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Fuel model Validation in the TASS/SMR-S code by Comparing with Experimental Results

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1. Introduction

An advanced integral pressurized water reactor, SMART (System-Integrated Modular Advanced ReacTor) has been developed by KAERI (Korea Atomic Energy Research and Institute). For the purpose of an electric power generation and seawater desalination by using nuclear energy, SMART has been developed by KAERI (KAERI, 2010). For the safety evaluation and performance analysis of the SMART, TASS/SMR-S (Transient And Setpoint Simulation/System- integrated Modular Reactor) code, has been developed.

In this paper, the gap conductance model for the calculation of gap conductance has been validated by using experimental results. In the validation, the behaviors of fuel temperature and off-center temperature are selected as the major parameters.

2. Methods and Results

2.1 Overview of the Gap Conductance Model

To calculate gap conductance, deformation of fuel rod and cladding, the gap conductance model has been developed. There are two kinds of gap conductance modes in the TASS/SMR-S code: a simple expansion model and dynamic gap conductance model. In the simple expansion model, gap conductivity is calculated by considering linear expansion coefficient (INSC Material properties database) and temperature variation of the fuel and cladding. The thermal gap conductivity is calculated by eq. (1).

$$k'(T) = k(T) \cdot \left[\frac{R_2 - R_1}{R_2 \cdot \left[1 + \alpha_2 \cdot \overline{T_2}\right] - R_1 \cdot \left[1 + \alpha_1 \cdot \overline{T_1}\right]} \right] \quad (1)$$

Where R is radius(m), $\overline{T}$ is average temperature in the gap, subscript 1, 2 are fuel and cladding respectively, α(T) is linear expansion coefficient, k(T) is initial thermal gap conductivity (W/m/K).

The dynamic gap conductance model calculates the thermal gap conductivity by considering various factors which influence thermal gap conductivity. These factors are deformation in fuel and cladding, pressure and temperature in gap, thermal conductivity of mixed gases in gap. Heat transfer in gap can occur by radiation, conductance in the fill gas, and the contact conductance when the pellet is physical contact with the cladding. Eq. (2) shows the thermal conductance of the gap in the dynamic gap conductance model.

$$h_{gap} = h_{rad} + h_{gas} + h_{contact} \quad (2)$$

The gas conduction in fill gas is calculated by eq.(3) (J.B. Ainscough, 1982).

$$h_{gas} = \frac{k_g}{\delta + g + A \cdot \left(R_f + R_c\right)} \quad (3)$$

Where k_g is conductivity of the interior gas mixtures, δ is gap width [m], g is temperature jump distance in the fuel and cladding[m], R is roughness[m].

2.2 Validation of the Gap Conductance Model

The gap conductance model of TASS/SMR-S code has been validated by comparing with experimental data results which are conducted by EG&G Idaho, Inc. In that report, the experimental test results and analysis of three gap conductance tests series were described in the Power Burst Facility (PBF) at the Idaho National Engineering Laboratory (Rechard W. Garner et al.).

Three gap conductance test including GC 2-1, GC 2-2 and GC 2-3 have been performed the experimental. The gap width was 2.2% of nominal design pellet diameter. The interior region of the gap is filled with a single gas component such as helium, xenon and argon. The material of the fuel and cladding are UO_2, Zircaloy-2, respectively. The overall length of the fuel rod is approximate a 1.0m. The cladding outside and inside diameter is 12.50 mm, 10.79 mm, respectively.

Figure 1 shows the schematic of the pellet, gap, cladding and shroud in the test.

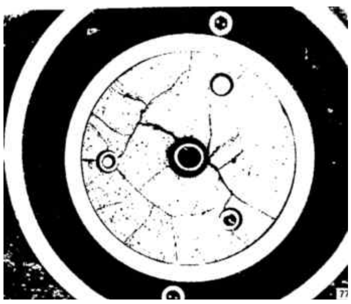

Fig. 1. Fuel rod schematic for experiment.

To the validation, the number of nodalization to the axial and radial direction is 10 nodes and 9 nodes, respectively. To demonstrate the transient condition, power fraction level increases 5 kW/m stepwise from 5 kW to 30 kW during the calculation time.

2.3 Results

For the validation of the gap conductance model, the temperatures of the fuel center and off-center(near pellet surface) have been compared with experimental data. Figure 2 shows the fuel centerline temperatures for 2.2% gap width in the case of using helium gas as fill gas. The centerline temperatures calculated by the TASS /SMR-S code are somewhat higher compared to those of experimental results.

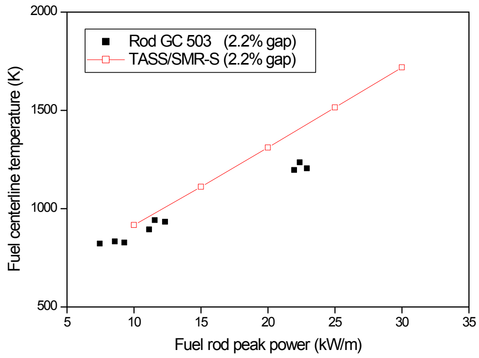

Fig. 2. Fuel center temperature (filled with Helium).

Figure 3 shows fuel off-center temperatures for 2.2% gap widths in the case of using helium gas as fill gas. Here, the position of the fuel off-center is near the pellet surface as shown in fig. 1. The temperatures of fuel off-center temperatures are calculated relatively higher compared to those of experimental results with power.

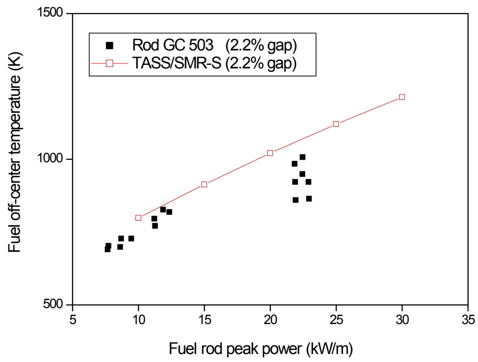

Fig. 3. Fuel off-center temperature (filled with Helium).

Figure 4 shows the fuel centerline temperatures for 2.2% different gap width in the case of using argon gas as fill gas. As shown in the figure, calculated temperatures by the TASS/SMR-S are also shown. As well as the case of helium gas as fill gas, fuel centerline temperatures predict somewhat higher compared to those of experimental results. Comparing with the case of using helium gas, the TASS/SMR-S code predicts well these experimental behaviors.

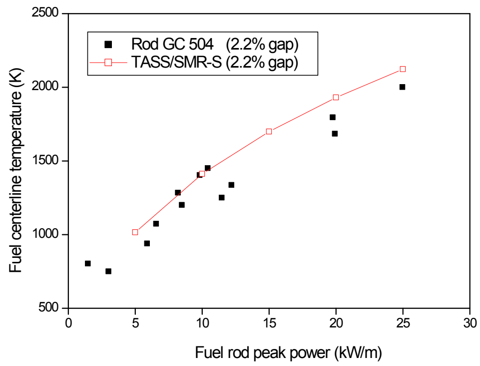

Fig. 4. Fuel center temperature (filled with argon).

Figure 5 shows fuel off-center temperatures for 2.2% gap width in the case of using argon gas as fill gas. As shown the figure, the fuel off-center temperature increases sharply over the 10 kW/m power comparing with experimental data.

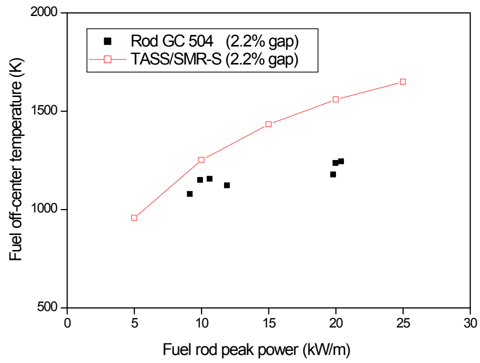

Fig. 5. Fuel off-center temperature (filled with argon).

3. Conclusions

The validation of the gap conductance model by the TASS/SMR-S code is performed comparing with results of the experimental data.

The temperatures in the fuel center and off-center calculated by TASS/SMR-S code predict higher compared to those of experimental results. The fuel temperature increase rate as a function of peak power is predicted well these experimental results.

Acknowledgements

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REFERENCES

[1] KAERI, 2010, "System description", KAERI, Korea 000-NA403-001.
[2]J.B. Ainscough, 1982, "Gap conductance in Zircaloy-clad LWR fuel rods", OECD/NEA-CSNI Report No. 72.
[3] Rechard W. Garner et al., 1978, "Gap Conductance Test Series-2 Test results report for Test GC2-1, GC2-2, and GC2-3", NUREG/CR-0300,TREE-1268.