Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

Evaluation of Core Bypass Flow in the Prismatic VHTR with a Multi-block Experiment

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1. Introduction

The core of Prismatic Modular Reactor (PMR) consists of assemblies of hexagonal graphite fuel and reflector elements. The core bypass flow of Very High Temperature Reactor (VHTR) is defined as the core flow that does not pass through the coolant channels but passes through the bypass gap between fuel elements. The increase in bypass flow makes the decrease in effective coolant flow. Since the core bypass flow has a negative impact on safety and efficiency of VHTR [1], core bypass phenomena have to be investigated to improve the core thermal margin of VHTR. For this purpose, the international project, I-NERI project, has been carried out since 2008. I-NERI project is collaborative project that KAERI and SNU of Korea side and INL, ANL and TAMU of U.S side are involved. In order to evaluate the core bypass flow, the multi-column and multi-layer experimental facility is designed by SNU. In this experiment, the effect of cross-flow and local variation of bypass gap on the bypass flow distribution is investigated. Furthermore, the experimental data will be used for validation of CFD code or thermal hydraulic analysis codes such as GAMMA [2] or GAS-NET [3].

2. Experimental Apparatus and Conditions

Experimental facility mainly consists of the flow supply system, measuring devices and data acquisition system. Figure 1 shows a schematic diagram of experimental apparatus. Experimental system was designed as open-loop system. Test section consists of 7 block columns horizontally and 4 block layers vertically. Test block was scaled down to one-second of actual core block. Hence, the flat-to-flat width is 180 mm. The number of coolant holes within the fuel block is ninety. Actual number of coolant hole is one hundred and eight, in the present experiment. However, in the present experiment, coolant holes around center point are reduced to install guide pipe for the pressure tubes. 10 pressure taps at the coolant holes in the fuel block are installed and 6 pressure taps at the side wall of the fuel block are installed to measure the pressure distribution of the coolant holes and the bypass gap, respectively. In addition, 14 pressure taps along the bypass gap are installed at the side wall of the test section. Pitot tube flow meters are installed at the inlets and outlets of block columns and the outlet pipe behind blower to measure the flow distribution.

The cross-flow gap size and the axial bypass gap size are controlled to examine the effect of the cross-flow and the multi-block structure. The test matrix is tabulated at Table I. The bypass gap size is determined by referencing the previous study for the bypass gap distribution [4]. Respective notations EC, EOC and CG mean equilibrium core, end-of-cycle and cross-flow gap.

Air at normal temperature and pressure is used as a working fluid. Total mass flow rate is 0.55 kg/s. This value is determined to preserve the dynamic similarity based on the Reynolds number of coolant hole. The degree of the similitude of the Reynolds number is 0.5. However, the flow distribution pattern would be similar to the actual core, because the flow distribution is not strongly dependent on the Reynolds number in the fully developed turbulent regime [5]. The Reynolds numbers of coolant hole in the present experiment is the order of 10^4 which satisfies the flow condition for the turbulent regime.

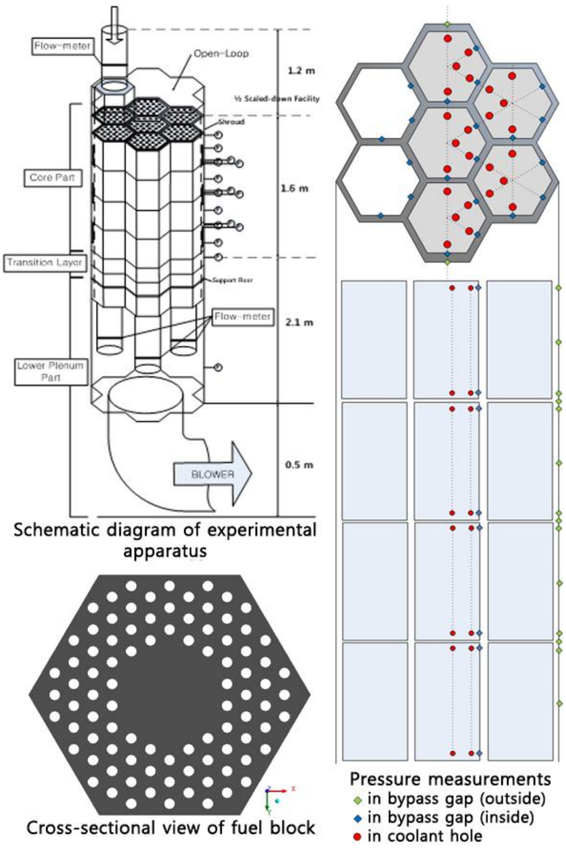

Fig. 1. Schematic diagram of experimental apparatus, cross-sectional view of fuel block and the cross-sectional view and longitudinal view of test-section

Table I: Test Matrix

Case	Bypass gap size along the layers 1st, 2nd, 3rd,4th (mm)	Cross-flow gap size (mm)
EC-EOC1-CG0	2, 2, 2, 2	0
EC-EOC1-CG2	2, 2, 2, 2	2
EC-EOC8-CG0	6, 4, 2, 4	0
EC-EOC8-CG2	6, 4, 2, 4	2

3. Results and Discussion

This experiment consists of 4 cases. The experiment for EC-EOC1-CG0 case was carried out preliminarily. In the present study, the experimental results for EC-EOC1-CG0 case were described. The analysis on the results will be complemented after experiments of the rest cases are performed.

Figure 2 shows the experimental results of the EC-EOC1-CG0 case. In this case, the pressure drops of the coolant hole and bypass gap have to be linear. Although the experimental result was not completely linear, total pressure drop of the experiment was equal to the value calculated from the Blasius equation with assumption of linear pressure drop. Total pressure drops of the test section were 1091 Pa and 1399 Pa at the coolant hole and the bypass gap, respectively. Pressure drop of the coolant hole calculated from the Blasius equation was 1100 Pa.

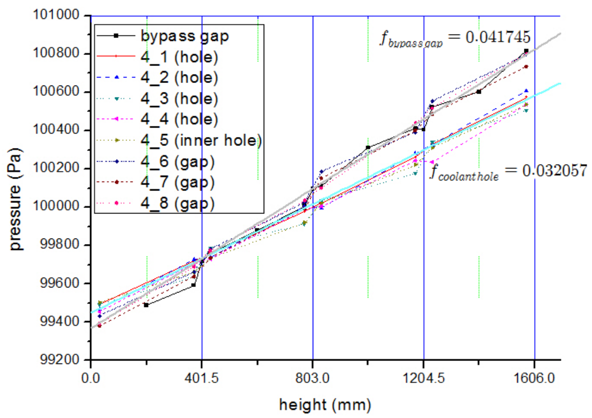

Fig. 2. Pressure drops of the coolant hole and bypass gap channel

The pressure of bypass gap is higher than that of coolant flow channel at the fourth and third layers, and is reversed at the middle of the test section. The reason is that the frictional losses between the coolant hole and bypass gap are different each other. Since the flow channel of bypass gap is similar to the parallel plate, the wall effect of bypass gap was stronger than that of coolant hole.

The target bypass gap size of EC-EOC1-CG0 case was 2 mm. However, the measured bypass gap size of first, second, third and fourth layer are 2.35 mm, 2.43 mm, 2.55 mm and 2.34 mm, respectively. This affect to the pressure distribution but the effect on the overall pressure drop was minor. The ratio of core bypass flow to the total mass flow was 17.013%.

4. Conclusions

Multi-column and multi-layer bypass flow experiment was carried out to examine the flow distribution of the prismatic VHTR core. From this experiment, the amount of the bypass flow rate was measured according to the variation of the bypass gap and the cross-flow gap. Also, the pressure distribution of the core was measured. In particular, the experimental data of the local pressure distribution will be used for validation of thermal-hydraulic analysis codes. Furthermore, it is expected to be used for study to secure safety and evaluate the thermal margin of VHTR core.

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