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Development of Special Tools for the Straightness Measurement of JRTR Core Inner Shell

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Abstract

The inner shell of the heavy water vessel surrounding the core is the most critical part from the viewpoint of deformation due to the neutron irradiation during the service life of JRTR. The periodic measurement of the dimensional changes in the vertical straightness of the inner shell is considered as one of the in-service inspections. Special tools have been developed to measure the deformation of the inner shell for the in-service inspection and pre-service inspection as well.

1. Introduction

Jordan Research and Training Reactor (JRTR) is an open pool type nuclear research reactor, 5 MW power, JRTR core made from Zircaloy. The JRTR will be used for nuclear applications such as isotopes production, nuclear researches, neutron transmutation doping (NTD), and training… etc. JRTR core structures will be exposed to a large amount of neutron irradiation during the life time of the reactor. The core inner shell also will be exposed to a pressure that comes from heavy water system. JRTR core inner shell will deform due to the neutron irradiation and the mechanical stress [1]. Therefore, the dimensional change of the core inner shell should be periodically (every 10 years) measured as an in-service inspection to confirm the structural integrity. As a result of neutron irradiation, pressure difference of the heavy water vessel, and the mechanical stress, the reactor core will deform as shown in figure 2 to figure 4. The maximum deformation to the normal direction of inner shell wall is 0.75 mm as shown in figure 3. This study discusses development of special tools that will be used for pre-service and in-service inspection of JRTR inner shell.

2. Measurement Method

There may be several methods to check the core deformation using sensors such as; dial gauge, laser triangulation which uses laser diode as source, ultrasonic, linear variable differential transformer, and eddy current. We have decided to use the dial gauge for the measurement of the JRTR core. This method has many advantages such as; proven technology in a similar reactor (HANARO), low cost, and easy to use. We are going to measure on 6 specific vertical lines which represent the maximum deformation of the core inner shell for JRTR. Figure 1 shows the core of JRTR and the positions (dot marks) to be measured.

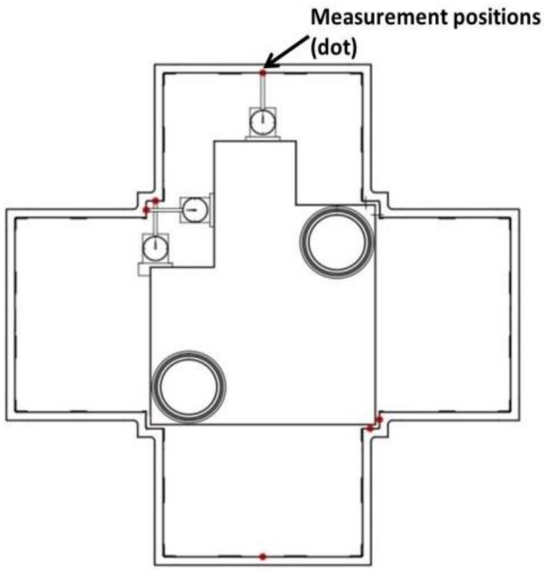

Figure 1 Deformation measurement positions

The dial gauge is a mechanical sensor for the scanning the shape of the inner shell. The dial gauge meets the requirement of radiation resistance due to that the sensor is fully mechanical and made from series of steel without corrosion under water during the measurement. Another advantage for the dial gauge is small size to easily assemble into a special tool which fits in the limited space of the core.

3. Analytical Result and Discussion

An analytical study has been done using ABAQUS 6.12 to evaluate the possible deformation of the JRTR reactor core. The analysis result shows that the maximum deformation could reach 0.75 mm which meets the design requirement (1.0 mm).

The study is to find the vertical and horizontal deformation of the JRTR core during its 40 years lifetime. As shown in the figure 2 the vertical deformation (z-direction) of JRTR inner shell is very low. The result shows that the maximum vertical displacement (U) is 9.49×10^{-4} mm which does not make any operational problem to the reactor. We have to note that maximum neutron flux in reactor core is 1.50×10^{14} neutron/cm^2-s.

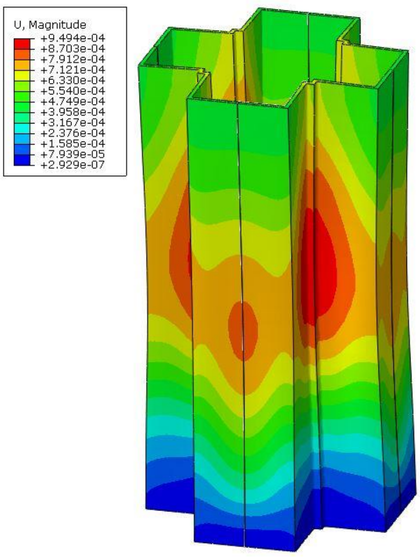

Figure 2 Analytical deformation study for JRTR core, U is vertical displacement of the core

Figure 3 shows the maximum horizontal displacement. The analysis has been done on a quarter core because of the symmetry of the core with the result within the accepted design requirement. It is shown that results vary between 0.60 – 0.75 mm in y-direction and about 0.59 mm in x-direction. These results do not have any hazardous effect on the reactor core during the lifetime.

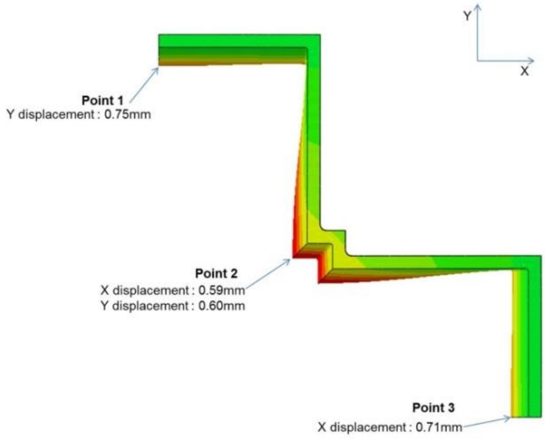

Figure 3 Maximum deformation

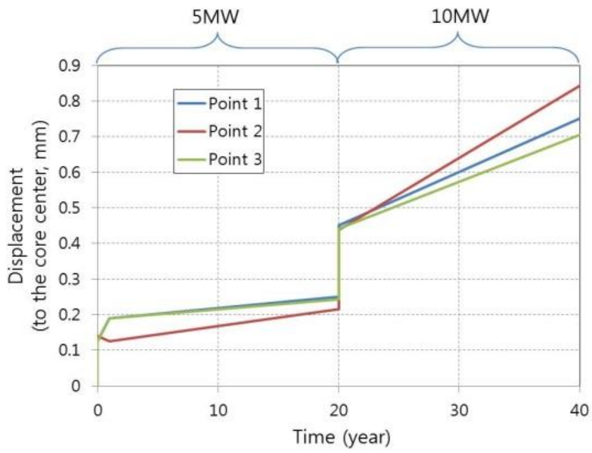

Figure 4 Deformation measurements for JRTR core along reactor lifetime.

Figure 4 shows the deformation estimated for JRTR core along the lifetime. The result is for the current core with 5MW power and for the upgradable core which will be 10MW as planned. The result shows that the deformation of the core will not exceed 0.3 mm for the first 40 years of the reactor lifetime if the reactor operated only with 5MW.

4. Tool Development

Inner shell deformation measurement tool will be used during reactor commissioning and operation. At the beginning the tool will be used in the pre-service inspection of the reactor core in JRTR site in Jordan. The measurement result will be a standard reference for the future measurements during the in-service inspection. We developed a set of special tools composed of an inner shell measurement tool and a gauge positioning tool. The inner shell measurement tool consists of three dial gauges and three linear motion guide (called LM guide) assembled on a frame structure made from stainless steel. The frame structure has two mounting screws which fit on the threads of grid plate on which four control rod guide tubes are installed. Figure 5 shows bird-eye view of the inner shell measurement tool.

The dial gauge of the inner shell measurement tool is individually manipulated by a thin stainless steel from the positioning tool. This tool is installed on the pool working platform. Figure 6 shows the conceptual side view for tool installation in the JRTR core.

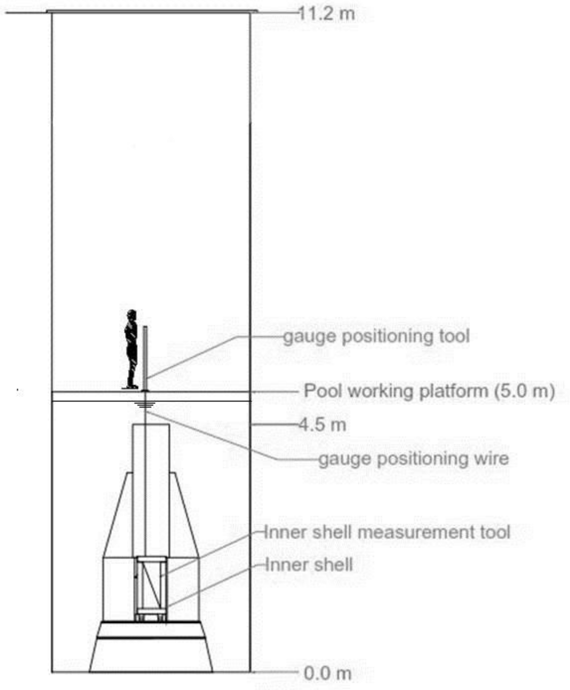

Figure 6 Inner shell measurement concept

5. Future works

The performance and procedure for the measurements tools will be verified using by the real inner shell of the heavy water vessel at factory before shipping to Jordan.

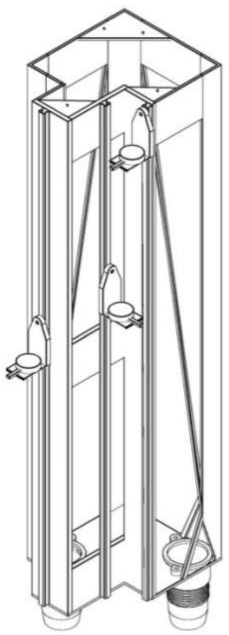

Figure 5 Inner shell measurement tool for JRTR.

There will be very delicate working procedure for the measurement in the limited space in JRTR core. Therefore, we will develop the detail procedures to cover the removal of the core components, installation of the measurement tools, measurement, and re-installation of the core components. The measurement of the inner shell at JAEC site during commissioning stage will be the first remote measurement at the same conditions of pool water and heavy water system.

References

[1] Abdullah S. Al-Singlawi, Yeong-garp Cho, Jung-ha Chung, "Study of different types of underwater methods of physical shape inner shell for JRTR", IGORR-2013 Daejeon, South Korea.