Irradiation of Parts of the X-Gen Nuclear Fuel Assembly made by KNF in HANARO

K.N. Choo[a]*, M.S. Cho[a], Y.T. Shin[a], B.G. Kim[a], S.H. Lee[b], K.B. Eom[b]
[a]*Korea Atomic Energy Research Institute 150 Deokjin-dong, Yuseong-gu, Daejeon 305-353, Korea,*
[b]*Korea Nuclear Fuel Co.,Ltd. 493, Deokjin-dong, Yuseong-gu, Daejeon, 305-353, Korea*
[*]*Corresponding author: knchoo@kaeri.re.kr*

1. Introduction

An instrumented capsule has been developed at HANARO (High flux Advanced Neutron Application ReactOr) for the neutron irradiation tests of materials [1]. The capsule system has been actively utilized for the various material irradiation tests requested by users from research institutes, universities, and the industries. As a preliminary test, some specimens made of the parts of a nuclear fuel assembly were inserted in the 05M-07U instrumented capsule [2] and successfully irradiated at HANARO. Based on the results and experience, a new irradiation capsule of 07M-13N was designed, fabricated, and irradiated at HANARO for the evaluation of the neutron irradiation properties of the parts of the X-Gen nuclear fuel assembly made by KNF (Korea Nuclear Fuel). Specimens such as bucking and spring test specimens of spacer grid, microstructure and tensile test specimens of welded parts, tensile, irradiation growth and spring test specimens made of HANA tube, Zirlo, Zircaloy-4 and Inconel-718 were placed in the capsule. The capsule was loaded into the CT test hole of HANARO of a 30MW thermal output and the specimens were irradiated at 295 ~ 460℃ up to a fast neutron fluence of 1.2×10^{21}(n/cm^2) (E>1.0MeV).

2. Irradiation Test at HANARO

2.1 Specimens

This capsule was designed to evaluate the nuclear characteristics of the parts of the X-Gen nuclear fuel assembly for a PWR fabricated by KNF in HANARO. Various types of specimens such as buckling and spring test specimens of a 1x1 cell spacer grid, microstructure and tensile of welded parts, tensile, irradiation growth and spring test specimens made of HANA tube, Zirlo, Zircaloy-4 and Inconel-718 alloys were placed in the capsule. Some other specimens including Polyimide requested by Hanyang university were also inserted in this capsule.

461 specimens of the parts of the X-Gen nuclear fuel assembly, control rod materials and Polyimide were inserted in the capsule as shown in Table 1 and Fig. 1. Small size specimens were inserted into a case of a similar material to simplify the handling and thermal calculation of the capsule.

Table 1 Specimens of the 07M-13N capsule

Specimen	Dimension(mm)	No
KNF SG (spacer grid) 1x1 cell, Buckling	14x14x42/46(Zirlo)	8
KNF SG cell, Spring	14x14x42/46(Zirlo)	11
KNF SG plate, Spring	4x14x30(Zirlo, Inconel718)	50
KNF SG inter/external Strip, Growth	0.46x8x77(HANA4/6, Zirlo)	150
KNF SG inter/external Strip, Tensile	0.46x5x26(HANA4/6, Zirlo)	118
KNF Welding property	6.77x1.4/4.4x26(Zirlo, Inconel 718)	50
HY university Tensile	2x9.53x63.5(Polyimide,TiH_2)	70

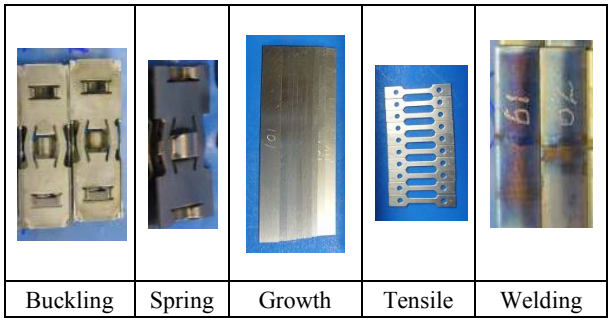

Fig. 1. KNF specimens of the parts of a fuel assembly.

2.2 Capsule Design and Fabrication

An instrumented capsule of 07M-13N was designed, fabricated and irradiated for an evaluation of the neutron irradiation properties of the parts of the X-Gen nuclear fuel assembly of KNF (Korea Nuclear Fuel) as shown in Fig. 2. The basic structure of the capsule was based on the 05M-07U capsules, which had been irradiated in HANARO as a preliminary irradiation test of parts of similar nuclear fuel assembly.

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 with 14 thermocouples and 5 sets of Ni-Ti-Fe neutron fluence monitors installed in the capsule. In addition, 2 sets of Ni-Ti-Fe-Nb-Ag neutron fluence monitors for the first measurement of the thermal neutron fluences of specimens in HANARO capsule were installed in this capsule [3]. A new friction welded tube between STS304 and Al1050 alloys was also

introduced in the capsule to prevent a coolant leakage into a capsule during a capsule cutting process in HANARO [4]. Lots of technical tests and safety analyses were performed to apply this capsule in HANARO safely [4]. The out-pile tests was performed by using the 1-channel test facility.

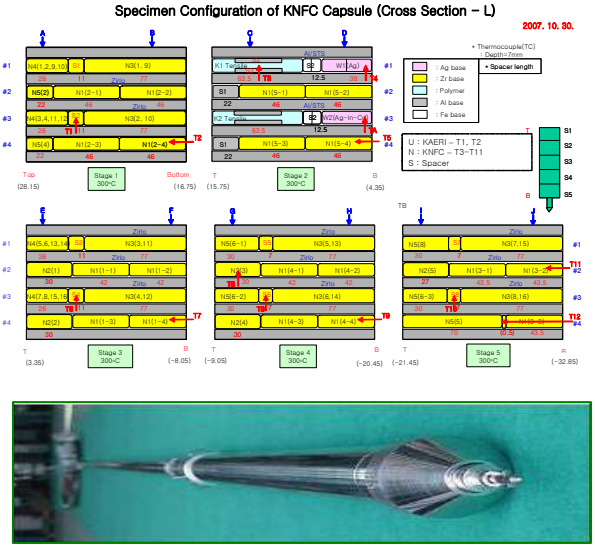

Fig. 2. Specimen configuration in the 07M-13N capsule

2.3 Irradiation Test at HANARO

The capsule was safely irradiated in the CT test hole of the HANARO of a 30MW reactor output power for 4 cycles (about 96days). 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 of the specimens was maintained in a range of 295~460℃ less than 500℃ of recrystallization temperature of Zr-Sn-Fe alloy [4]. The large temperature difference was attributed to a vacant area in the stacked spring specimens of spacer grid.

Fig. 3 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 KNF specimens was obtained in the range of $0.51\sim1.28\times10^{21}$(n/cm^2) (E>1.0MeV). The amount of neutron fluence of the specimens was calculated using the computer code of VENTURE and will be compared with the measured values from the neutron fluence monitors. The capsule is being maintained in the reactor water pool for radioactivity cooling. After the cooling, the main body of the capsule will be 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 the X-Gen fuel assembly in the IMEF hot cell.

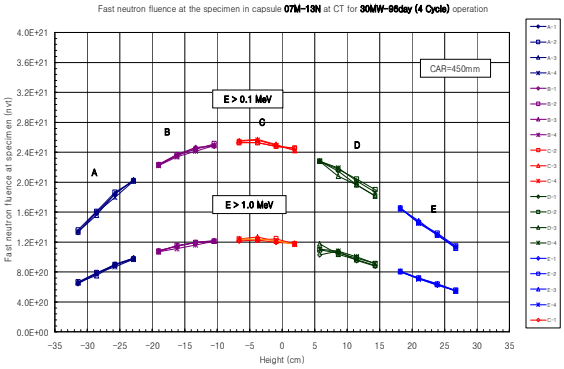

Fig. 3. The axial distribution of the fast neutron fluence of the specimens in 07M-13N capsule

3. Conclusion

An instrumented capsule of the 07M-13N was designed, fabricated and irradiated for an evaluation of the neutron irradiation properties of the parts of the X-Gen nuclear fuel assembly made by KNF. Various types of specimens such as bucking, spring test, tensile, microstructure and an irradiation growth of a spacer grid and parts including welded parts of Zr and Inconel alloys were successfully irradiated in HANARO in the range of $0.51\sim1.28\times10^{21}$(n/cm^2) of a fast neutron fluence (E>1.0MeV).

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