Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

Test of Capsule (11M-22K) with Double Layered Thermal Media for Irradiation of Future Nuclear System Materials

Man Soon Cho*, Kee Nam Choo, Seong Woo Yang, Young Hwan Kang, Sang Jun Park
Korea Atomic Energy Research Institute
1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-600, The Republic of Korea
* *mscho2@kaeri.re.kr, Tel : +82-42-868-8431, Fax : +82-42-863-6521*

1. Introduction

As future nuclear systems will be operated under conditions of high temperature and high neutron flux, a new capsule with double-layered thermal media composed of two kinds of materials, Al-Ti and Al-graphite, is being designed and fabricated, enabling it to be tested at higher temperature than a single thermal media capsule. Graphite and Ti materials combined with Al are used as thermal media instead of Al in this capsule because Al might melt at high temperature. This capsule was irradiated at the CT hole of HANARO with a 30MW thermal power. The irradiation temperatures and fluence of specimens were in the range of 800-900℃ and 7.0×10^{20} (n/cm^2) (E>1.0MeV). By the irradiation test, the structural integrity and safety of the capsule during irradiation at high temperature were confirmed.

The outlet temperatures of VHTR and SFR are 1,000 ℃ and 550 ℃, respectively, which are much higher than the irradiation temperatures of the material capsules tested at HANARO up to recently. The capsule for high-temperature materials was designed as a double layered thermal media, in which the outer layer is aluminum and the inner layer is Ti or graphite. This capsule aims at allowing irradiation at temperatures of up to 1,000 ℃ in the near future.

2. Design of Capsule

2.1 Design model

A new capsule aims to be irradiated at temperatures higher than 800 ℃. Ti and graphite were selected as materials for the thermal media in this capsule. Fig. 1 shows the section of the thermal media. It has a double-layered structure, the outer of which is made of aluminum and the inner is made of Ti or graphite as shown in Fig. 1. 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 between the outer thermal media and outer tube the gap is 0.16-0.36 mm, which was designed to effectively control the temperature of each stage. All gaps are filled with He gas.

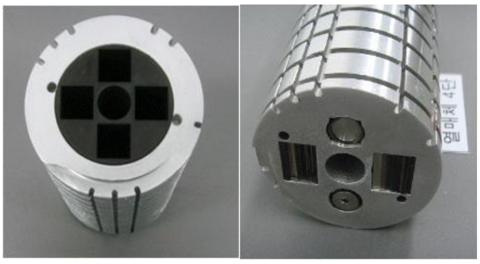

Fig. 1 Double-layered thermal media

2.2 Nuclear and thermal analysis

As the double layered thermal media is a new concept and graphite and Ti are the first irradiated material at HANARO, the evaluation of nuclear characteristics is important for the design of the capsule and safety of irradiation. The reactivity is calculated to be 9.6 mk even if the thermal media are all Ti, which will make it the highest. Therefore, the irradiation test is proved to be safe because it is less than +12.5 mk of the limit value required at HANARO [1]. Fig. 2 shows the neutron spectrum at the CT hole, which is the average value at all specimens.

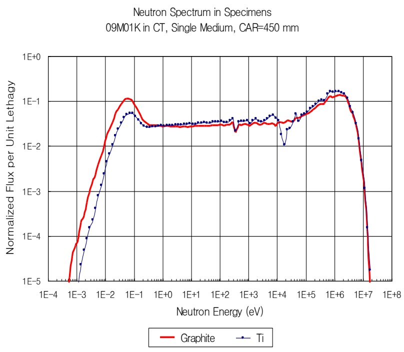

Fig. 2. Neutron Spectrum in CT hole

2.3 Thermal analysis

The ANSYS program was used for the thermal analysis. A two-dimensional model for the specimen section was generated. 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.

Table 1 shows the temperature analysis results of the 11M-22K capsule by ANSYS code. An analysis was performed repeatedly until the calculated values converged on the target temperatures by adjusting the He gap between the outer tube and the thermal media [2].

Table 1. Results of Temperature analysis

Stage	Thermal media	Gap size (mm)	Maximum temperature (at 101kPa)		
			Target Temp.	ANSYS	
				Specimen	Al thermal media
1	Gr/Al	0.65	700	721	440
2	Gr/Al	0.45	950	963	500
3	Ti/Al	0.30	950	970	525
4	Ti/Al	0.32	950	963	520
5	Ti/Al	0.50	800	826	510

Fig. 3 shows the target and calculated temperatures of the specimen and temperatures of Al thermal media at each stage. In stages 1 and 2, it is difficult to reduce the He gap and increase the temperatures because the graphite used in stage 1 and 2 has a small heat generation rate and good heat conductivity. If the gap between the outer tube and thermal media increases excessively in size, the temperature of the Al thermal media might reach the melting point.

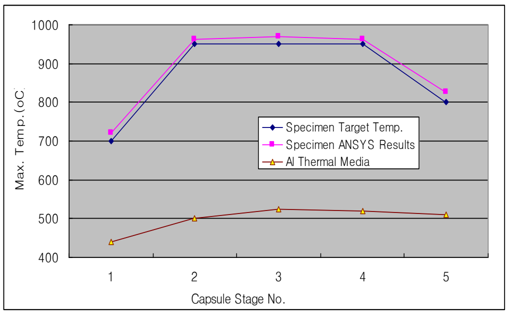

Fig. 3. Temperatures of specimen and Al thermal media at each stage

In stages 3, 4, and 5, the heat generation rates of the specimen and inner thermal media are high, and thus the temperature of the specimen goes up over 1,000 °C when the inner gap increased by more than 0.25 mm, and thus the temperature of Al thermal media might rise over the melting point. Fig. 4 shows the result of the temperature analysis of stage 3. The temperature of the specimen reaches 970 °C at stage 3. This value was 5% higher than the target temperature by adjusting the He gap. The temperature of the Al thermal media is 525 ℃ which is less than the melting point, and thus its soundness is judged to be preserved.

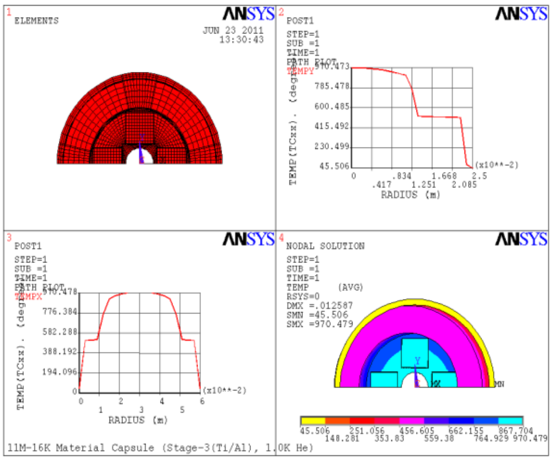

Fig. 4. Temperatures distribution at stage 3 of 11M-22K capsule

3. Conclusions

As future nuclear systems are to be operated at high temperatures, the irradiation tests at high temperature are necessary. In accordance with this requirement, a capsule suitable for an irradiation test at high temperatures is being developed to overcome a restriction on the use of aluminum at high temperature. A new capsule with thermal media of a double layered structure, the outer of which is Al and the inner is Ti or graphite, was designed. This capsule was applied to an irradiation test up to 900 ℃. The capsule for use at the irradiation test up to 1,000 ℃ will be developed at the beginning in 2014.

Acknowledgements

This work was supported by the Nuclear Research & Development Program of the National Research Foundation of Korea (NRF) grant funded by the Korean government (MEST).

REFERENCES

1. S.Y. Oh, "Analysis of Nuclear Characteristics of 09M-01K Capsule," KAERI Internal Memo", HAN-NE-CR-920-09-17 (2009)
2. J.H. Lee, "Analysis of Temperature of Material Capsule due to Change of Gap", KAERI Internal Memo, HAN-IC-CR-11-026 (2011)