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Bottom-mounted control rod drive mechanism for KJRR

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HIGHLIGHTS

- The basic design features and characteristics of the KJRR BMCRDM are described.
- The similarities and differences of some research reactor CRDMs are compared.
- The current status of the design and development of the CRDM is described.
- The future plan of the qualification tests of the CRDM is summarized.

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ABSTRACT

The KIJANG research reactor (KJRR), which is currently being designed by Korea Atomic Energy Research Institute, is a pool type research reactor with 15 MW of thermal power. Contrary to the top-mounted control rod drive mechanism (CRDM), the main drive mechanism of the KJRR CRDM is located in a reactivity control mechanism room under the reactor pool bottom. Recently, we accomplished the design and development of a prototype CRDM. In this paper, we introduce the basic design concept of the bottom-mounted CRDM for KJRR, and compare the similarities and differences of some research reactor CRDMs. The current status of the prototype CRDM development based on a finite element analysis and experimental verification, and the future plan of the CRDM qualification tests, are both described.

1. Introduction

Based on the 20 years of experience of the HANARO research reactor and the design and construction of the Jordan research and training reactor (JRTR), the Korea Atomic Energy Research Institute (KAERI) has been designing a new research reactor, the KIJANG research reactor (KJRR), from 2012, to produce radioisotopes including Mo-99, and to increase the neutron transmutation doping (NTD) capacity (Wu et al., 2013).

The control rod drive mechanism (CRDM) is a device used to regulate the reactor power by changing the position of a control absorber rod (CAR) and shut down the reactor by fully inserting the CAR into the core within a specified time. The main drive mechanisms of CRDM and SSDM (second shutdown drive mechanism) of HANARO, which is a 30 MW thermal multi-purpose research reactor in operation in the Republic of Korea, and JRTR, which is being constructed in Jordan by the Republic of Korea, are located at the reactor pool top, which is called a top-mounted-type (Cho et al., 2010; Choi et al., 2011; Kim et al., 2012). Compared to the top-mounted CRDM, the bottom-mounted CRDM (BMCRDM) for KJRR is quite a different design concept. The main drive mechanism of the BMCRDM is located in a reactivity control mechanism (RCM) room under the reactor pool bottom, which reduces interference with the equipment in the reactor pool. The arrangement of the BMCRDMs and irradiation holes in the core therefore becomes easier than that of the top-mounted-type. Hence, many research reactors, such as JRR-3M, JMTR, OPAL, and CARR, adopted the BMCRDM concept (Sakurai et al., 2002; Kim, 2006; Wu and Yan, 2011).

Compared to the top-mounted CRDM, however, some critical issues exist on the BMCRDM design, such as preventing leakage into the RCM room, the design of the driving part, and the handling

Abbreviations: BMCRDM, bottom-mounted control rod drive mechanism; BMSSDM, bottom-mounted second shutdown drive mechanism; CAR, control absorber rod; CRDM, control rod drive mechanism; ES, extension shaft; ESA, extension shaft assembly; FE, finite element; FFA, follower fuel assembly; HANARO, high-flux advanced neutron application reactor; JRTR, Jordan research and training reactor; KJRR, KiJang research reactor; KAERI, Korea Atomic Energy Research Institute; LVDT, linear variable differential transformer; NTD, neutron transmutation doping; RCM, reactivity control mechanism; SSR, second shutdown rod; SSDM, second shutdown drive mechanism.

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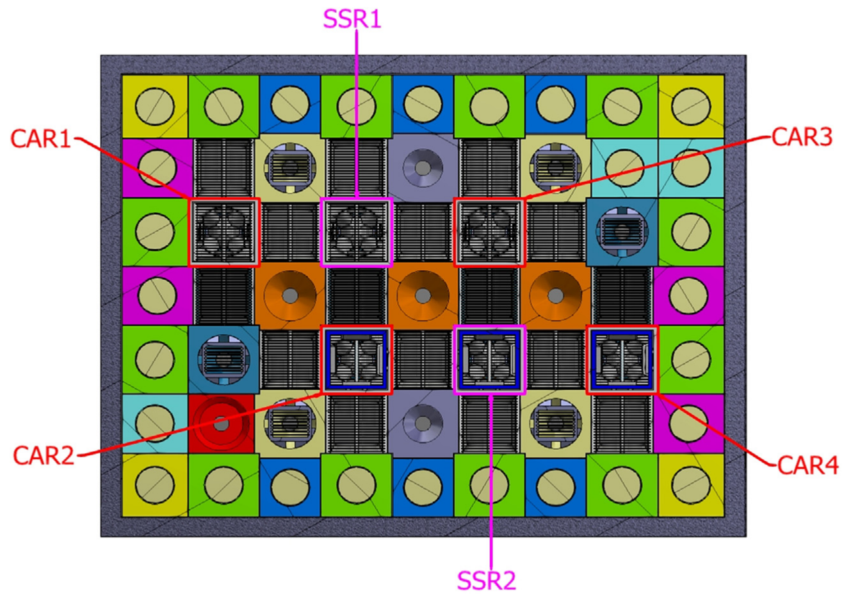

Fig. 1. The core configuration of KJRR.

and maintenance procedures of the CRDM. Keeping these points in mind, we have accomplished the design and development of a prototype CRDM. The purpose of this paper is to introduce the basic design concept of the BMCRDM for KJRR, explain the current status of the design and development of the CRDM components, and describe our future plan. This paper is organized as follows. In Section 2, the basic design features and characteristics of the KJRR BMCRDM are described, and the similarities and differences of some research reactor CRDMs are compared. In Section 3, the current status and future plan of the design, development, and qualification tests of the CRDM components are described. A summary and concluding remarks are given in Section 4.

2. Design features of KJRR CRDM

2.1. Basic design concept of KJRR CRDM

The KJRR is a pool type research reactor with 15 MW of thermal power. The reactor core of KJRR consists of two types of fuel assemblies, 16 Standard Fuel Assemblies (SFAs) and 6 follower fuel assemblies (FFAs). The arrangement of the CARs for CRDM and the second shutdown rods (SSRs) for SSDMs in the reactor core is shown in Fig. 1 (Seo et al., 2013; Kim et al., 2013). The reactivity control mechanisms of KJRR consist of four BMCRDMs driven by an individual step motor and two bottom-mounted second shutdown drive mechanisms (BMSSDMs) driven by an individual hydraulic system located in the RCM room. The CRDMs control the position of the CARs and FFAs in the core during the normal operation by the command from the Reactor Regulating System (RRS). The four CARs drop by the force of gravity when required by the Reactor Protection System (RPS), Alternate Protection System (APS), Automatic Seismic Trip System (ASTS), or an operator for a reactor shutdown.

The CRDM comprises a CAR, a CAR guide tube, an extension shaft assembly (ESA), a seal valve, a connector, an armature, an armature guide tube, an electromagnet assembly, and a CRDM drive assembly, as shown in Fig. 2. There is a penetration assembly located between the reactor pool bottom and the RCM room ceiling to guide the ESAs. The CRDM components in the RCM room are supported by the CRDM support structures. The four CRDMs are identical and interchangeable. The details of the subassemblies of the CRDM are described below.

2.2. System description of CRDM

2.2.1. CAR and CAR guide tube

The CAR is a square tube made of hafnium, which is the most upper part of the CRDM (Fig. 2). The CAR latches, which are located on both ends of the tube, are mechanisms to connect/disconnect the CAR to/from the FFA when it is needed to refuel the FFA, to replace the CAR, or to shuffle the FFAs and the CARs. The main factors that affect the lifetime of the CAR are the degradation of the material properties of the connecting mechanisms and the decrease in neutron absorbing ability of the absorbing material. Hence, to prolong the lifetime of the CAR, CAR is to be periodically turned over before connected to the FFA. For the purpose of the rotation, we use dual latches that have identical connecting mechanisms on both ends of the CAR, whereas traditional CARs have connecting mechanisms on the bottom side only. The material properties and positions of the connecting mechanisms on the top and bottom of the control absorber rod are identical.

The CAR guide tube is an aluminum square tube supported at the grid plate and at the reactor cover. The CAR guide tube guides the CAR, and absorbs the flow induced force on the parts of the CAR from the fuel channels' coolant flow.

2.2.2. ESA and ES guide tube

The extension shaft assembly (ESA) supports the CAR and FFA, and connects the FFA to the armature. The ESA mainly consists of an extension shaft (ES) adapter and an extension shaft (Fig. 2). The ES adapter provides the means of engagement to the FFA and the extension shaft, and sufficient coolant paths from the fuel channels. The armature is attached at the lower end of the extension shaft by means of a locking mechanism, and this coupling can be separated by electromagnetic force induced by the connector electromagnet. The ES adapter is directly in contact with the FFA, and its lifetime is shorter than the extension shaft. Hence, in our ESA design, if necessary, the ES adapter can be separated from the extension shaft and is replaceable.

The ES guide tube is a part of the penetration assembly for the RCM. It guides the ESA, and protects the ESA from external loads.

2.2.3. Seal valve and connector

The seal valve assembly, which is a gate valve having a valve cover, is located between the ES guide tube of the penetration