Gap Conductance model Validation in the TASS/SMR-S code using MARS code

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been developing the TASS/SMR-S (Transient and Setpoint Simulation/Small and Medium Reactor) code, which is a thermal hydraulic code for the safety analysis of the advanced integral reactor. An appropriate work to validate the applicability of the thermal hydraulic models within the code should be demanded. Among the models, the gap conductance model which is describes the thermal gap conductivity between fuel and cladding was validated through the comparison with MARS code. The validation of the gap conductance model was performed by evaluating the variation of the gap temperature and gap width as the changed with the power fraction.

In this paper, a brief description of the gap conductance model in the TASS/SMR-S code is presented. In addition, calculated results to validate the gap conductance model are demonstrated by comparing with the results of the MARS code with the test case.

2. Methods and Results

2.1 Overview of the Gap Conductance Model

To analyze the safety analysis and performance of the advanced integral reactor, Korea Atomic Energy Research Institute (KAERI) has been developing the TASS/SMR-S code which is a one dimensional, thermal hydraulic system analysis code for an advance integral reactor.

The gap conductance model which analyzes the heat transfer phenomena between fuel and cladding is included in the TASS/SMR-S code. The role of this model is to calculate the thermal gap conductivity and deformation of the gap width. To do more quantitative analysis, behaviors such as the deformation of the fuel and cladding should be considered together.

There are two kinds of gap conductance models in the TASS/SMR-S code: a simple expansion model, and dynamic gap conductance model. In the simple expansion model, gap deformation is calculated by considering the simple thermal expansion with the temperature variation of the fuel and cladding. The thermal gap conductivity is calculated by using the initial thermal conductivity regardless of the deformation of the initial gap width

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

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 is calculated the thermal gap conductivity by using the various factors which influence the thermal gap conductivity. The factors are the deformation in the fuel and cladding, the pressure and temperature in the gap, the thermal conductivity of the interior individual gases. Heat transfer phenomena influencing the model are the thermal radiation in the high temperature, the thermal conductivity of the individual gas and the physical contact of the fuel and cladding.

$$h_{gap} = h_{rad} + h_{gas} + h_{contact}$$

$$h_{rad} = \sigma\cdot\left[\frac{1}{\varepsilon_f} + \frac{A_f}{A_c}\cdot\left(\frac{1}{\varepsilon_c} - 1\right)\right]^{-1}\cdot\left(T_f^2 + T_c^2\right)\cdot\left(T_f + T_c\right)$$

Where σ is the Stefan-Boltzmann Constant, A is surface area [m^2], T is surface temperature [K], ε is emissivity on the surface, subscript *f*, *c* are fuel and cladding respectively.

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

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].

A few assumptions of the dynamic gap conductance model in the TASS/SMR-S code are as follows ; 1) Considered only thermal expansion in the fuel. 2) the deformation of the thermal, elastic and plastic are considered in the cladding. 3) the direct contact with fuel and cladding is not occurred. 4) the deformation of the gap is equal to the radial direction.

2.2 Validation of the Gap Conductance Model

Figure 1 shows the geometrical configurations of the nodalization to the axial direction in the TASS/SMR-S code. The nodalization is composed of 12 nodes and 11 flow-paths. Node 11 and node 12 are modeled as the mass flow rates and pressure boundary, respectively.

Figure 2 shows the nodalization to describe the fuel, gap and cladding in the fuel rod to the radial direction. The radial geometry of the fuel rod is divided by 5 meshes in the TASS/SMR-S code. Thermal hydraulic parameters such as pressure and temperature are calculated at the center of node. In the MARS code, it is divided by 6 meshes and the parameters are calculated at the boundary of the node. The gap region is composed of five gas mixtures such as helium, nitrogen, xenon, krypton and argon in the ratio of the mole fraction. The roughness of the gap and fuel are 0.8e-6, 1.8e6, respectively. The initial gap pressure is 7.88e6 Pa.

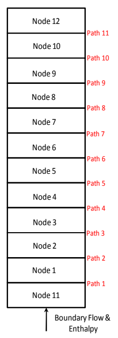

Fig. 1. TASS/SMR-S Nodalization to the axial direction.

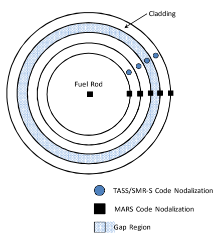

Fig. 2. Fuel rod nodalization to the radial direction.

To demonstrate the transient calculation, the power fraction is varied in a stepwise fashion during the 300 seconds. From 10(s) to 100(s), power fraction is keeping on 1.5 times of the initial power level. From 100(s) to 200(s), power fraction is keeping on 0.8 times of the initial power level. Before performing the transient calculation, initial gap width and gap temperature between the two codes have accordance through the steady state calculation.

2.3 Results

To validate the dynamic gap conductance model in the transient condition, the width and temperature in the gap region are calculated under the condition of the power fraction variation. Figure 3 shows the gap temperature variation along the time. The initial gap temperatures to the axial direction are approximately similar between the two codes. In the decreased region of the power fraction, gap temperatures between the two codes are well accorded than in the increased region. The gap width result is shown in Figure 4. According to the calculation results, TASS/SMR-S code predicts the value conservatively comparing with the MARS code. The one of the major difference between the two codes is that the thermal gap conductivity in the MARS code is calculated by the initial gap width during the transient calculation. Whereas, the TASS/SMR-S code use the gap width which is calculated each time step during the transient calculation.

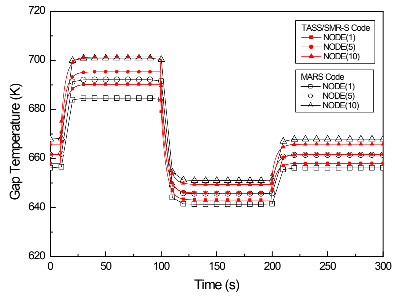

Fig. 3. Gap Temperature Variation along the time.

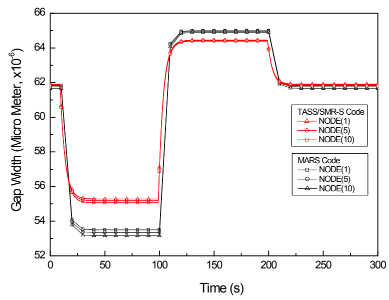

Fig. 4. Gap Width Variation along the time.

3. Conclusions

The dynamic gap conductance model in the TASS/SMR-S code has been validated by comparing it with the MARS code.

According to the analysis results for the validation, gap width and gap temperature calculated by the TASS/SMR-S code shows similar behavior with the MARS code in the same power fraction variation. In addition, TASS/SMR-S code predict conservatively the gap width compared to the MARS code.

Acknowledgements

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