Performance Test of Prototype SSDM for KJRR with on a Simulated Normal Operating Condition

Jihoon Lee*, Sanghaun Kim, Hyokwang Lee, Gyeongho Kim and Yeon-Sik Yoo
Korea Atomic Energy Research Institute, 989-111 Daedeokdaero, Yuseong, Daejeon, 305-353, Korea
**Corresponding author: jihoonlee@kaeri.re.kr*

1. Introduction

The KiJang Research Reactor (KJRR) has two types of reactivity control mechanisms which are consisted of four independent Control Rod Drive Mechanisms (CRDMs) and two independent Second Shutdown Drive Mechanisms (SSDMs). The CRDM is a reactor regulating mechanism driven by a step motor and first shutdown mechanism by a Control Rod Assembly (CAR) drop. The SSDM is second shutdown mechanism driven by hydraulic system. The hydraulic cylinder assembly and hydraulic system of the SSDM, as shown in Fig. 1, poises the Second Shutdown Rod (SSR) at the top of the core during a reactor normal operating condition. The SSR is dropped by gravity within the specific time due to the loss of hydraulic force in the cylinder when the reactor trip signal is commanded by the Reactor Protection System (RPS), Alternate Protection System (APS), Automatic Seismic Trip System (ASTS), or by the reactor operator.

The SSDM is a safety-related mechanical equipment and, thus, the equipment for which the qualified life object has been established shall be demonstrated to perform its safety functions by a type test in accordance with KEPIC END 1100 (IEEE-323). The purpose of qualification tests on a prototype SSDM is to verify that the design of SSDM is adequate for its design requirements before the construction of production units. The prototype SSDM is constructed in accordance with the equivalent quality assurance procedure for the production unit. The qualification test consist of performance test, followed by endurance test and seismic test. The requirements for performance are the most basic ones for confirming the SSDM design prior to qualification tests. This paper shows that the withdrawal and drop performance of the prototype SSDM with the modified design of the development-type one [1] for KJRR satisfies the related requirements from the performance test which is conducted at a simulated Reactor Structure Assembly (RSA) including dummy core internals on a simulated reactor normal operating condition of KJRR..

2. System Descriptions of SSDM and Test Rig

The prototype SSDM consists of a SSR, SSR Extension Shaft Assembly (ESA), seal valve assembly, hydraulic cylinder assembly, and hydraulic system as shown in Fig. 1. In comparison with the development-type SSDM, the connector assembly and RCM tank are eliminated and SSR ESA, hydraulic cylinder assembly, and hydraulic system designs are optimized by the development experience of the HANARO and JRTR [2-3]. The SSR is mechanically connected to the piston-piston rod sub-assembly in the cylinder assembly through the Follower Fuel Assembly (FFA) and the SSR ESA. They are guided vertically within an SSR guide tube of the RSA, an ES guide tube of the Penetration Assembly (PA) and the hydraulic cylinder of the SSDM.

The actuation mechanism of SSDM is as follows. During normal operation of the reactor, the hydraulic

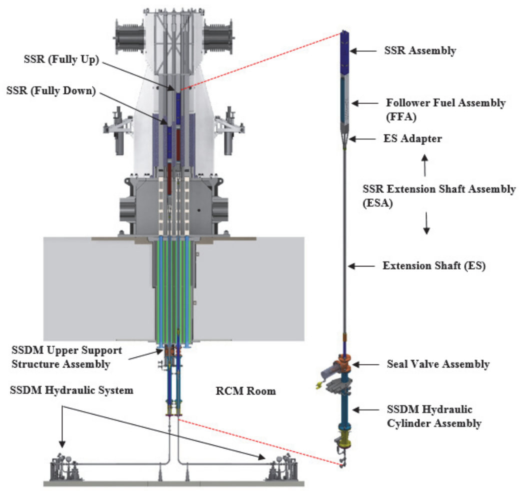

Fig. 1. Configuration of the SSDM for KJRR

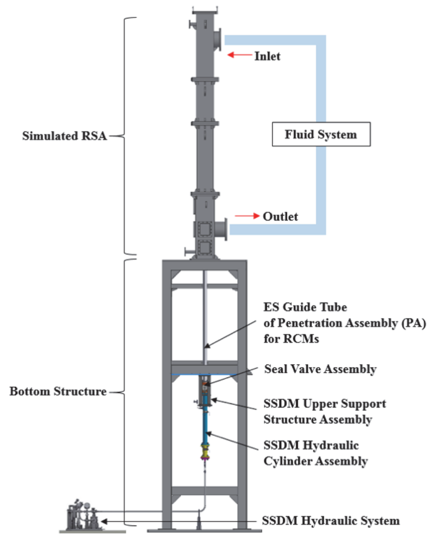

Fig. 2. Configuration of the test rig for performance test of SSDM

force by the pumping water of the hydraulic system withdraw the SSR and then the SSR is poised at the top of the core. When a reactor trip signal by an event occurs the solenoid valves of the SSDM hydraulic system are de-energized, the piston valves are opened and then the hydraulic force in the hydraulic cylinder is lost, therefore the SSR is dropped into the core by gravity.

The test rig is designed to simulate the actual installation and operation environment or conditions for the SSDM as shown in Fig. 2. The test rig consists of a simulated RSA, a bottom structure, a fluid system and a control system (test kit). The test rig adapts a full scale nine-channel (FSNC) configuration, which is adequate for the reactor operating condition for SSDM including FFA. The simulated RSA is composed of an outlet plenum, a grid plate, a core box, a SSR guide tube, an Upper Guide Structure (UGS) which is divided into an upper UGS and a lower UGS, a Reactor Cover Assembly (RCA). The bottom structure with an ES guide tube is used for supporting the simulated RSA and the simulated ES guide tube of PA. The simulated ES guide tube is inserted into the bottom hole of the outlet plenum. The fluid system is used for water circulation and heat balance as required in the reactor operating condition and it provides functions for water draining in the rig, water quality and level control. The control system (test kit) that consists of a control panel and measurement system is used for the operation of the fluid system, test condition and testing of the SSDM.

Fig. 3. The fabricated test rig with installed SSDM

Table I: Normal Operating Condition

No.	Design Variable	Value
1	Total flow rate through core	105 kg/s ± 4 % (378 m^3/h ± 4 %)
2	Pressure at core inlet	80 kPag ± 5 % (0.8 kgf/cm^2 ± 5 %)
3	Pool water temperature	34 ± 3 ℃
4	Simulated RCM room temperature	At least 50 ℃

Table II: Acceptance criteria for SSDM performance test

No.	Design Variable	Criteria
1	SSR pure drop time	Less than 1.5 sec
2	SSR full drop time	Less than 5.0 sec
3	Initial drop delay time	Less than 0.2 sec
4	SSR withdrawal time	15 ~ 60 sec
5	SSR impact for full drop	Less than 10g

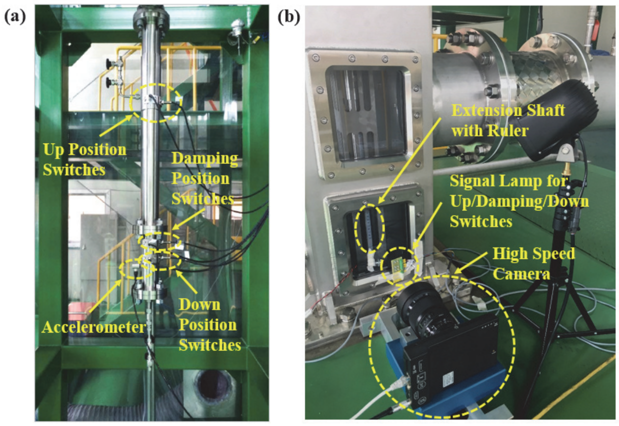

Fig. 4. Equipment for measuring withdrawal and drop times (a) Position switches and accelerometer and (b) high speed camera

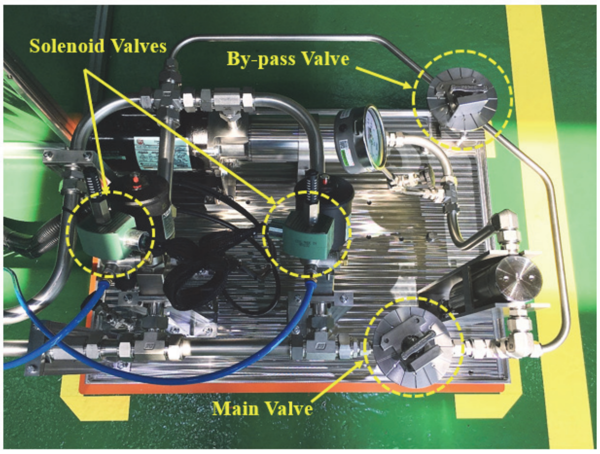

Fig. 5. SSDM hydraulic system

3. Performance Test on the Simulated Normal Operating Condition

The SSDM was installed in the test rig as shown in Fig. 3. The SSDM was manufactured in accordance

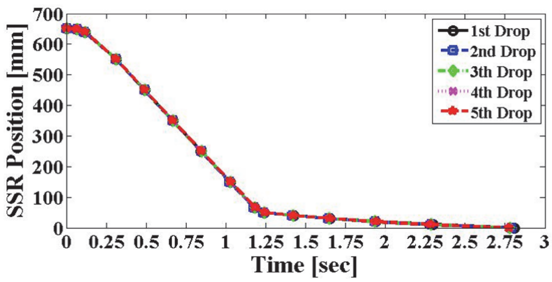

Fig. 6. SSR drop time result

with the material and fabrication requirements of the design specification and drawings.

To measure of the withdrawal and drop times of the SSR, some equipment and instruments were installed as shown in Fig. 4. The accelerometer was attached at the damper cylinder of SSDM hydraulic cylinder assembly for measuring the SSR drop impact value. The pump, solenoid valves and up/down/damping position switches were connected to the control panel and up/down/damping position switches and damping monitor was connected to the measurement system. In addition, a high speed camera was installed in front of the sight window of the simulated RSA for measuring the SSR drop position and drop time. Also, the fluid system and simulated RCM room temperature were set to the normal operating condition in accordance with Table 1 and the demineralized water was filled in the pool of the test rig.

After the completion of test preparation and functionality checks, the parametric performance test was conducted as shown in Fig. 5. The valve parametric performance test is the SSR withdrawal and drop tests according to the SSDM pump flow rates and outlet pressures varying over their maximum range, which is resulted from the turn-combinations between main valve and by-pass valve. From this test, the drop times and the impact value had no relation with the main valve and by-pass valve combinations. 4 turns of main valve and 7/8 turns of by-pass valve was chosen for the optimal valves condition.

The SSR withdrawal and drop tests were performed 5 times with the optimal valves condition. The withdrawal time of the SSR was measured by the power-on signal of solenoid valves in the SSDM hydraulic system and the up position switches. The SSR drop times were measured by the power-off signal of solenoid valves, the up/damping/down position switches and the high speed camera. The initial drop delay time was measured by the high speed camera. The initial delay time is caused by the solenoid/piston valve's operation times and the elapsed time from the power-off of solenoid valves to 1 mm drop of the SSR from the fully withdrawn position of the SSR.

Fig. 6 shows the SSR drop position-time curve. The average initial delay time, pure drop (before damping) and full drop (full stroke) times are 0.068 seconds, 1.180 seconds and 2.787 seconds, respectively. Also, the average SSR impact value is 0.6g and the average SSR withdrawal time is 33.88 seconds. All these results satisfied the acceptance criteria of performance test for SSDM as shown in Table 2.

4. Conclusions

The prototype SSDM was constructed in accordance with the equivalent quality procedure for the production units. The test rig was designed, fabricated and installed for the performance and endurance test of the prototype SSDM. The performance test for the prototype SSDM was conducted.

The prototype SSDM met all the related performance requirements. From the test results, the SSDM was well-designed basically in the aspect of performance. In addition, the SSDM was maintained the structural integrity and performed the safety-related functions without malfunction during the test. The SSDM design will be confirmed through the endurance and seismic qualification tests for the construction of production units which shall be constructed in accordance with the equivalent design of the prototype SSDM qualified.

Acknowledgement

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