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# Performance Test of the Prototype SSDM for KJRR

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## 1. Introduction

The reactivity control mechanisms of Ki-Jang Research Reactor (KJRR), a new research reactor in Korea with plate type fuels, consist of four Bottom-Mounted Control Rod Drive Mechanisms (BM CRDMs) driven by an individual step motor and two Bottom-Mounted Second Shutdown Drive Mechanisms (BM SSDMs) driven by an individual hydraulic system located in Reactor Control Mechanism (RCM) Room as shown in Fig. 1. The CRDM acts as the first reactor shutdown mechanism and reactor regulating as well. The SSDM provides an alternate and independent means of reactor shutdown. The Second Shutdown Rods (SSRs) of the SSDM are poised at the top of the core by the hydraulic system during the normal operation and drop by gravity within the specific time. The SSR drop is commanded by the Reactor Protection System (RPS), Alternate Protection System (APS), Automatic Seismic Trip System (ASTS), or by the reactor operator in KJRR.

The purpose of this paper is to introduce the basic performance test results for a prototype of BMSSDM for KJRR

## 2. Design Features

The basic concept of the components for the BMSSDM driving system started from the similar concept to the Shut-Off unit for HANARO (High-Flux Advanced Neutron Application Reactor) and the SSDM for JRTR (Jordan Research and Training Reactor) . The drive mechanism and connecting components to the second shutdown rod (SSR) for the SSDMs of HANARO and JRTR are located above the reactor core; hydraulic system at the reactor pool top and track and carriage are at Upper Guide Structure (UGS) of the Reactor Structure Assembly (RSA). These cases are called a Top-Mounted type [1-3]. However, there are many differences among three reactors in the design, construction, operation, maintenance, and inspection owing to their operating purposes, different reactor operation conditions, fuel types, core configurations, layouts, installation position, etc. In particular, BMSSDM is quite different in comparison with SSDMs of HANARO and JRTR. Some similar design features such as a hydraulic system have been applied to the BMSSDM. However, the BMSSDM for the KJRR has been on optimizing for the improved design and performance from the proven technology of the design, operation and maintenance for HANARO and the design, construction and test for JRTR [1].

The driving parts of the BMSSDM are located in a RCM room, about 2 m below the reactor pool bottom. This design concept in comparison with the top-mounted-types good for easy core design, improved core-accessibility, and reduced interference with neighbor structures, systems, and components in the reactor pool.

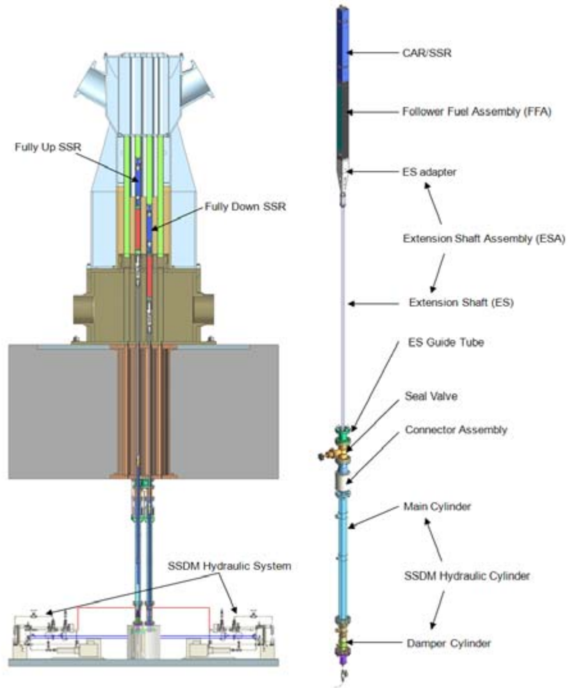



Fig. 1 Configuration of SSDMs.

## 3. Summary of System and Structures

The SSDM is consisted of a SSR, SSR guide tube, Extension Shaft Assembly (ESA), ES guide tube, connector assembly, seal valve, hydraulic cylinder and hydraulic system as shown in Fig.1. The hydraulic force derived from the hydraulic system raises the piston in the hydraulic cylinder which is pressure boundary. The piston is connected to the SSR through the ESA which is guided by the ES guide tube. The SSR is guided by the Aluminum CAR/SSR guide tube in the core.

During the normal operation, the SSRs are raised to the top of the core and poised. When the reactor trip is required, the SSRs drop by gravity into the core by the de-energizing the two solenoid valves to dump the pumping water to the RCM tank through opening of the air-operating piston valves. There is a proper hydraulic damping mechanism in the hydraulic cylinder to absorb the impact during the SSR drop. The SSRs drop also under the abnormal operation transients such as a loss of electric power for the pump. The top and bottom positions of SSR are monitored by the two pressure switches respectively.

## 4. Design and Fabrication of Components and Test Facility

The hydraulic cylinder assembly was manufactured in accordance with the material and fabrication requirements of the design specification and drawings except for quality class due to the development stage of the BMSSDM. The hydraulic system was assembled with the actual items in accordance with the drawings except for the tube bending and quality class. Here, the proper fittings are applied instead of tube bending, which affects the performance conservatively, but this effect can be negligible in the bottom-mounted type and development stage.

To simulate the moving parts, which consist of SSR, FFA, and ESA, the dummy weight assembly with the same total weight was applied in the performance test. The dummy weight assembly has the same size and connection mechanism as the ESA bottom end. The dummy weight assembly was installed with only vertical direction movement without lateral displacement and friction. In addition, an additional weight can be added to the dummy weight assembly for simulating the moving and fluid friction in the actual reactor operating conditions.

To simulate the reactor and reactor pool conditions, a pressurized vessel accepting the drop stoke of the SSR was fabricated. For measuring the SSR drop/withdrawal position over time, optical sensors are installed in the vessel. The sensor positions are 5, 15, 25, 35, 45, 55, 65 (damping starting point), 150, 250, 350, 450, 550, and 650 mm from the SSR dropped position. The monitoring window for the SSR movement was applied to the vessel.

The support frame was designed and manufactured enough for supporting the components and test facility even during the impact by SSR drop without influencing all of the test results.

The control panel for all kinds of testing, measuring, and actuation was designed and fulfilled.

## 5. Preparation of Performance Test

All the components, facilities, and equipment described in Section 4 were assembled and installed as shown in Fig. 2. The demineralized water was filled in this test mock-up. The pool water level (about 15.5m from RCM room bottom) was matched by adding air pressure of 1.1 bar at a 4.5 m water level from the top of the pressure vessel to the pressure gauge positions of the hydraulic system. The two solenoid valves are connected to the compressed air line individually with their operation pressure range.

Fig. 2 Installed view of BMSSDM test facility.

## 6. Tests

A functionality check is conducted to confirm the design adequacy of the BMSSDM and test facility including the movement, operation, and measurement. The functionality checks may also be used to calibrate test instrumentations and correlate test indications with the indicators provided. The parametric performance test involves a series of drop and withdrawal cycles performed under various conditions to evaluate the effect of each variable studied on the BMSSDM performance. The performance test is for demonstrating the BMSSDM performance with a certain number of withdrawals and drops for the full stroke at the optimal settings of the hydraulic cylinder assembly and hydraulic system. The functionality checks, a parametric performance test, and a performance test were conducted.

## 7. Test Results

### *7.1 Parametric Performance Test*

Fig. 3 shows the contour for the withdrawal time according to the valve setting conditions of the main and by-pass valves along the parametric performance test matrix. The drop time and impact were not affected by the valve settings. The withdrawal time changes greatly by changing the number of turns of the by-pass valve in a range between 1/4 and 7/4 turns of the main valve. Except for the above region of the main valve opening, the withdrawal time is kept less than 45 seconds. The optimal range of the valve settings are 2 to 8 turns of the main valve, and 3 to 8 turns of the by-pass valve to meet the performance requirement for the withdrawal time, 15 to 60 seconds. For the following performance test, the 5 turn number of the main valve and 5.5turn number of the by-pass valve are chosen for the optimal valve settings because the change of withdrawal time is relatively less senstive

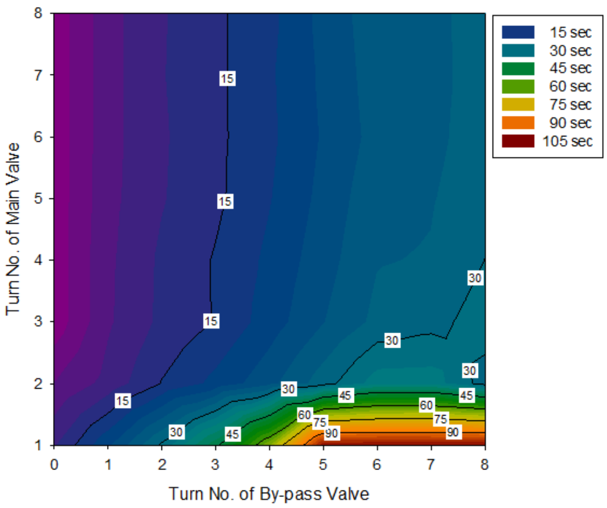
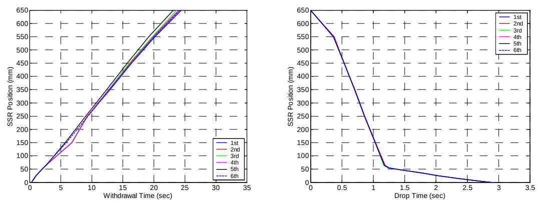


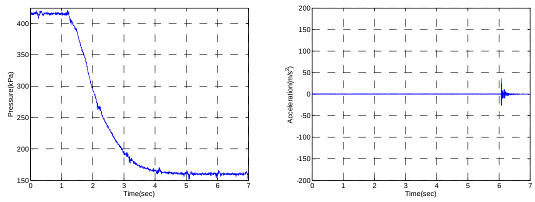

Fig. 3 Contour for withdrawal time at parametric performance test.

### *7.2 Performance Tests*

Fig. 4 shows the results of a performance test by both solenoid valves on/off at the optimal valve settings of the main and by-pass valves decided by the parametric performance test. The withdrawal time is about 24 seconds. The pure (before damping) and full drop times are 1.18 seconds and 2.9 seconds, respectively. Fig. 4(c) shows the pressure-time curve during the SSR drop. In addition, the operation pressure range is about 0.155-0.43 MPa. The impact is measured to be about 3.5g, which is not acceleration subjected to moving parts, especially the bottom region of the main piston, but the impact transferred to the hydraulic cylinder outer surface of the damping starting point. The actual impact subjected to a piston rod or moving parts as rigid motion is less than 1 g from the dynamic solution by using Fig. 4 (b).



(a) (b)



(c) (d)

Fig. 4 Performance test results

## 8. Conclusions

From the evaluations for the various test results with a prototype, we have verified that all of the BMSSDM components in the current design and development status satisfied their design requirements. In summary, all of the performance requirements are satisfied from the performance test results. We confirmed that there are no structural failures for the impacted parts, or negligible wear for the moving parts, and no leakage for the hydraulic cylinder assembly and hydraulic system during all of the tests.

However, the design for the BMSSDM can be improved because its related reactor components, which are the CRDM, penetration assembly, RSA, and FFA, will be progressed continuously to meet their requirements and interfaces. In addition, accurate environmental conditions including a thermal hydraulic response and FRS will be determined in the near future. At that time, some BMSSDM design parameters will be finally optimized to be simplified hydraulic cylinder and system with an improved performance. Therefore, if necessary, further calculations and experiments will be performed before the qualification tests on the construction stage. However, sufficient design margins are considered in this current design stage, and thus the basic features and concepts would not be seriously affected.

## REFERENCES

[1] S. Kim et al., Bottom-mounted Reactor Shutdown Mechanism, Trans. of the KNS Spring Meeting, 2013.

[2] S. Kim et al., Reactor Shutdown Mechanism by Top-mounted Hydraulic System, Trans. of the KNS Autumn Meeting, 2012.

[3] K.R. Kim, Y.G. Cho, An experimental study on the factors for the performance of a shutoff unit in the half-core test loop of HANARO, Trans. of the KNS Autumn Meeting, 2005.