Performance Test of the Damping System Using a Spring-Hydraulic Damper

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1. Introduction

A control element drive mechanism (CEDM) is a reactor regulating system, which is to insert, withdraw or maintain a control rod containing a neutron absorbing material within a reactor core to control the reactivity of the core. The ball-screw type CEDM for the small and medium research reactor is under development in KAERI[1,2]. The CEDM is placed at the top of the reactor pressure vessel head, and is connected with the top of the control element assembly located in the reactor core through the extension shaft. The CEDM consists of the pressure vessel, the step motor, the gear and the ball-screw assembly. Also, to reduce the impact force due to the free drop of the movable parts in the emergent situation, a damping system using a spring-hydraulic damper is installed at the top of ball-screw assembly as shown in Fig.1. This paper describes the experimental results to verify the damping performance in case of the emergent drop of the CEDM. The performance tests are performed by using a full-scale structure except the control element assembly, and a displacement after an impact of a guide shaft and the damping system is measured by using a linear variable differential transformer (LVDT). The influence of the drop height on the damping behavior is also estimated on the basis of test results.

2. Experiment

The internal structures of the CEDM are complex due to the mechanism to drive the control element assembly, and no sensors can be installed. Thus, a facility to perform the performance test of the damping system as shown in Fig. 2 is designed and manufactured. The facility consists of the support structure, the cylindrical shell made of acryl, the dummy weight simulating the control element assembly and the fixing jig of the sensor. An extension shaft and the control element assembly are connected to the bottom of the ball-screw, and those are simulated as the dummy weight of 127 kg. The motion of the dummy weight can be shown through the acryl cylinder, and is recorded by using a digital camera to analyze the drop time of the CEDM. However, the vibration behavior of the damping system after the impact can not be obtained by the camera. Therefore, the non-contact type sensor is considered, and the LVDT is used to measure the small displacement. Table 1 presents the specification of the LVDT using in the experiment. It consists of a body and a core as DCST 1000 model which is the measurement range of ±25mm and a sensitivity of 400mV/mm.

The tests are performed in the water of the normal temperature and pressure, and the movable parts of the CEDM internal are dropped by the power off of a step motor (SM) and/or an electromagnet (EM). The LVDT signals measured are saved and analyzed using an oscilloscope and a personal computer, respectively.

Table 1 Specification of the LVDT

	Body	Core
Diameter (mm)	ID: 9.35 OD: 20.5	6.35
Length (mm)	212.7	102
Material	Stainless Steel	NiFe
Nominal Range	±25 mm	
Sensitivity	400 mV/mm	
Output Voltage	±10 Vdc	

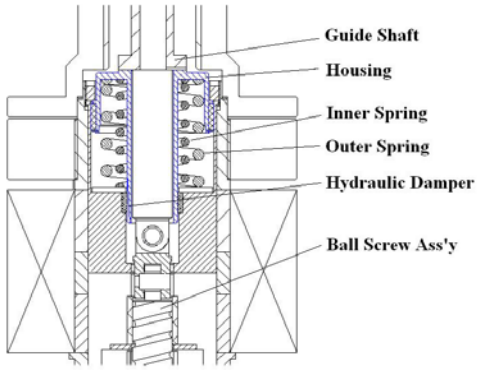

Fig. 1 Damping system using a spring-hydraulic damper.

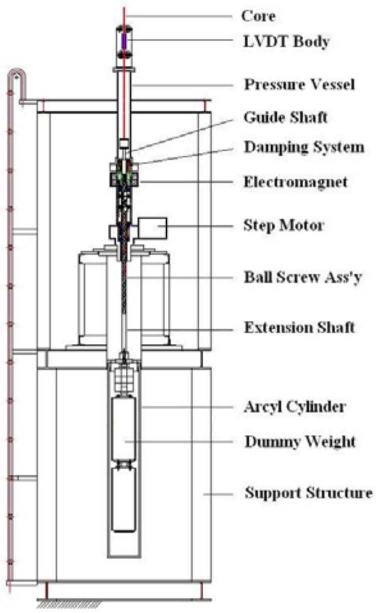

Fig. 2 Schematic view of the drop test facility.

3. Results and Discussion

The performance of the damping system is estimated as the vibration curve and the displacement after the impact in the final stroke of the drop. Fig. 3 shows the typical LVDT's voltage signal in case of the SM power off only. The converted maximum displacement of the spring due to the first impact is 15.6mm, and the displacement due to the rebound is 9mm. For the second impact, the displacement is smaller than that of the first impact, and the rebound does not occur. From this result, it is found that the damping system of the CEDM has a good damping performance.

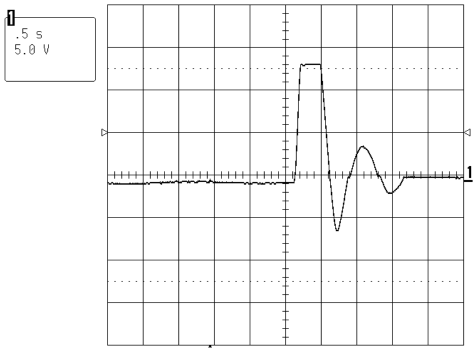

Fig. 3 LVDT signal for the SM off.

Fig. 4 shows the whole drop process of the dummy weight from the start to the end of the damping. In case of the SM power off only, the dummy weight is dropped with a linear motion except the initial stage. All drop process including the vibration after the impact is completed within 4.5 seconds. For the SM/EM power off, we can confirm the performance of the initial rapid drop due to the electromagnet off, and the intermediate process has the same drop motion as the SM off. However, the damping behavior is different from the SM power off with a general damping motion of the spring-damper system. The displacement after the impact is very small, and the oscillation does not occur. The reason is because the rotary inertia of the movable anchor, which turns a rotation to the upside, absorbs most of the impact force.

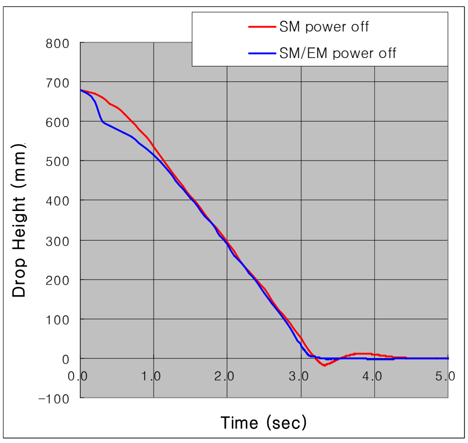

Fig. 4 Drop behavior for the SM and SM/EM off.

The effect of the drop height on the behavior of the damping system is shown in Fig.5. The drop time is decreased in proportion to the height, and the displacement after the impact equals regardless of the drop height. From the above results, it is found that the drop of movable parts for the CEDM is a uniform motion moving along the ball-screw without the change of the velocity.

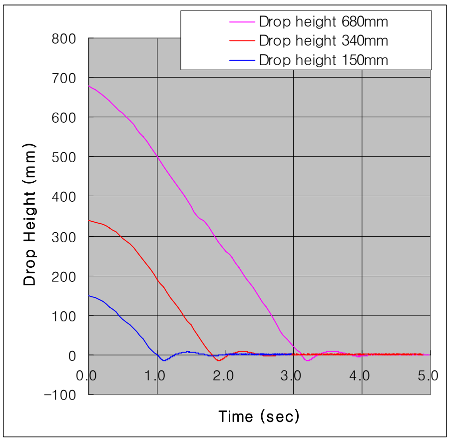

Fig. 5 Effect of the drop height.

4. Conclusions

The displacement of the damping spring is measured by using the LVDT to verify the damping performance of the CEDM. The drop behavior of the CEDM movable parts shows a uniform motion, and is finished within 4.5 seconds. In case of the SM power off, the maximum displacement due to the first impact is 15.6mm, and the damping system has good performance. Also the damping behavior with the drop height shows the same result. However, in the case of the SM/EM power off, the damping system does not play a damper role because of the rotary inertia of the movable anchor.

REFERENCES

[1] J.H. Kim et al., Design of Ballscrew type CEDM for SMART, Transactions of the Korean Nuclear Society Spring Meeting, 2004.
[2] J.Y. Yu et al., Development of Seismic Resistance Position Indicator for the Integral Reactor, Transactions of the Korean Nuclear Society Spring Meeting, 2008.