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Improvements in the Modeling Capability of the Whole-Core Thermo-fluid Analysis of Prismatic Gas-Cooled Reactors

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1. Introduction

A new computer code for a whole-core thermo-fluid analysis of a prismatic gas cooled reactor is under development in Korea Atomic Energy Research Institute (KAERI). The new code adopts a practical method proposed by the present authors [1] for fast computation with reasonable accuracy. It solves the multi-dimensional heat conduction equation for solid structures as in a computational fluid dynamics (CFD) code and the one-dimensional conservation equations for a fluid as in a system code. In this paper, two kinds of improvements recently achieved in the modeling capability of the new code are presented.

2. Modeling of Axially Different Materials

The proposed basic unit cell concept by Tak et al. [2] is useful to model the complex geometry of the prismatic fuel block in the horizontal plane. However, an additional model is required to consider axially different materials such as the graphite plugs, the dowel pins, and the fuel handling hole in the fuel block as well as the upper and lower reflector blocks. Therefore, the existing basic unit cell concept is extended to "axial sets of basic unit cells" in order to model axially different materials. In particular, the modeling of the graphite plugs and seats are important since it could affect the temperature of the fuel. The graphite plug and seats are located at the top and the bottom of the fuel block, respectively, as shown in Fig. 1. Since they do not contain nuclear fuel materials, sharp power drops exist at their locations.

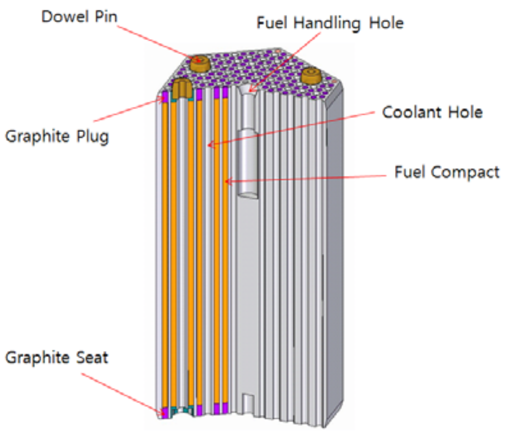

Fig. 1. Standard fuel block used for a prismatic core.

In order to examine the effect of the graphite plug and seat on the temperature profile of the fuel, a thermal analysis was performed for the control fuel block studied by Kim et al. [3]. Fig. 2 shows the arrangement of the basic unit cells to simulate the control fuel block. The meanings of the basic unit cells are provided in Table I.

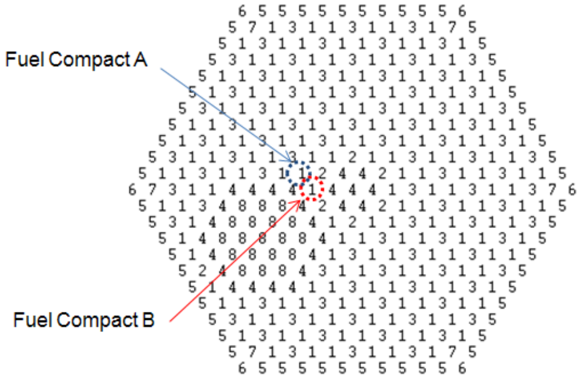

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Fig. 2. Arrangement of the basic unit cells for the control fuel block.

Table I: Adopted Basic Unit Cells

Index	Meaning
1	Fuel compact
2	Small coolant channel
3	Standard coolant channel
4	Graphite region within block
5	Graphite region at block edge
6	Graphite region at block corner
7	Burnable poison rod
8	Control rod hole

Fig. 3 shows the results with the improved model. It shows that the analysis without the graphite plug and seat model slightly under-predicts the fuel temperature. The maximum temperature of the fuel is reduced by 1 ^{o}C but sharp temperature drops are observed at the graphite plugs and seats in the case with the graphite plug and seat model.

3. Modeling of Large Convection Holes

One of the pitfalls in the previous work [4] was the absence of the heat convection model through the control rod holes. Since the control rod holes are too large to cover with single unit cell, the existing unit cell concept needs to be modified. A similar situation exists in the inlet riser holes in the permanent side reflector block.

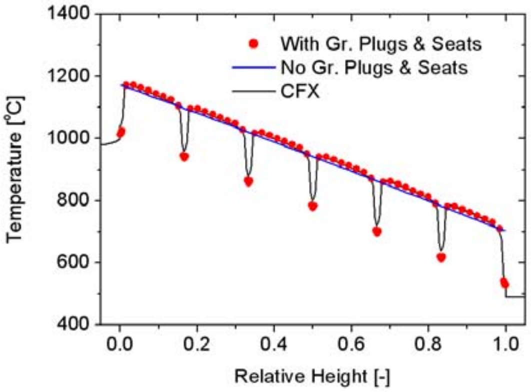

Fig. 3. Effect of the graphite plug and seat model on the predicted temperature profile along the center of the fuel compact A in the control fuel block (axially uniform power profile).

As shown in Fig. 2, one control rod hole occupies 19 unit cells. Such unit cells were removed in the heat conduction cells and one fluid cell was assigned to model heat convection through the large hole.

Figs. 4 & 5 show the effect of the control rod hole model on the temperature of the fuel. The calculated temperature profiles are plotted along the centers of the fuel compacts A and B. Both figures clearly show that the temperature of the fuel is significantly over-predicted in the case without the control rod hole model. The impact on the fuel compact B (Fig. 5) is found to be larger than that on the fuel compact A (Fig. 4). This result can be explained by the closer distance of the fuel compact B to the control rod hole.

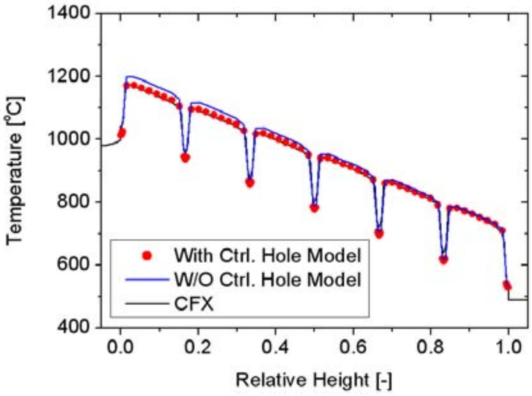

Fig. 4. Effect of the control rod hole model on the predicted temperature profile along the center of the fuel compact A in the control fuel block (axially uniform power profile).

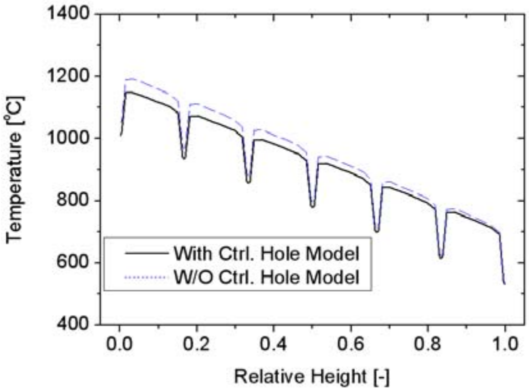

Fig. 5. Effect of the control rod hole model on the predicted temperature profile along the center of the fuel compact B in the control fuel block (axially uniform power profile).

4. Conclusions & Outlook

The development of the new code for a whole-core thermo-fluid analysis of a prismatic reactor is in progress in KAERI. More accurate temperature predictions of prismatic fuel blocks were achieved with the improved modeling capability described in this paper. The next step for the development will focus on the improvement in the fluid model. In addition, a parallel computing method is going to be implemented in order to enhance the computational efficiency.

Acknowledgements

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