Development of a Capsule for Irradiation Tests at Medium and High Temperatures

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1. Introduction

A capsule was developed for the irradiation tests of materials, aiming at irradiation at medium and high temperature. Recently, the capsule with double layered thermal media was developed for irradiation of the high-temperature materials for VHTR and SFR [1]. Graphite and Ti materials were used as the thermal media instead of aluminum in this capsule. The high-temperature parts of stages 1-3 and 5 reached 900 ℃, and the medium-temperature part of stage 4 was operated at 400 ℃

2. Design and Fabrication of the Capsule

The capsule was designed and fabricated for irradiation at a target temperature of 700 ℃. It was made up of 5 stages of specimen holders, 4 of which were parts with double thermal media, and while remaining stage had single thermal media. The appearance of the capsule is shown in Fig. 1.

Fig. 1. Appearance of material capsule

2.1 Configuration of the thermal media

Stage 4 of the capsule has the configuration of single thermal media, as shown in Fig. 2. This part was designed for irradiation at a medium temperature of up to 400 ℃. The material of the thermal media is Al., which is same as in a standard material capsule.

Other parts except stage 4 of the capsule have double-layered thermal media, which are shown in Fig. 2. Ti and graphite were used as materials of the inner thermal media. Ti is lower in density and price when compared with other materials such as Zr, Nb, or Mo, but the cross-section absorption of thermal neutrons is relatively high. Graphite was also selected as a candidate material as its mechanical properties are excellent at high temperature, and it is therefore used as the in-core material in a VHTR [2]. The gap between the holder and specimen is 0.1 mm, while that between the inner and outer thermal media is 0.15 mm, and the gap between the outer thermal media and outer tube is 0.16-0.36 mm, which was designed effectively to control the temperatures of each stage. All gaps were filled with He gas at 101 kPa. Fig. 2 shows the configurations of the thermal media.

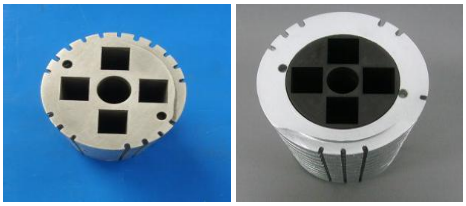

Fig. 2. Configurations of thermal media

2.2 Specimens

This capsule was designed to investigate the soundness of the parts and the instruments in the environment of high-temperature irradiation, and to irradiate the RPV materials of a commercial nuclear power plant at medium temperature.

16 specimens for high-temperature irradiation were made of STS 304L with a size of 10 x10x 114 mm and mounted at stages 1, 2, 3 and 5. In particular, the 5 carbon specimens were inserted in stage 2, which will be used for the sheath of the VHTR control rod. These specimens were irradiated at 600-900 ℃.

The specimens for medium-temperature irradiation were mounted into stage 4 for testing the irradiation corrosion properties, which were furnished by universities including Dongkuk and Hanyang universities. These specimens were tested at a temperature of 400 ℃. The configurations of the specimens are shown in Fig. 3.

Fig. 3. Specimens(L :STS 304L & carbon/R : Zry)

3. Irradiation Test

The capsule was safely irradiated in the CT test hole of HANARO at 30MW reactor power for one cycle (28days). Fig. 4 shows the irradiation temperatures. The temperatures rose to 635 ℃ at stage 2 at the condition of 760 torr without heater power. The temperatures of the specimens were controlled by the internal He pressure and a micro-heater according to the user requirements. The temperatures of each stage were adjusted to 600-900 ℃.

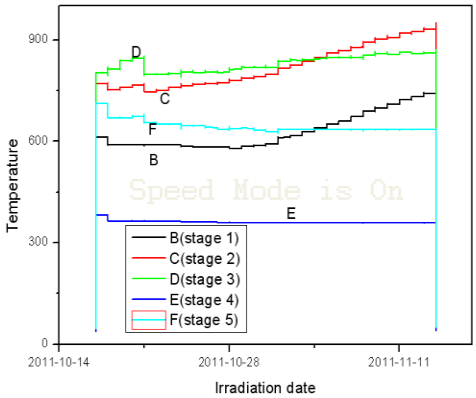

Fig. 4. Irradiation temperatures
(He pressure of 30-50 torr)

The measured and calculated temperatures of the capsule specimens are listed in Table 1. The ANSYS and GENGTC codes were used for calculation of the temperatures. In comparison with the calculated and measured temperatures of the specimens, the differences are all less than 10%. The maximum difference is 8.6% at stage 3. This shows that the forecast based on the calculation coincides with the measured values.

Table 1. Comparison of specimen temperatures between measurement and analysis

Stage	Gap size (mm)		Temperature at 101kPa		Error (%)
	g2	g3	Calculat -ed	Measur-ed	
1	0.4	0.65	554	548	1.1
2	0.5	0.45	678	635	6.8
3	0.2	0.30	661	614	7.6
4	0.2	0.32	625	580	7.7

Error=(Calculated-Measured)/Measured x 100(%)

4. Conclusions

In accordance with the development plan of future nuclear systems in Korea, which will be operating at high temperatures, a capsule, some parts of which are made up of double-layered thermal media, and some made out of single thermal media, was developed to overcome the restrictions in the use of aluminum at high temperature. This capsule was irradiated at a temperature of up to 900 ℃. This capsule will be used for irradiation tests at a wide range of medium to high temperatures.

Acknowledgements

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