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Irradiation Test of Parts of a Nuclear Fuel Assembly in HANARO

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1. Introduction

A material capsule system including a main capsule, fixing, control, cutting, and transport system was developed for an irradiation test of non-fissile materials in HANARO [1-3]. The capsule system has been actively utilized for the various material irradiation tests requested by users from research institutes, universities, and the industries. For an evaluation of the neutron irradiation properties of the parts of a nuclear fuel assembly, the 05M-07U instrumented capsule was designed, fabricated, and successfully irradiated at HANARO. However, because of a limited number of specimens, the remaining space in the capsule was filled with various KAERI specimens for researches on a nuclear core and SMART materials, and specimens for one university. The capsule was loaded into the CT test hole of HANARO of a 30MW thermal output and the specimens were irradiated at 270 ~ 400℃ up to a fast neutron fluence of 5.7×10^{20}(n/cm^2) (E>1.0MeV).

Based on the 05M-07U capsule irradiation, another instrumented capsule is under consideration for a more precise control of the irradiation temperature of a specimen and for a higher neutron fluence up to 10^{21}(n/cm^2) (E>1.0MeV).

2. Capsule Irradiation Test at HANARO

2.1 Capsule Design and Fabrication

An instrumented capsule of 05M-07U was designed, fabricated and irradiated for an evaluation of the neutron irradiation properties of the parts of a nuclear fuel assembly for PWR of KNFC (Korea Nuclear Fuel Co.,Ltd.). However, because of a limited number of specimens and the budget, the remaining space in the capsule was filled with various KAERI specimens for researches on a nuclear core and SMART materials, and specimens for researches on a fuel cladding materials of a university. The basic structure of the capsule was based on the 04M-07U capsules which had been successfully irradiated in HANARO as part of the 2004 project for an active utilization of HANARO.

Various types of specimens such as tensile, Charpy, TEM, hardness, compression and growth specimens made of Zr 702, Ti and Ni alloys, Zirlo, Inconel, STS 316L and Cr-Mo alloys were placed in the capsule. Especially, this capsule was designed to evaluate the nuclear characteristics of the parts of a nuclear fuel assembly fabricated by KNFC in HANARO. 88 specimens such as spring, buckling, growth and tensile specimens of Zirlo and Inconel alloys were inserted in the capsule as shown in Table 1 and Figure 1. Small size specimens were inserted into a case of a similar material as shown in Figure 2, to simplify the handling and thermal calculation of the capsule.

Table 1 KNFC specimens of the parts of a fuel assembly

Specimen	Dimension(mm)	No
Spacer grid 1x1 cell, Spring	14x14x42(PLUS7 Zirlo)	4
Spacer grid 1x1 cell, Buckling	14x14x42(PLUS7 Zirlo)	4
Spacer grid plate, Spring	3.0x12x40(PLUS7 Inconel)	10
Spacer grid internal Strip, Growth	0.46x8x75(PLUS7 Zirlo)	10
	0.46x8x75(17ACE7 Opt. Zirlo)	10
Spacer grid external Strip, Growth	0.66x8x75(PLUS7 Zirlo)	10
	0.66x8x70(PLUS7 Zirlo Trans)	10
Spacer grid internal Strip, Tensile	0.46x5x26(PLUS7 Zirlo)	5
	0.46x5x26(17ACE7 Opt. Zirlo)	5
Spacer grid external Strip, Tensile	0.66x 5x26(PLUS7 Zirlo)	5
	0.66x5x26(PLUS7 Zirlo Trans)	5
Guide Tube, Growth	1.02x8x75(SRA Zirlo)	10

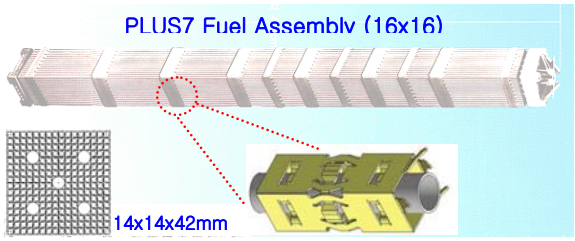

Figure 1. Fuel assembly and spacer grid

The capsule was composed of 5 stages having many kinds of specimens and an independent electric heater at each stage. During the irradiation test, the temperature of the specimens and the thermal/fast neutron fluences were measured by 14 thermocouples and 5 sets of Ni-Ti-Fe neutron fluence monitors installed in the capsule.

Lots of technical tests and safety analyses were performed to apply this capsule in HANARO safely. The out-pile tests was performed by using the 1-channel test facility.

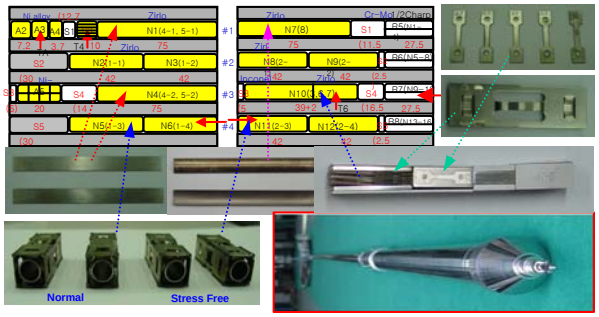

Figure 2. Specimen configuration in the capsule

2.2 Irradiation Test at HANARO

The capsule was safely irradiated in the CT test hole of the HANARO of a 30MW reactor output power for 2 cycles (about 44days) as shown in Figure 3. The irradiation temperature of the specimen was determined by the micro-heater output and He gas pressure of the gap in the capsule as well as the neutron flux of the capsule itself. Although the specimens from parts of a nuclear fuel assembly were designed to be irradiated at around 300℃, the irradiation temperature showed a large difference depending on the type of a specimen. Plate type specimens showed a stable irradiation temperature at around 300℃. However, spacer grid specimens showed a large difference of 100℃ depending on the location in the capsule. The unstable temperature of the specimens seems to be related to an uncertain location of the internal thermocouple.

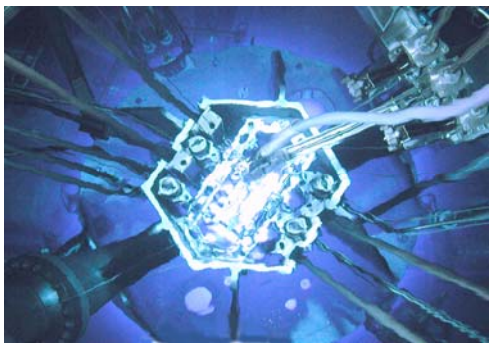

Figure 3. Reactor core during an irradiation test in HANARO

Figure 4 shows the calculated axial distribution of the fast neutron fluence of the specimens in the 05M-07U capsule according to the vertical location in the reactor core. A fast neutron fluence of the KNFC specimens was obtained in the range of $5.1\sim5.7\times10^{20}$(n/cm^2) (E>1.0MeV). The amount of neutron fluence of the specimens was calculated by the computer code of VENTURE and will be compared with the measured values from the neutron fluence monitors. After an irradiation test, the main body of the capsule was cut off at the bottom of the protection tube with a cutting system and it was transported to the IMEF (Irradiated Materials Examination Facility). The irradiated specimens will be tested to evaluate the irradiation performance of the parts of a fuel assembly in the IMEF hot cell.

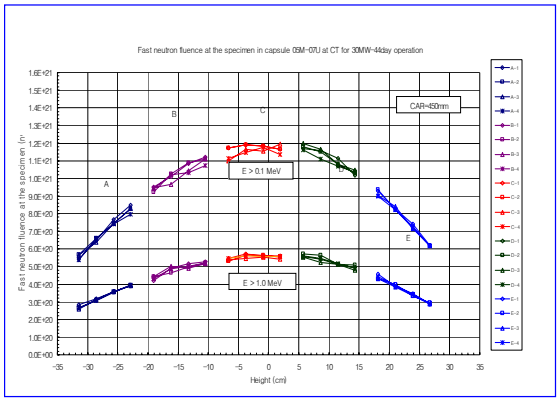

Figure 4. The axial distribution of the fast neutron fluence of the specimens in 05M-07U capsule

2.3 New Capsule Design

Based on the irradiation experience of the 05M-07U capsule and the 01M-05U capsule [4], a new instrumented capsule for an irradiation test of the parts of a nuclear fuel assembly is under consideration. New capsule will be designed for a more precise control of the irradiation temperature of a specimen and for a higher neutron fluence up to 10^{21}(n/cm^2) (E>1.0MeV).

3. Conclusion

An instrumented capsule of the 05M-07U was designed, fabricated and irradiated for an evaluation of the neutron irradiation properties of the parts of a nuclear fuel assembly. Various types of specimens such as spring, buckling, growth and tensile specimens of Zirlo and Inconel alloys were irradiated in HANARO in the range of $5.1\sim5.7\times10^{20}$(n/cm^2) of a fast neutron fluence (E>1.0MeV). Based on the capsule irradiation tests, another instrumented capsule is under consideration for a more precise control of the irradiation temperature of a specimen and for a higher neutron fluence up to 10^{21}(n/cm^2) (E>1.0MeV).

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