Design and fabrication of irradiation testing capsule for research reactor materials

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1. Introduction

Recently, the demand of research reactors is increasing because there are many ageing research reactors in the world[1]. Also, the production of radioisotope related with the medical purpose is very important. Korea Atomic Energy Research Institute (KAERI) is designing and licensing for Jordan Research and Training Reactor (JRTR)[2] and new type research reactor for export which will be constructed in Amman, Jordan and Busan, Korea, repectively. Thus, It is expected that more research reactors will be designed and constructed by KAERI.

To design the research reactor, the irradiation performance and behavior of core structure material are necessary. However, the irradiation behavior of these materials is not yet investigated. Therefore, the irradiation performance must be verified by irradiation test.

11M-20K and 11M-21K irradiation capsules were designed and fabricated to conduct the irradation test for some candidate core materials, Zircaloy-4, berillium, and graphite, at HANARO. In this paper, the design and fabrication features of 11M-20K and 11M-21K were discussed.

2. Methods and Results

2.1 Capsule design

11M-20K and 11M-21K capsules for irradiation testing of research reactor materials has the same outward shape as a typical material irradiation capsule. However, to maintain the specimen tempaerture below 100°C and make the similar environment with research reactor, the coolant-flowing concept into the capsule was considered which was different with conventional material capsule[3]. Fig. 1 shows the cross-sectional schematic diagram for arbitrary including the specimens with three different shapes.

The specimens are basically canned by a tube of 1 mm in thickness made of stainless steel. Also, there are two kinds of canning tubes; a closed tube for the graphite circular specimens and an opened tube with side slots to contact between the specimen and the cooling water. All canning tubes are fixed by the supporting structure in both ends between the stages. They are also supported by the capsule external tube. The surfaces of canning tubes and the external tube come in contact with the cooling water in the test hole during the irradiation tests.

To obtain the detailed design data of the capsule with various specimens and the temperatures, a nuclear analysis was carried out using MCNP and a thermal analysis using ANSYS.

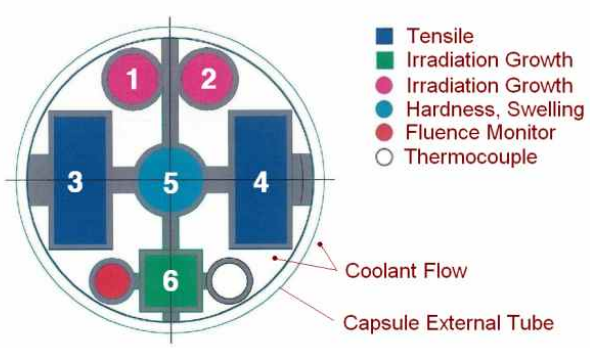

Fig. 1. The Cross-sectional schematic diagram of 11M-20K and 11M-21K capsule

2.2 Nuclear and thermal analysis

11M-20K and 11M-21K capsules are irradiating at CT and IR2 test holes of HANARO. Neutron fluxes and heat generation rates of specimens at 30 MW thermal power of HANARO were evaluated using an MCNP. Then, the reactivity effect owing to the capsule loading in the core was analyzed to confirm the reactor safety. The expected neutron fluxes at the specimens were evaluated to satisfy the required value.

Three models according to the shape of specimens are considered in the thermal analysis. Three FE models in this study are generated using a FE analysis program, ANSYS. One is the 2-dimensional model of a quarter sections for all specimens. Another is the axi-symmetric model for circular specimens. The other is the 3-dimensional model for rectangular and square specimens. In the thermal analysis the temperature (40 ℃) of the cooling water and a heat transfer coefficient (h = 30.3×10^3 W/m^2 ℃) at the outer surface of the canning tube are applied as boundary conditions. The heat generation densities of materials in the CT hole of the reactor in-core are used as an input force.

Fig. 2 shows a typical 2D and axi-symmetric models generated for the canned graphite specimen. In this case the gap size between the specimen and the canning tube is 1.1 mm considering the irradiation growth.

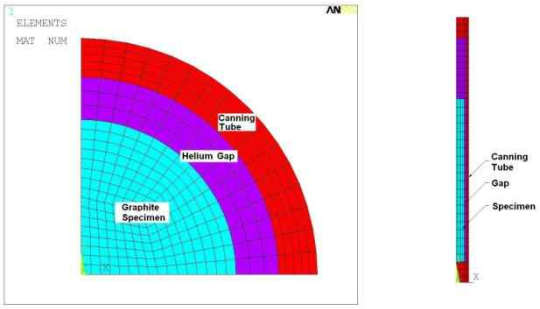

Fig. 2. typical 2D and axi-symmetric models generated for the canned graphite specimen

2.3 Neutron fluence measurement

A new type of fluence monitor (F/M) container was designed and prepared for 11M-20K and 11M-21K capsules. It has some difference as compared with the conventional F/Ms to prevent the contact between the coolant and F/M wires. Each container will contain wires encapsulated in Al 6061 tube. The encapsulation will be about 18 mm long with an outer diameter of 6 mm and will be engraved with unique identification number. And, wires will be placed within holes drilled of each pure aluminum sample holder or within tube which will be directly exposed to coolant. A new type of F/M container with fluence wires such as Fe, Ni. Ti and Nb, can be easily assembled under a helium atmosphere. These containers will be easily dismantled from the capsule, and fluence wires will be easily separated from the containers using a special tool in a hot cell after irradiation testing. These containers, 10 sets, as shown in Fig. 3, were installed in a capsule, and the containers will be loaded with the specimens in the capsule.

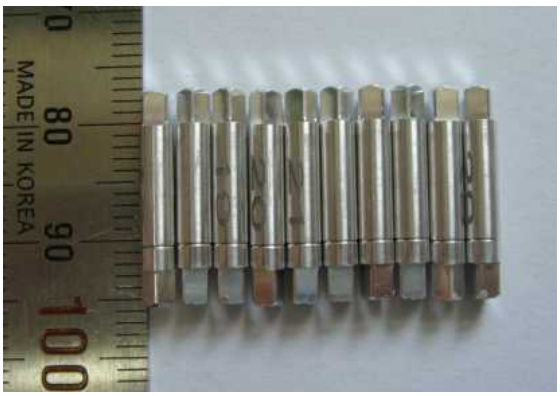

Fig. 3. The new type fluence monitors for 11M-20K and 11M-21K capsules

2.4 Fabrication of capsules

According to the results of nuclear analysis and thermal evaluations, the detailed design of the capsule was completed, and a mockup capsule was fabricated to carry out out-of-pile test. After carrying out the out out-of-pile test using this capsule, compatibility and requirements, such as pressure drop (> 200 kPa at of 19.6 kg/sec of rated flow) and vibration (less than 300 μ m at 110% of rated flow) were verified. Then, detailed drawing was accepted, and two capsules were fabricated to load in test holes, CT and IR2, of HANARO. These capsules is irradiating at the test holes from September 2012 in HANARO. And then, measured temperatures of specimens during irradiation and/or after irradiation will be compared with calculated temperatures.

3. Conclusions

11M-20K and 11M-21K capsules to conduct the irradiation test for core materials, graphite, beryllium, and zircaloy-4, of the research reactor were designed and fabricated. The nuclear and thermal analysis were conducted to design the capsules. Also, new type of fluence monitor (F/M) container was designed and prepared. Two capsules is irradiating at the test holes from September 2012 in HANARO. The measured temperatures of specimens during irradiation and/or after irradiation will be compared with the calculated temperatures.

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