Drop Performance Test of Recently Designed Control Rod Assembly for PGSFR

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1. Introduction

The Control Rod Assembly (CRA) should be rapidly dropped into the reactor core to shut down chain reactions under scram conditions whereas it controls the reactor power by adjusting its position during the normal operation. Therefore, the drop performance of the CRA is one of most important factors for the safety of a nuclear reactor and must be experimentally verified before being employed in an actual reactor [1-5].

This paper presents the drop performance test of the recently designed CRA for PGSFR. The drop performance of the CRA is mainly affected by the drag force which is varied with the shape of the CRA and the coolant flow condition. To investigate the drop performance of the CRA, therefore, free drop tests under different flow rate conditions were carried out. In addition to this, free drop tests under several types and magnitudes of seismic loading conditions were also conducted to investigate the effect of the earthquake.

2. Drop performance test

Figure 1 shows the drop performance test facility consisting of a control assembly, a support structure and a 6-DOF shaking table. The control assembly consisting of a hexagonal duct, a damper, a nose piece and the recently designed CRA was installed inside the support structure to prevent unexpected accidents caused by the applied seismic loading. To continuously measure the CRA position during its drop, a wire displacement meter was employed and installed at the top of the test facility as shown in Fig. 2. The wire displacement meter was then connected to an extension bar additionally installed at the top of the CRA.

In the test, the CRA was lifted up to the drop position, at a height of 1 m, by a pneumatic device connected with an electromagnet. Once the CRA lifted up to its drop position, it was then dropped by cutting off the current flowing into the electromagnet under given flow rate and seismic loading conditions. The CRA position measured by the wire displacement meter is finally indicated and saved by an oscilloscope. The weight of the CRA, the working fluid and the designed flow rate used in the test are listed in Table I. Note that water of which the density and viscosity are larger than those of liquid sodium was used as the working fluid in the test to obtain more conservative results [3-5].

Table I: Test conditions of drop performance test.

Weigh of CRA	57 kg
Working fluid	Water
Designed fluid rate	2.109 kg/s

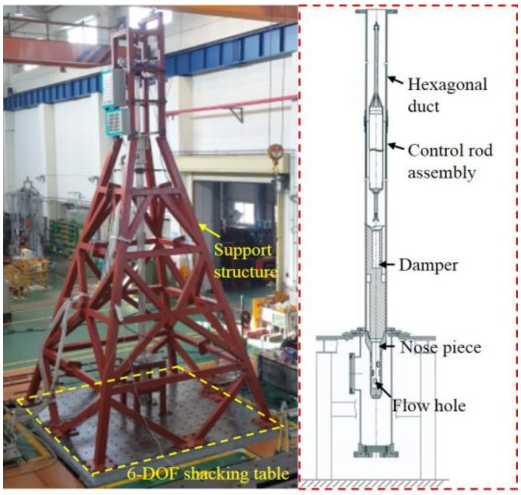

Fig. 1. Drop performance test facility.

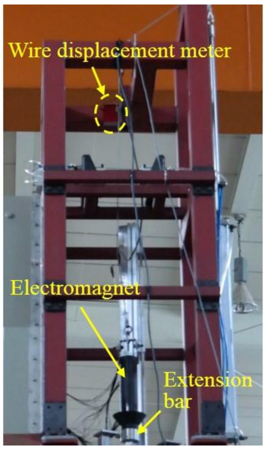

Fig. 2. Upper part of the drop performance test facility.

3. Test Results

Two kinds of free drop tests were carried out to evaluate the effects of flow rate and seismic loading on the drop performance of the recently designed CRA. To decrease a measurement error, tests were conducted three times for each condition and measured values were then averaged.

3.1 Effect of flow rate on drop performance

Figures 3 and 4 show the CRA positions and velocities according to the drop time under different flow rate conditions, 0%, 100% and 120% of the designed flow rate. From figures, one can clearly see that the CRA rapidly drops until it meets the damper and then the drop velocity dramatically decreases. And one can also see that the CRA drops faster under the lower flow rate condition. Averaged drop times before damping and averaged total drop times measured under 0%, 100% and 120% flow rate conditions are listed in Table II.

3.2 Effect of seismic loading on drop performance

Figure 5 show the CRA positions according to the drop time under the 100% flow rate condition with and without seismic loadings. The Soil Response Time History (SRTH) with the magnitude of 0.3g was used as the seismic loading in this case. From the figure, one can see that the effect of the seismic loading on the drop performance of the CRA is not significant; the discrepancies in drop time before damping and total drop time are less than 0.1 s, about 0.034 s and 0.096 s, respectively.

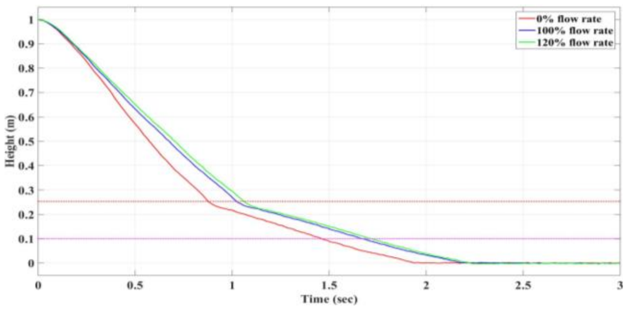

Fig. 3. CRA positions according to the drop time under 0%, 100% and 120% flow rate conditions.

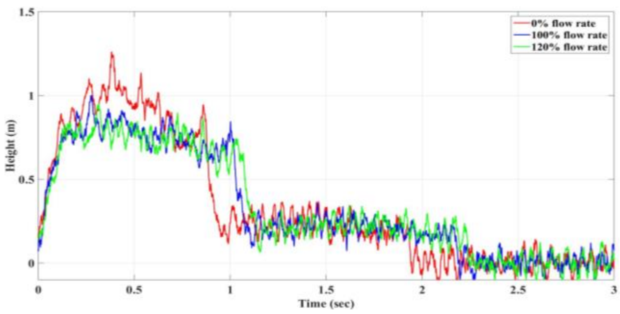

Fig. 4. Velocity of CRA according to the drop time under 0%, 100% and 120% flow rate conditions.

Table II: Test results obtained under different flow rate conditions.

Flow rate	Drop time before damping (s)	Total Drop time (s)
0%	0.9059	1.9462
100%	1.0743	2.2103
120%	1.0855	2.2378

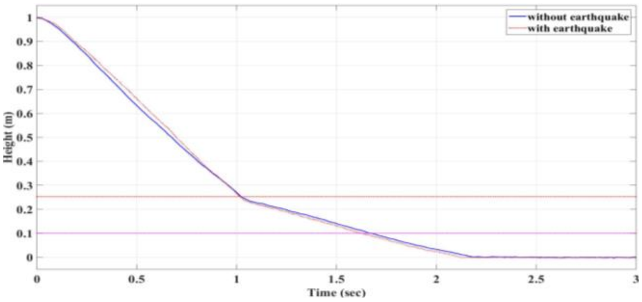

Fig. 5. CRA positions according to the drop time under 100% flow rate condition with and without seismic loadings.

Table III: Test results obtained with and without seismic loadings.

Seismic loading	Drop time before damping (s)	Total Drop time (s)
O	1.0408	2.1148
X	1.0743	2.2103

4. Conclusions

In this work, the drop performance of the recently designed CRA for PGSFR was experimentally investigated under different flow rate conditions with and without seismic loadings. Through the several drop performance tests, it was observed that the drop time of the CRA before damping was about 1 s even under 120% flow rate condition and the effect of the seismic loading was not significant.

Acknowledgement

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