Effects of Design Changes of a Capsule on a Specimen's Temperature

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1. Introduction

The R&D programs for generation IV systems such as a SFR and a VHTR were launched in Korea. These programs require key material property data on the candidate fuels, claddings, and structural materials necessary for the development of an advanced reactor system. In order to demonstrate that candidate materials have an adequate performance over a long service life, the in-pile test programs focus on verification tests using a loop as well as high temperature tests using a capsule. In the initial development stages, capsule tests are enough for selecting the candidate materials as one of the separate tests. The existing design concept of a capsule, however, is not satisfactory for the high temperature tests. Thus, various approaches, i.e. usability of several test holes of HANARO, applicability of a new specimen holder [1] and design changes such as the internal geometry and shapes of a capsule, are investigated.

2. Methods and Results

2.1 General Description of a HANARO capsule

An instrumented capsule consists of a main body, a flexible guide tube, a protection tube, and wire type springs [2]. The main body with the test specimens to be placed in the in-core region of HANARO is a cylindrical shell with a 2mm thickness, 58mm in external diameter and 870mm in length, and it is divided into 5 stages of specimen holders in which an independent heater and thermocouples are installed. The typical specimen holder with a length of 120mm is a cylinder with 4 specimen holes. The protection tube part connected to a capsule's main body is 34mm in diameter, 1.65mm in thickness and 5,120mm in length.

2.2. Modeling and Boundary Conditions

The temperature calculations for a capsule are performed using a conventional finite element analysis program, ANSYS [3]. The analysis model for the circular cylinder with multi holes is generated by the coupled-field elements of PLANE223 with a 2D thermal field. Fig. 1 shows the two-dimensional analysis model for a quarter section with 4-specimens and one center hole. This model consists of four main parts; an external tube, a specimen holder, the specimens and the helium gaps as shown in Fig. 1. The gamma heat data for the aluminum holder, the stainless specimen as well as the external tube are determined based on the predicted nuclear data [4].

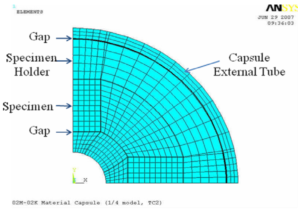

Fig. 1 Typical finite element model of a capsule

The boundary conditions in the FE analysis are symmetric for the x and y axis in the model. Heat transfer coefficient used in this study is 30.01 x 10^3 $KW/m^2.C$ [5] for the OR holes, and the reactor coolant temperature is about 40 ^oC. The stainless steel 304 specimens with a 10mm x 10mm square size are assumed to be loaded into a capsule. The gap between a holder and a specimen in Fig. 1 is fixed as 0.1mm in size while the gap between a holder and an external tube 0.5mm. The hole size for an analysis are assumed to be 12, 7, 0.2 mm in diameter. A proper selection of the thermal and mechanical properties of both the holder materials and other capsule components for the analysis is considered to be of high importance [1]. As the helium gap size in the capsule is small, only a heat conduction is considered for the analysis, thus ignoring a convection and radiation in the gap [6].

2.3. Analysis Results and Discussions

A thermal analysis for the design modification of a capsule was performed. In order to obtain a uniform temperature distribution and to improve the heat transfer capability, a center hole of a capsule was designed. The center hole size of a typical capsule is 12mm in diameter. To examine the specimen temperature with the size of a center hole, two different sizes of holes of 7 mm and 0.1mm were additionally considered. FEA was conducted for a capsule with a different size of holes, and they all have a similar temperature distribution trend as shown in Fig 2. Fig. 3 shows the influence of a hole size on a specimen's temperature. The temperature differences in Fig 3 are less than 2%. From the analysis results, we found that the size of a center hole is not an important factor affecting the temperature distribution of a capsule.

Another approach was implemented to offer a considerable advantage in obtaining high temperature test conditions: an introduction of an additional gap for a capsule as shown in Fig. 4.

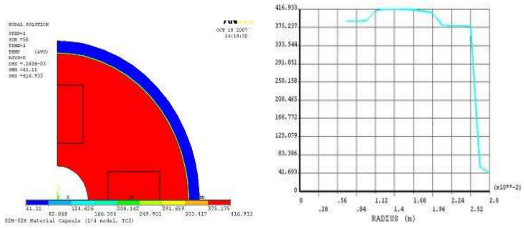

Fig. 2 Temperature distribution of a capsule with a hole size of 12mm

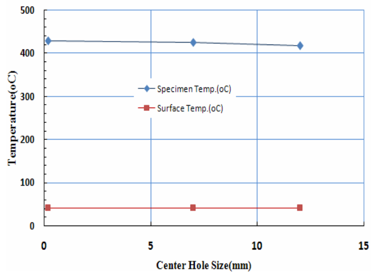

Fig. 3 Effect of a hole size on a specimen's temperature

FEA study was conducted for an introduction of three different gap sizes of 0.15, 0.35, and 0.55mm. By using the new design, the temperature at the position of the new gap of a capsule was much higher than that of the existing design. More evidently, Fig. 5 shows a temperature distribution profile along the horizontal direction of a capsule. Results showed that the maximum temperature of a specimen with an increasing additional gap size of 0.15, 0.35, and 0.55 mm increases to 160, 201, 239 ^{o}C, respectively. These investigations clearly indicate that an introduction of an additional gap could contribute strongly to an increase in a specimen's temperature by up to 27-90 %.

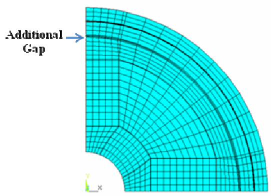

Fig. 4 FE model of a capsule with an additional gap at a specimen holder

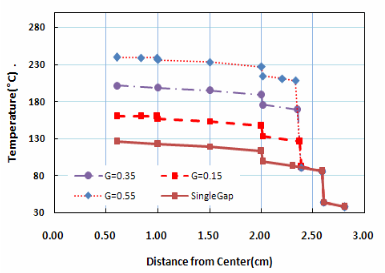

Fig. 5 Effect of an additional gap size on a specimen's temperature

III. Conclusions

The results of this investigation show that the size of a center hole, which is located at a specimen holder of a capsule, did not cause temperature changes of a specimen. The temperature differences were found to be less than 2%.

In addition, an additional gap in a specimen holder of a capsule could contribute strongly to an increase in a specimen's temperature by up to 27-90 %.

The results obtained from this study are to be directly used for solving the expected problems for the high temperature irradiation tests.

Acknowledgement

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REFERENCES

[1] Kang, Y.H., et al., "High Temperature Test Possibility at the HANARO Out-core Region through a Thermal Analysis", Proc. of KNS Autumn Mtg., Pyungchang, Korea, Oct. 24-26, 2003.
[2] Kang, Y.H., et al., "Current Status and the Future of the Irradiation Services in the HANARO Reactor", 2004 ANES Miami Beach, Florida U.S.A. 27-28(2004).
[3] ANSYS IP Inc., "ANSYS User's manual", Ver. 7.0 (2002).
[4] Kang, Y.H., "Nuclear Characteristics of the HANARO Test Holes", Internal Memo HAN-IC-CR-07-017, 2007, KAERI
[5] Cho, M.S., 2007, "Out-pile test results for the design verification of a capsule in the OR hole of HANARO and for the determination of a capsule outside diameter", Internal Memo, HAN-IC-CR-07-34, KAERI.
[6] Lee, Y.S., Choi, M.H., Kang, Y.H., Shin, D.S., "A structural analysis of the circular cylinder with multi holes under thermal loading", Nuclear Eng. and Des., 212 (2002) 273-279.