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Design and Fabrication of Capsule for RPV Plates Material to be irradiated in the CT hole of HANARO

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1. Introduction

An instrumented capsule (17M-01K) for irradiation of the plate type material of reactor pressure vessel was designed, fabricated for an evaluation of irradiation properties of the reactor pressure vessel material. The basic structure of the capsule was based on the previously fabricated capsule 11M-25K [1]. 171 specimens such as ST-PCVN, 1/2 PCVN, plate & small tensile, TEM, SP, IIT specimens of SA508 RPV plates material are placed in the capsule. The capsule is 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 will be measured by 14 thermocouples installed in it. A friction welded tube between STS304 and Al1050 alloys is introduced in the capsule to prevent a coolant soak into the capsule while cutting in the working pool of HANARO. The capsule will be irradiated in the CT hole of HANARO of a 30MW thermal output at 290±10℃ up to the fast neutron fluence up to 1.0×10^{20} n/cm^2 (0.1 dpa) (E>1.0 MeV).

2. Material and Specimens

The specimens are made of SA533 Gr. B1 Mn-Mo-Ni low carbon steel which was used in the RPV of Gori II and Hanbit II nuclear power plant. They include 0.4 round compact tension specimens, ST-PCVN, 1/2 PCVN, small tensile, plate tensile, IIT (instrumented indentation test) and SP specimens as shown in Table 1. SP case includes 16 specimens in it, and so total 144 specimens are included in 9 cases. Specimens are inserted into an Al thermal media as a square bar shape with spacers of a same material to simplify the handling and thermal calculation of the capsule as shown in Figure 1.

Table 1. Specimens in the RPV capsule

Specimen	Size(mm)	stage # placed in capsule	Number
0.4 RCT	10mmT-CT	1 upper	4
1/2 PCVN	27.5x10x10	1	45
ST PCVN	55x10x10	2, 3, 4, 5	24
Plate tensile	15x10x66	2, 4	20
Small plate tensile	27.5x5x0.5	1, 5	15
IIT	10x10x2	2, 4	52
SP(case)	10x10x10	1, 4	9
TEM	10x10x15	2	2
Total			171

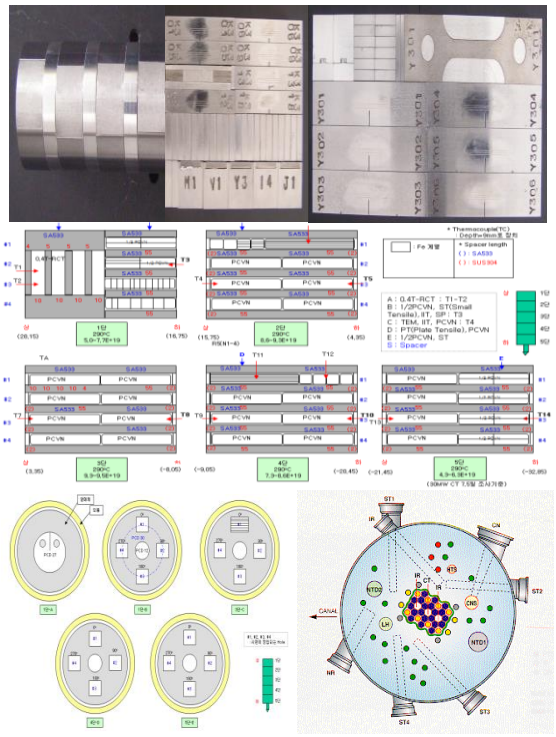

Figure 1. Specimen and the arrangement

3. Irradiation Capsule

The irradiation capsule 17M-01K was designed, fabricated for an evaluation of the irradiation properties of the RPV SA 508 Gr. B1 steel at higher neutron fluence. The capsule was designed to be irradiated at the temperature of 290±10℃ at CT test hole according to the user's requirements as shown in Figure 2. The irradiation test of the capsule was proven safe for SA 508 steel through the previous irradiation test in HANARO. The irradiation temperature of the specimen is determined by the gamma heating, He gas pressure, and widths of gaps between the capsule parts. The irradiation temperature is preliminary analyzed by using the GENGTC and ANSYS codes. The capsule is divided into 5 stages with an independent electric heater at each stage. 14 thermocouples and 5 sets of Ni-Ti-Fe neutron fluence monitors were installed in it to measure the irradiation temperatures and the fast neutron fluence of the specimens, respectively.

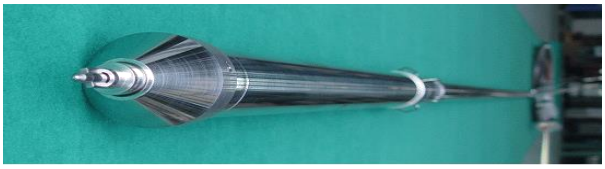

Figure 2. Irradiation capsule for CT test hole

4. Thermal analysis

The reactivity is calculated to be +1.7 mk on the basis that the control rod is 450mm and the capsule is fully inserted at CT [2]. The irradiation test is proved safe because it is less than +12.5 mk of the limited value required at HANARO. Figure 3 shows the neutron flux and spectrum distribution at the hole, which is the average values at all specimen.

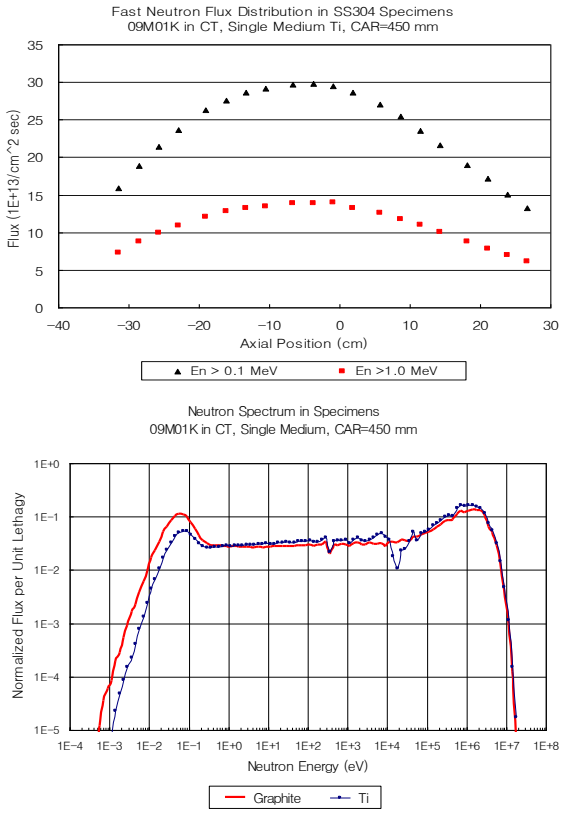

Figure. 3. Neutron flux and spectrum distribution in CT

The GENGTC program was finally used to determine gaps for an evaluation of temperatures of specimens and the parts. A one-dimensional model for the specimen section was generated and used for the code calculation. The temperature of the cooling water in the reactor in-core is about 33 ℃, and the heat transfer coefficient at the outer surface of the external tube is 30.3 x 10^3 W/m^2℃, which was determined experimentally [3].

Table 2 shows the temperature analysis results by GENGTC code. The analysis was performed repeatedly until the calculated values collected in the target temperatures adjusting the gap between the outer tube and the thermal media. The measured temperatures in the previous tests are almost within ±10 % of the calculated values.

Table 2. The gap and the specimen temperatures

Stage	Heat generation	Gap (mm)	Design Temperature	
			1 atm	0.4K
1 up	2.61	0.12	195	293
1 low	3.73	0.11	216	306
2	4.32	0.07	221	306
3	6.0	0.03	233	305
4	5.94	0.03	232	304
5	3.34	0.14	232	336

5. Irradiation Test in HANARO

The capsule will be irradiated in the CT test hole of the HANARO of a 30 MW reactor output powers. This capsule will be irradiated for only 8 days at CT test hole because the required neutron fluence for RPV material is ~1.0×10^{20} n/cm^2 (0.1 dpa) (E>1.0MeV). The amounts of neutron fluence of the specimens were calculated by the MCNP code and will be compared to the obtained values from the irradiated fluence monitors. The temperatures of specimens during irradiation will be initially increased by the gamma heating and then roughly adjusted to an optimum condition by the He gas control system. It will be finally adjusted to the desired value by micro-electric heaters. During the irradiation test, the temperatures of specimens will be measured and monitored with thermocouples to keep within ± 10% of the target temperatures.

6. Conclusion

A capsule for an evaluation of the irradiation characteristics of the RPV SA533 Gr. B1 Mn-Mo-Ni low carbon steel at higher neutron fluence was designed and fabricated for irradiation test at CT test hole of HANARO. Various specimens such as ST-PCVN, 1/2 PCVN, plate & small tensile, TEM, SP, IIT of SA508 RPV plates material are placed in the capsule. The obtained test results will be very valuable to evaluate the irradiation characteristics of the plate type SA533 material and improve the performance of the RPV steel in the nuclear power plant.

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