Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Under-Sodium Inspection Techniques for Reactor Internals of KALIMER-600 using Ultrasonic Waveguide Sensor

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1. Introduction

KALIMER-600 is a pool type liquid metal reactor (LMR) which is operated with a sodium coolant. The reactor internals of KALIMER-600 are submerged in a liquid sodium pool. As the liquid sodium is opaque to the light, a conventional visual inspection can not be used for observing the internal structures under a sodium condition. An under-sodium viewing (USV) technique using an ultrasonic wave should be applied for the observation of the refueling maneuver and the in-service inspection of the reactor internals. Under-sodium inspection technology utilizing ultrasonic waves has been widely developed for a visualization of the reactor core and internal components of LMR [1]-[3]. Immersion sensors and waveguide sensors have been applied to the USV inspection. 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. The new plate-type waveguide sensor has been developed as a useful alternative to immersion sensors for USV applications [4]. In the viewing and monitoring applications, a beam steering function of a waveguide sensor might be required. A new waveguide sensor and technique are being developed to overcome the limitations of a waveguide ultrasonic sensor. In this study, the under-sodium inspection techniques using the newly developed waveguide sensor for the reactor internal structures of KALIMER-600 is proposed.

2. ISI Guidelines for Reactor Internals of LMR

ASME Section XI Division 3 provides rules and guidelines for an in-service inspection and testing of the components of liquid metal cooled plants [5]. For the ISI of reactor internals, the ASME code specifies visual examinations and a continuous monitoring. Visual examinations can be direct, remote, or can use less conventional equipment such as a dimensional gauging and under-sodium scanning. In hard-to-access areas of the reactor pool, a continuous monitoring may give more reliable and accurate information about the structural integrity. In-service inspection of above the sodium level will be done by a direct visual examination using a remote CCTV camera. As the liquid sodium is opaque to the light, a visual inspection using ultrasonic waves can be used for observing the internal structures under the sodium.

3. Under-Sodium Inspection Techniques using Ultrasonic Waveguide Sensor

The waveguide sensor 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. New waveguide sensor with a long strip plate has been developed. This waveguide sensor utilizes the zero-order anti-symmetric A_0 mode of the Lamb wave. The new technique which is capable of steering an ultrasonic radiation beam by an excitation frequency tuning has been developed. By utilizing the new waveguide sensor, the tasks involving an under-sodium imaging, dimensional gauging and the detection of obstacles can be applicable for applications of an under-sodium inspection.

3.1 Visualization Technique

Visualization image of the reactor core provides valuable information concerning the distortion of the fuel assembly due to a neutron-induced swelling. The linear array waveguide sensors are installed in the large rotating plug as shown Fig. 1. The C-scan imaging can be achieved by a scanning of the waveguide sensor assembly above the core top plane by a rotation of the large rotating plug.

3.2 Telemetry Technique

The position of the core structures and components can be determined directly through the under-sodium ultrasonic telemetry before a refueling operation. Using this technology it has been possible to explore the space between the bottom of the upper internal structure (UIS) and the top of the core in order to detect if there is some obstacle to the free rotation of the rotating plug during the refuelling process. Fig. 2 shows the schematic inspection concept for ranging inspection above the reactor core during a refuelling process by using the waveguide sensor.

3.3 Monitoring Technique

In-service inspection of the core support structure is difficult and time-consuming because of a space and access restriction. The core support structure is designed with a sufficient redundancy and fault tolerance to obviate the need for a volumetric inspection. In-service inspection of the internals consists of a continuous monitoring of structural displacements. Waveguide sensors can be placed for a displacement monitoring in specific locations of particular internal components, as shown Fig. 3. Dimensional gauging will be used to check the dimensional stability of the internal structures by tracking the relative indexing positions. If a significant change is indicated by the dimensional gauging, the under-sodium viewing (USV) will be used to further investigate the condition.

4. Conclusion

The methodology of under-sodium inspections for the reactor core and internals is proposed and described. The under-sodium inspection techniques for the structural safety concerns of the reactor internals are the measurement of the location and alignment of the structures and a detection of any mechanical damage in the structures. The under-sodium inspection using a waveguide sensor can be successfully applied in LMR for the visualization, telemetry and monitoring applications in the ISI of the reactor internals.

ACKNOWLEDGEMENT

This study was supported by the Korean Ministry of Science & Technology through its National Nuclear Technology Program.

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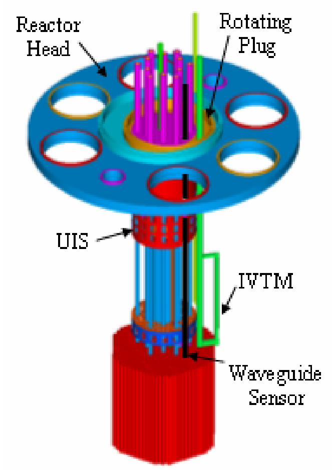

Figure 1. Visualization of reactor core using waveguide sensor assembly

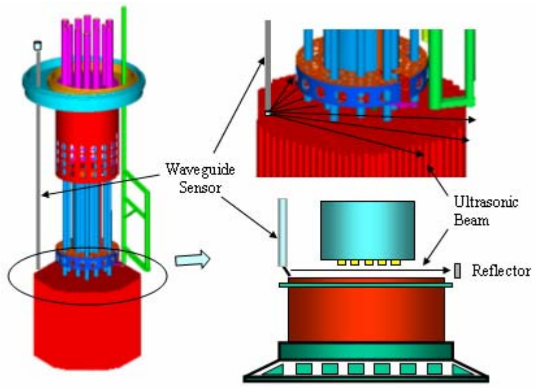

Figure 2. Ranging inspection above reactor core using waveguide sensor

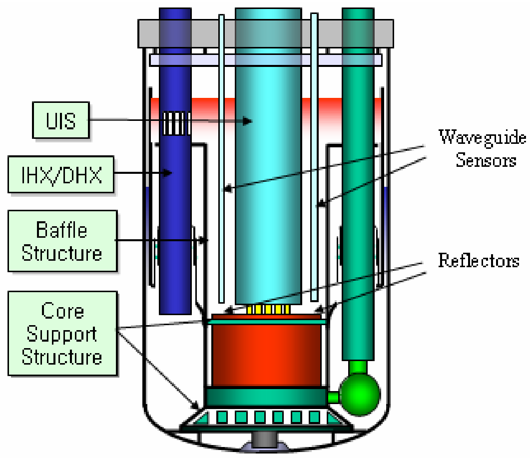

Figure 3. Monitoring inspection of reactor internal structures using waveguide sensors