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Preliminary Thermal Analysis of the Capsule for Gr and Be Irradiation Tests

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1. Introduction

A capsule has been used for an irradiation test of various nuclear materials in the research reactor, high-flux advanced neutron application reactor (HANARO) [1]. As a part of the research reactor development project with a plate type fuel, the irradiation tests of beryllium (Be) and graphite (Gr) materials using the capsule have been investigating to obtain the mechanical characteristics such as an irradiation growth, hardness, swelling and tensile strength at the temperature below 100°C and the 30MW reactor power.

In this study, in order to obtain the preliminary design data and thermal characteristics of the capsule with various specimens, a finite element (FE) thermal analysis is performed by using an ANSYS program [2]. The 2-dimensional model for the cross section of the capsule containing the specimen is generated, and the maximum temperature is obtained. The influence of the gap size on the temperature of the specimen is also discussed.

2. Model and FE analysis

The capsule under development has the same outward shape as a typical fuel capsule which consists of the main body, the protection and guide tube etc. [3]. The capsule main body has five stages of which contain canned specimens in the longitudinal direction. Fig. 1 shows the typical cross section of the capsule for each stage. The specimens with three different shapes are canned by a tube of 1mm in thickness made of aluminum. The Aluminum (Al) Cans containing the specimens are fixed by the supporting structures in the top and bottom ends between the stages. All internal components are supported by the external tube of 58mm in diameter. Also, the surfaces of Al Cans and the external tube come in contact with the coolant flow in the test hole. Therefore, we consider six different models to obtain the temperature of canned specimens in the thermal analysis.

Fig. 2 shows a typical quarter FE model generated for the capsule's cross-section with a circular shape. The gap size between the specimen and Al Can is modeled as 0.25~1.1mm depending on the kinds of the specimen. In the thermal analysis the temperature (35°C) of the cooling water and a heat transfer coefficient (h=30.3×10^3 W/m^2 °C) at the outer surface of the Al Can are applied as boundary conditions. The gamma-heating rates of the materials in the CT hole of the reactor in-core are also used as an input force. Table 1 presents the mechanical properties of Gr and Be used in the thermal analysis.

Table 1. Mechanical properties of Gr and Be

Material	Density (g/cm^3)	Thermal Expansion Coefficient (x10^{-6}/°C)	Thermal Conductivity (W/m °C)
Gr	1.77	3.8	120
Be	1.85	11.3	200

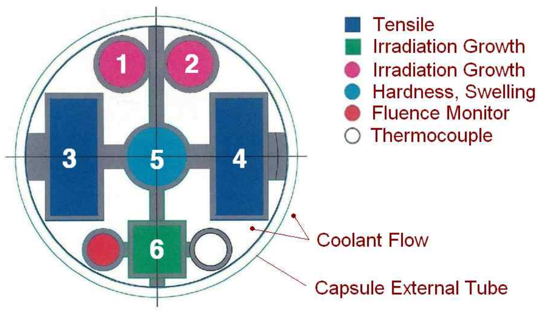

Fig. 1. Cross section view of the capsule

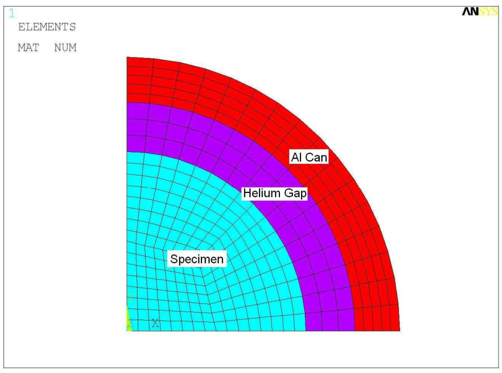

Fig. 2. Typical model of the circular canned specimen

3. Results and Discussion

Among five stages of the capsule, the stage 3 located in the middle of the reactor in-core has the highest gamma heat. Thus, the analysis is performed for six canned specimens of the stage 3 only. Table 2 presents the design data and maximum temperatures for the specimens. The temperatures of circular specimens (#1~2, #5) are relatively higher than those of the rectangular specimens. The reason is because the gap sizes designed between the specimen and Al Can are relatively large.

Table 2. Temperatures of the stage 3 specimens

Specimen No.	Material	Design gap (mm)	H.G.D $\times 10^6$ (W/m^3)	Max. temp. (^{o}C)
1	Gr	1.1	9.61	146.4
2	Gr	1.1	9.66	146.9
3	Be	0.25	11.06	97.0
4	Be	0.25	11.06	97.0
5	Be	0.85	10.58	171.2
6	Be	0.35	10.23	84.6

Fig. 3 shows the temperature distribution of the graphite specimen with a circular shape. The maximum temperature is 146.9°C and they are uniformly distributed at the specimen. The heat transfer occurs from the inside of the capsule to the outside because of the low temperature of cooling water. Also this figure shows that the temperature is rapidly decreased due to the gap between the specimen and Al Can.

The temperature distribution of the beryllium specimen with a rectangular shape is shown in Fig 4. The maximum temperature is 84.6°C and the distribution shows the same trend with that of the capsule with the circular specimen.

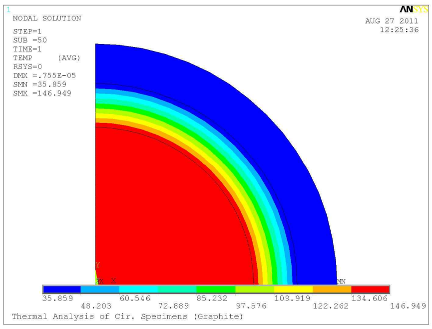

Fig 3. Temperature distribution of the specimen #2(Gr)

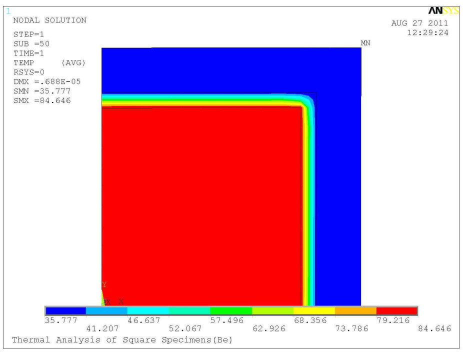

Fig 4. Temperature distribution of the specimen #6(Be)

As shown in figures 3 and 4, the gaps between the specimen and Al Can have a larger effect than other parameters on the temperature because the helium with the low thermal conductivity plays a role of an adiabatic material. Table 3 presents the effect of gap sizes for the specimens #2 and #3. When the gap is reduced as a half size, the maximum temperatures of the specimen are decreased up to 30~35 percents.

Table 3. Effect of gap sizes on the temperature

Mat	Graphite (Specimen #2)			Beryllium (Specimen #3)	
Gap (mm)	1.1	0.55	2.75	0.25	0.125
Temp. (^{o}C)	146.9	96.7	68.3	97.0	68.3

For the present capsule with canned specimens, the temperature for some specimens is slightly higher than the irradiation target temperature. Thus it is found that the capsule design needs to be changed such as the reduction of the gap size for circular specimens or the design change for the canning of specimens including the direct contact of the specimen and the cooling water.

4. Conclusions

The capsule for irradiation tests of Graphite and Beryllium is under development, and the preliminary thermal analysis is performed on the basis of the conceptual design data. The temperature of the circular specimen is larger than the irradiation target temperature. It is necessary to reduce the maximum temperature by changing the shape of the Can and/or the gap between the specimen and the Can for the present design. The gap size has significantly effect on the specimen temperature. If the gap size becomes a half, the temperature is decreased about 30 percents. Based on those results the detail design and analysis of the capsule will be performed in the future.

REFERENCES

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