US-MultiVIEW) have been developed to apply this waveguide sensor technology to an under-sodium inspection of in-vessel structures of SFR by using a LabVIEW (Laboratory Virtual Instrumentation Engineer's Workbench) graphical programming language.

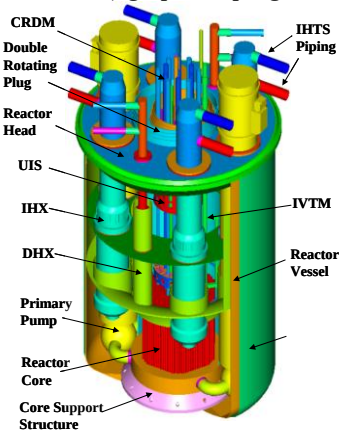

Figure 1. KALIMER-600 reactor system and double rotating plug

2. Double Rotating C-scan System

Figure 2 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, 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. A scanner driving module supplies the electric power and the moving pulse for a scanner and takes a feedback a moving distance to a motion controller. Tone burst signals are sent to the ultrasonic sensor and reflected signals are received by a high power ultrasonic pulser/receiver. A signal processing module digitalizes the received ultrasonic signals and makes a signal processing for the image mapping.

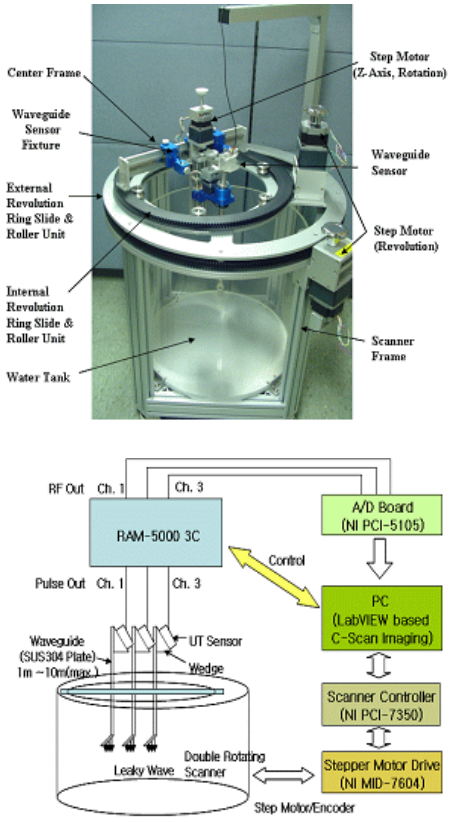

Figure 2. Experimental setup of the double rotation C-scan system

3. Under-Sodium MultiVIEW Program

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. VI (Virtual Instrument) is for an instrument control, data acquisition and data processing [6]. A VI consists of a front panel and block diagram. The front panel is to control a VI and the block diagram is to edit a VI through a wiring of objects in the front panel. The wires connect to executable icons and describe the data flow. LabVIEW is operated by an interface of data collection cards and device controllers. A signal digitized can be processed by a digital signal processing (DSP) of LabVIEW.

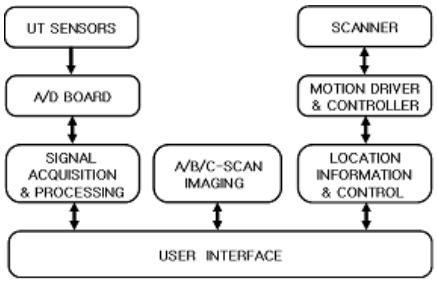

Figure 3. Data flowchart for the ultrasonic C-scan VI

Figure 3 shows the data flowchart for C-scan VI to organize a scanner control and C-scan mapping. Ultrasonic C-scan image can be obtained from the ultrasonic signal information from the signal acquisition module and position information from the position acquisition module results processed in the A/B/C-scan/TOF processing module. Figure 4 shows a front panel of the Under-Sodium 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. The sections for B-scan and C-scan are display the image mapping results. In the 'scanner control and positioning' section, the movement controls of the waveguide sensor assembly and the setting of the scanning range and resolution are contained. 'RAM-5000 setting' section contains the controls for a pulser/receiver such as the frequency, voltage, cycles, gain and low/high pass filter. The performance verification test of double rotation scanner system and Under-Sodium MultiVIEW program has been carried out by C-scan mapping of the test target which 'SFR' character is engraved. Figure 4 shows the C-scan image of the 'SFR' character obtained by double rotation scanning.

4. Conclusion

The double rotation C-scanning program which is named as Under-Sodium MultiVIEW has been developed to apply the new plate waveguide sensor technology to an under-sodium viewing of a reactor core and in-vessel structures of SFR by using a LabVIEW graphical programming language. The Under-Sodium MultiVIEW program has the functions of a double rotating scanner motion control, a RITEC RAM-5000 high power pulser receiver control, an image mapping and a signal processing. The performance of Under-Sodium MultiVIEW program was verified by a C-scan mapping test.

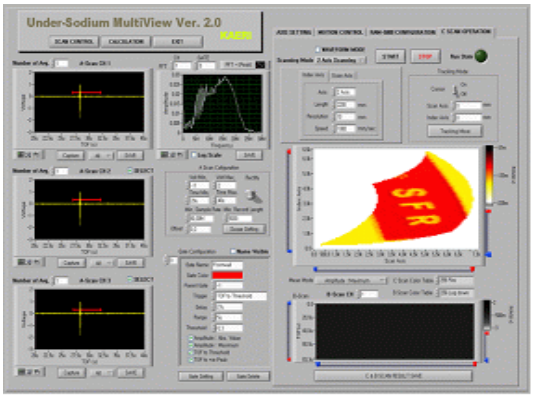

Figure 4. Front panel of Under-Sodium MultiVIEW

ACKNOWLEDGEMENT

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