Experimental Verification of Ultrasonic Waveguide Sensor for Under-Sodium Visualization

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1. Introduction

ASME Section XI Division 3 provides rules and guidelines for an in-service inspection and testing of the components of a sodium-cooled fast reactor (SFR) [1]. For the in-service inspection (ISI) of reactor internals, the ASME code specifies visual examinations. ISI of a upper internal structure above the sodium level will be done by a direct visual examination using a remote camera. As the liquid sodium is opaque to light, a conventional visual inspection can not be used for observing the internal structures under a sodium level. An ultrasonic wave should be applied for a under-sodium visualization of the reactor internals. Under-sodium ultrasonic sensors have been widely developed for an in-service inspection of the reactor core and internal components of SFR [2]-[4]. Immersion sensors and waveguide sensors have been applied to the under-sodium visualization. The immersion sensor has a precise imaging capability, but may have high temperature restrictions and an uncertain life. The waveguide sensor has the advantages of simplicity and reliability, but limited in its movement. Recently a new plate-type waveguide sensor and radiation beam steering technique has been developed to overcome the limitations of a waveguide sensor [5]. In a previous study, various under-sodium inspection techniques using the waveguide sensor for the reactor internal structures had been suggested [6]. In this study, visualization experiments using a plate-type waveguide sensor are performed for a feasibility verification of the waveguide sensor technology.

2. Ultrasonic Waveguide Sensor and Visualization Techniques

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. New waveguide sensor with a long strip plate, wedge and ultrasonic sensor has been developed. This waveguide sensor utilizes the zero-order anti-symmetric A_0 mode of the plate wave. The ultrasonic waveguide sensor can be applicable for applications of a under-sodium visualization, ranging and dimensional gauging. The waveguide sensors are installed in the rotating plug on the reactor head. The C-scan visualization imaging can be achieved by a scanning of the waveguide sensor assembly above the core top plane by a rotation of the rotating plug. Visualization image of the reactor core provides valuable information concerning the distortion of a fuel assembly due to a neutron-induced swelling. The position of the core structures and components can be determined directly through the ultrasonic under-sodium visualization before a refueling operation. Ranging visualization technique can be applied to detect if there is some obstacle to a free rotation of the rotating plug during a refuelling process.

3. Experimental Verification

An experimental facility was setup for a verification of the visualization techniques using a waveguide sensor and a underwater testing was performed. Figure 2 shows the bock diagram of the experimental hardware setup. It consists of a scanning system, a pulser/receiver (RITEC RAM-10000 system), a computer, a Lecroy oscilloscope and a waveguide sensor assembly. The waveguide is a 250 mm long stainless steel plate, 15mm wide and 1 mm thick. The transducer is excited by 1 MHz tone burst signals.

In the C-scanning visualization experiment, the end section of the waveguide sensor is inclined to the same radiation angle so that the emerging beam is vertical. An image of the test target is built up by the mechanical scanning of the transducers in a regular pattern over the target. The C-scan visualization experiment using the test target with the shape of reactor core was performed. The visualization image of reactor core shape is clearly identified as shown in Fig. 3. Another visualization experiment using a test target with slits of different sizes and loose parts was carried out for a verification of the imaging resolution. The test target is made of stainless steel with slits of different widths (2mm, 1mm, 0.8mm and 0.5mm) and loose parts (stepped plate, small nut and washer) on the surface. Figure 4 (b) shows the visualization image of the test target. The loose part reflectors were identified clearly and the slit of a 2mm width was observed successfully.

4. Conclusion

The structural safety concerns of the reactor internals of SFR are the detection of any mechanical damage, loose parts and a misalignment in the reactor internals. The under-sodium visualization technique is essential for the in-service inspection of reactor internals. The visualization technique using a plate-type waveguide sensor was proposed for a visual inspection of reactor internals. An underwater experiment has been performed for a verification of the visualization technique using a waveguide sensor. The feasibility of the waveguide sensor technique was successfully demonstrated for a visual inspection of reactor internals.

ACKNOWLEDGEMENT

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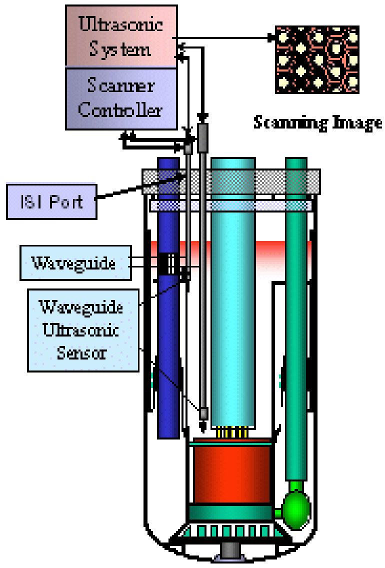


Figure 1. Visual inspection of reactor internals using ultrasonic waveguide sensor

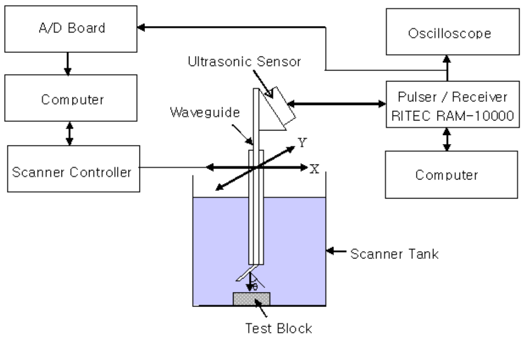
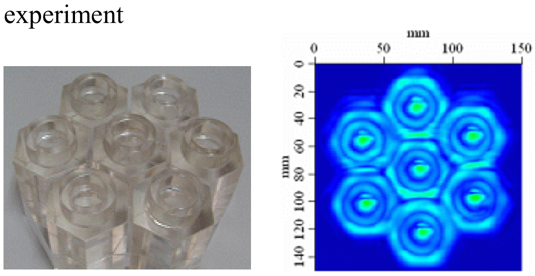
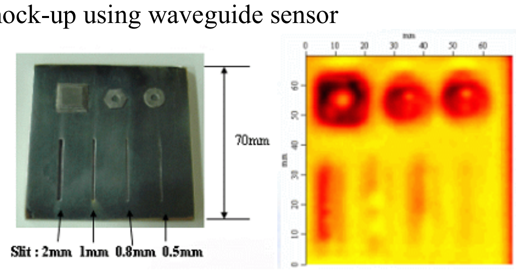


Figure 2. Block diagram of visualization experiment



(a) mock-up (b) C-scan image

Figure 3. Visualization image of reactor core mock-up using waveguide sensor



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

Figure 4. Visualization image of test target with slits of different sizes and loose parts for resolution verification