A Combined Method of Subchannel and Porous Media Approach for LMR Core Thermal Hydraulic Analysis

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1. Introduction

In LMR core, there are flow redistributions in the inter-assembly region of the core. The hotter counter flow in the upper region runs down into the center region and it may raise the duct wall temperature. This characteristic of the LMR core may have a significant effect on the thermo-mechanical integrity of the duct wall [1].

Up to date, subchannel analysis is considered to be the most suitable method for the LMR subassembly analysis when considering the geometrical complexities and computational resources needs [2]. But subchannel analysis is not suitable for analyzing the reversed or transverse flow redistribution because there are some constraints on the calculation scheme in the method. Therefore, it is required to develop another appropriate method to analyze the inter-assembly flow in the core. This paper describes a combined method of subchannel and porous media approach to analyze the inter-assembly flow redistribution and duct wall temperature calculation.

2. Method

The objective of the combined method is to obtain the temperature of a subassembly duct wall, strongly influenced by the inter-assembly flow distribution in the core. Figure 1 shows the simplified diagram of the calculation procedure between the subassembly and inter-assembly flow.

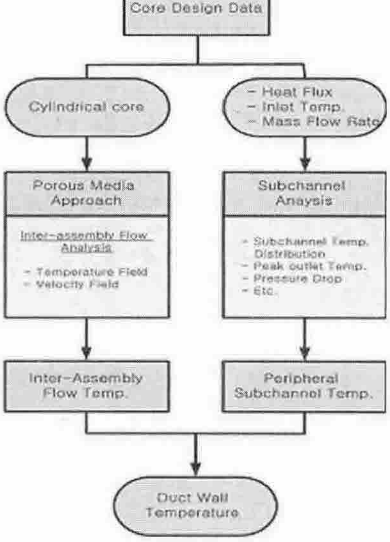

Figure 1.Calculation procedure of the combined method

The procedure consists of two main calculations and the coupling of these two calculations. These are the subassembly calculation using the subchannel analysis (MATRA-LMR) and the cylindrical core calculation using the porous media approach (COMMIX-1AR/P). After the convergence of these two codes, the duct wall temperatures are calculated.

3. Calculation results and Analyses

Reference calculations were performed with the inner driver and outer blanket subassemblies in the KALIMER-150 breakeven core [3]. The core radius is 1.76 m and the height is 3.6 m and the core is meshed by 11 × 36 meshes in the radial and axial directions, respectively. The core inlet temperature is 386.2 °C and the maximum pressure difference between the core inlet and outlet is about 0.2 MPa. Figure 2 shows the temperature and velocity fields of the core inter-assembly flow region. It is shown that the temperature and velocity fields are influenced by the pressure differences between the core inlet and outlet region. As shown in the figure 2, the reverse and radial direction flows strongly influence the inter-assembly flow in the core. The core inter-assembly flow comes down the center part and goes out through the outer part of the core.

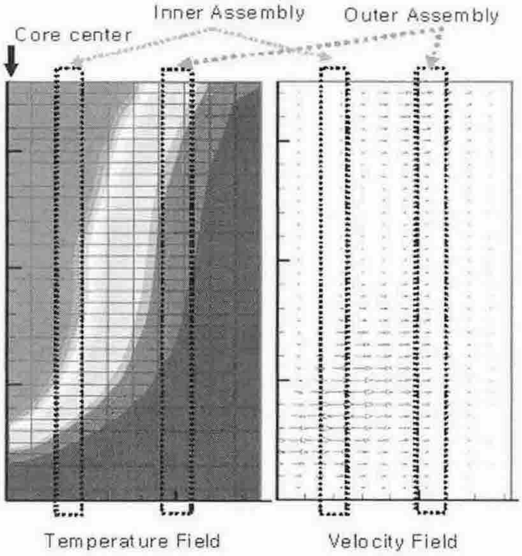

Figure 2.Temperature and Velocity field of inter-assembly flow (KALIMER-150 BRK core)

Figures 3 and 4 show the duct wall temperature distributions of DR0302 (inner) and RB0704 (outer) subassembly. In the case of DR0302, which is located at inner region of the core, the hotter inter-assembly flow (recirculation flow) has a significant influence on the duct wall temperature distributions. In the case of the 0704 subassembly, which is located at the outer region of the core, the colder inter-assembly flow even reaches the upper part of the core. Thus, the duct wall temperature distribution by the effect of inter-assembly flow is lower than that of the no flow redistribution case. For each subassembly case, the maximum duct wall temperature, the temperature differences of the duct walls and the temperature differences of coolant are summarized in Table 1.

As calculation results, It can be seen that the temperature distribution of the subassembly duct wall is mainly influenced by the thermal hydraulic condition of the inter-assembly flow, the subchannel temperature and the subassembly position in the core.

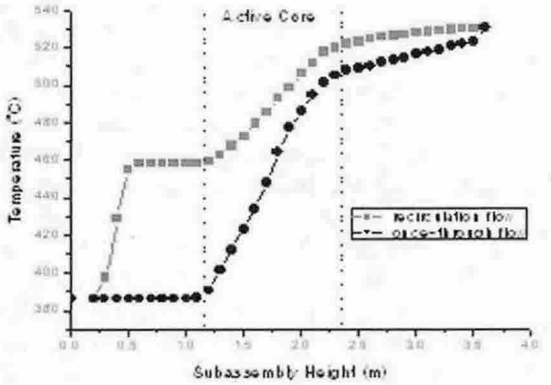

Figure 3. Duct wall temperature distributions of the DR0302 subassembly

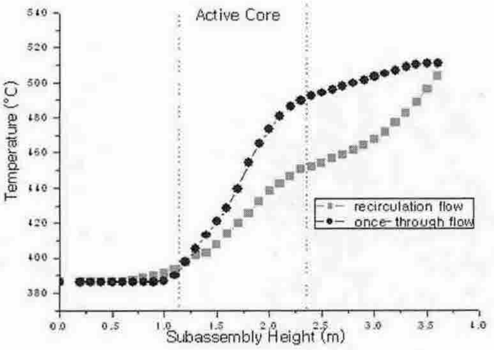

Figure 4. Duct wall temperature distributions of the DR0704 subassembly

Table 1. Calculation results of the duct wall and coolant temperatures (°C)

	T_{MAX}.(1)	ΔT_{MAX}.(2)	ΔT_{Axial} (3)	ΔTc (4)
DR0302	530.0	72.1	144.4	158.3
RB0704	503.3	- 40.6	117.2	141.8

(1) Maximum temperature of the duct wall
(2) Maximum temperature difference of duct walls for each calculation case (recirculation flow case- no recirculation flow case)
(3) Temperature difference of the duct wall (upper part– Lower part)
(4) Temperature difference of coolant in the subassembly (outlet – inlet)

4. Conclusion

To analyze the inter-assembly flow in LMR core, a combined method of subchannel and porous media approach was described in this paper. The combined method is evaluated to be a close to the operating conditions for analyzing the temperature distribution of the inter-assembly flow and the subassembly duct wall. The duct wall temperature distribution mainly depended on the thermal hydraulic conditions of the inter-assembly flow and the subassembly position in the core.

For the future works, development of an iterative calculation scheme between the subchannel and porous media code is required to get the converged values of duct wall temperature distribution. And the combined method of the subchannel and porous media code will be used as one of the basic methods for the LMR thermal hydraulic design and analysis code.

Acknowledgement

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References

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