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Drop Performance Test of CRDMs for JRTR

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1. Introduction

A control rod drive mechanism (CRDM) is a device to control the position of a control absorber rod (CAR) in the core by using a stepping motor which is commanded by the reactor regulating system (RRS) to control the reactivity during the normal operation of the reactor. The top-mounted CRDM driven by the stepping motor for Jordan Research and Training Reactor (JRTR) has been developed in KAERI. The CRDM for JRTR has been optimized by the design improvement based on that of the HANARO [1]. It is necessary to verify the performances such as the stepping, drop, endurance, vibration, seismic and structural integrity for active components [2]. Especially, the CAR drop curves are important data for the safety analysis. This paper describes the test results to demonstrate the drop performances of a prototype and 4 CRDMs to be installed at site. The tests are carried out at a test rig simulating the actual reactor's conditions.

2. System Description

The JRTR is a pool type reactor with 5MW power which is open to the atmosphere. The reactivity control mechanisms of this reactor consist of four CRDMs and two second shutdown drive mechanisms (SSDMs). The CRDM is composed of a CAR, a CAR guide tube, carriages, tracks, a tie rod, and a drive assembly as shown in Fig. 1. The more detail descriptions of CRDM components were found in reference [2].

During the normal operation of the reactor, the CAR position is controlled by a stepping motor commanded by the RRS. The CAR drops by gravity into the core by de-energizing the electromagnet when a reactor trip is required by the reactor protection system (RPS) or other systems. There is a proper hydraulic damping mechanism on the drive assembly to absorb the impact due to the CAR drop.

One prototype and 4 units of CRDM have been fabricated and tested in accordance with the performance qualification plan [3]. The major requirements related to the drop performance of CRDM are as follows;

- CAR drop time : < 1.5 sec (before damping)
  < 3.0 sec (including damping)
- Initial delay time : < 0.15 sec
- Drop impact : < 10 g

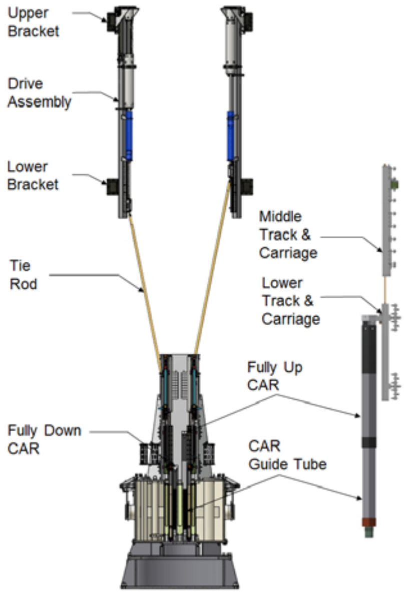

Fig. 1 Overall view of the CRDM

3. Drop Test

The purpose of the drop performance test is to confirm that the CAR drops within the specified time. The drop performance test is carried out at the test rig called as 'Full Scale Full Core (FSFC) test rig'. One set of CRDM and one set of SSDM are installed in this test rig. The core configuration is full size which is the same as the core for the real reactor structure. Dummy fuel assemblies and dummy beryllium with same configuration and weights are installed in the core. The functionality check of CRDM including all instruments is also completed before the drop test.

The test is performed by de-energizing the power of an electromagnet at several heights for a prototype and at full stroke height (650mm) for CRDMs. The drop times and impact values are obtained from the linear transducer attached to the drive assembly and the water proven accelerometer attached to the main cylinder lower bracket, respectively.

4. Results and Discussion

Table 1 presents the drop test results of four CRDMs with AC-type electromagnet. The initial delay time indicates the time from the instant that the magnet power switch is actuated to the instant that the CAR leaves it's parking position. The test results for four CRDMs show slightly different drop times due to the differences in the manufacturing state and assembled state. The pure and full drop times of CARs meet the specified requirements of 1.5 and 3.0 seconds before and after the damping, respectively. The accelerations due to the impact of moving parts at the start of damping are lower than the design requirement, 10g.

However, as shown in above results, the initial delay time for all CRDMs is found in the range of 0.23-0.41 seconds. The delay time shall be less than 0.15 seconds which was used in the safety analysis. Therefore, it is necessary to improve the drop performance related to the late initial delay times.

Table 1 Drop test results of CRDMs with AC magnet

CRDM No.	Drop time (sec.)			Acc.(g)
	Initial delay*	Pure drop	Full drop	
1	0.24	0.94	1.24	1.70
2	0.23	0.92	1.21	2.71
3	0.32	1.02	1.32	2.39
4	0.41	1.12	1.39	1.71

* Initial delay times of CRDM with AC magnet were not satisfied with the requirement, 0.15sec.

From various design reviews and tests, it has been confirmed that the reason of considerable delay is the use of AC-type magnet (EMR3.5 120VAC) for JRTR instead of DC-type magnet (12 VDC) used for HANARO. We decided to change the magnet model to EMR3.5 12VDC with the same diameter and height. This change does not require any change to the other mechanical components.

Table 2 presents the test results with drop heights using a prototype CRDM after the replacement to DC-type magnet. All test results meet the specified requirements of drop times, and it is found that the replacement of the electromagnet is acceptable.

Table 2 Drop test results of prototype CRDM with DC magnet

Drop Height (mm)	Drop time (sec)			Acc. (g)
	Initial delay	Pure drop	Full drop	
330	0.07	0.38	0.68	2.7
440	0.07	0.44	0.76	3.1
460	0.07	0.45	0.77	3.6
600	0.07	0.50	0.87	4.2
650	0.06	0.50	0.88	4.1

Table 3 presents the test results for 4 CRDMs with DC-type magnet to be installed at site. When these are compared with the results (Table 1) of CRDMs with AC-type magnet, the initial delay times are max. 0.07 seconds, and changed to meet the requirement. Also, the pure and full drop times are 0.72 and 0.98 seconds for CRDM #4, and become greatly shorter than those of CRDM with AC-type magnet satisfying all drop requirements.

Table 3 Drop test results of CRDMs with DC magnet

CRDM No.	Drop time (sec.)			Acc.(g)
	Initial delay	Pure drop	Full drop	
1	0.06	0.68	0.88	2.73
2	0.06	0.72	0.88	2.48
3	0.07	0.72	0.91	2.80
4	0.07	0.72	0.98	2.03

5. Conclusions

The drop test results of CRDMs with AC-type electromagnet show that the initial delay times are not satisfied with the requirement, 0.15 seconds. After the replacement of the electromagnet from AC-type to DC-type, the drop times of CARs and accelerations due to the impact of moving parts are satisfied with all requirements. As a result, it is found that four CRDMs to be installed at site have a good drop performance, and meet all performance requirements.

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