Validation of the CORONA Code with SNU Multi-block Experiments

Jeong-Hun Lee *, Nam-il Tak, Sung Nam Lee, Chang Keun Jo
Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 34057, Korea
**Corresponding author: leejhun@kaeri.re.kr*

1. Introduction

The high temperature gas-cooled reactor (HTGR) is one of promising Generation-IV (Gen-IV) reactors which can produce massive hydrogen as well as electric power [1]. The block type HTGR is one of main types of HTGRs. In the core of block type HTGR, bypass gap and cross gap make large uncertainty of the flow distribution and temperature distribution. To evaluate core flow and temperature distribution of the block type HTGR, the CORONA (COre Reliable Optimization and thermo-fluid Network Analysis) code has been developed in KAERI [2].

In this study, as a validation work of the CORONA code, SNU (Seoul National University) multi-block experiment [3] was simulated and the prediction results were compared with the experimental data and the results of other codes. In addition, cross flow model sensitivity test was carried out to find out proper model for flow analysis of the block type core of HTGR.

2. Description of SNU Multi-block Experiment [3]

SNU multi-block experiment was carried out to investigate the bypass flow and cross flow behavior in the block type core of HTGR [3]. The working fluid is air at room temperature and pressure and it flows through test section from the top to the bottom. The test section consists of four layers of seven columns (five fuel-block columns and two reflector-block columns) and a layer of transition-block columns which redistribute coolant flow from fuel columns to the lower plenum as shown in Fig. 1. Three cases were simulated for the validation work of CORONA as tabulated in Table 1.

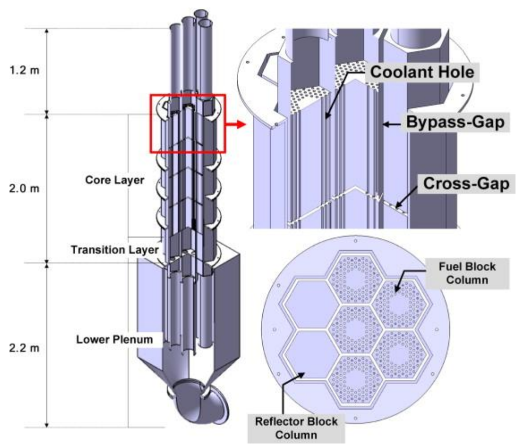

Fig. 1. SNU multi-block experimental facility [3]

Table I: Test cases

Case	Bypass gap from top to bottom (mm)	Cross gap from top to bottom (mm)
BG2CG0	2-2-2-2-2	0-0-0-0
BG6242CG2	6-2-4-2-2	2-2-2-2
BG62420CG2	6-2-4-2-0	2-2-2-0

3. Results

3.1 BG2CG0

BG2CG0 case has uniform bypass gap size (2 mm) at all layers and measured bypass gap size and geometrical information were summarized in Table II. The measured bypass gap size and geometrical information were applied to CORONA and GAMMA+ simulation. Fig. 2 shows comparison results of pressure drops along the height. Prediction results of CORONA show good agreement with experimental data and the calculation results of GAMMA+ [4], AGREE [4], and CFX [3]. The proportion of the bypass flow rate to total flow rate was presented in Fig. 3. CORONA and GAMMA+ show good agreement with the experimental data. Since the bypass gap was set to be 2 mm in the CFX simulation, there is some discrepancy between CFX results and others.

Table II: Geometrical information of bypass gap for each layer: BG2CG0

Layer	Bypass gap (mm)	Hydraulic diameter (mm)	Flow area (mm^2)
4	2.35	4.73	246
3	2.37	4.77	248
2	2.45	4.93	256
1	2.36	4.75	247

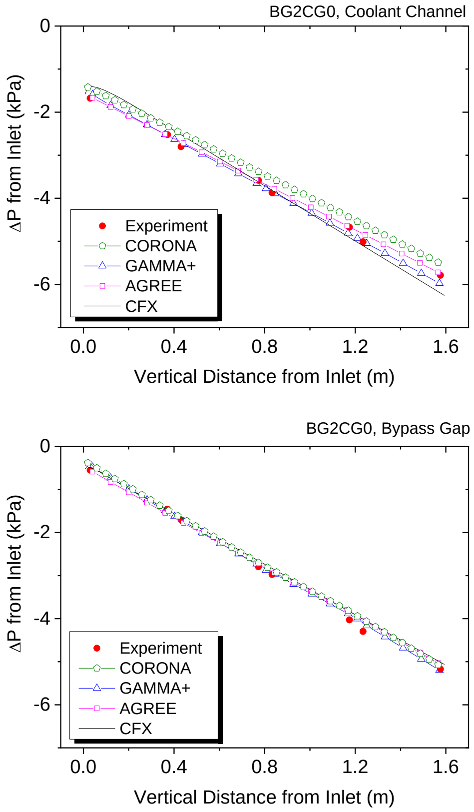

Fig. 2. Comparison of pressure drop: BG2CG0 (Experiment, CORONA, GAMMA+, AGREE, CFX)

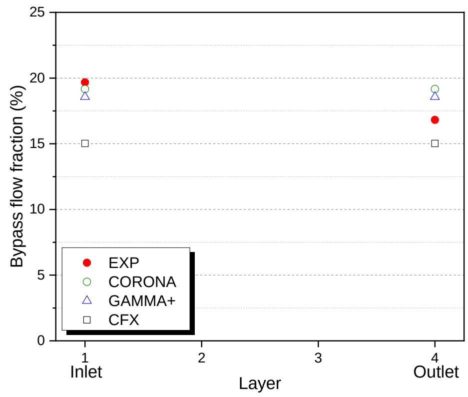

Fig. 3. Comparison of bypass flow fraction: BG2CG0 (Experiment, CORONA, GAMMA+, CFX)

3.2 BG6242CG2

The BG6242CG2 case means 6 mm, 2 mm, 4 mm, and 2 mm bypass gap from the top to the bottom and the 2 mm cross gap case. The measured gap size and geometrical information of bypass gap for each layer were tabulated in Table III. Comparison results show that calculation results of CORONA, GAMMA+, AGREE, CFX are all in good agreement with experimental data as plotted in Fig. 4. Fig. 5 presents cross flow model sensitivity test results. Used models in the test were Lee [5], Kaburaki [6], Groehn [7], and constant loss coefficient (K=1.5) and they are all in good agreement with experimental data. The comparison of bypass flow fraction was plotted in Fig. 6. The calculation results of CORONA (with various cross flow models) and GAMMA+ are in good agreement with experimental data. Unlike in CORONA and GAMMA+ analysis, bypass gap size was set to 6 – 2 – 4 – 2 mm for each layer in CFX simulation. Because of the difference of the bypass gap size in simulations, the discrepancy of the bypass flow fraction was observed in CFX calculation results.

Table III: Geometrical information of bypass gap for each layer: BG6242CG2

Layer	Bypass gap (mm)	Hydraulic diameter (mm)	Flow area (mm^2)
4	6.07	12.3	641
3	2.56	5.15	268
2	4.89	9.91	515
1	2.43	4.89	254

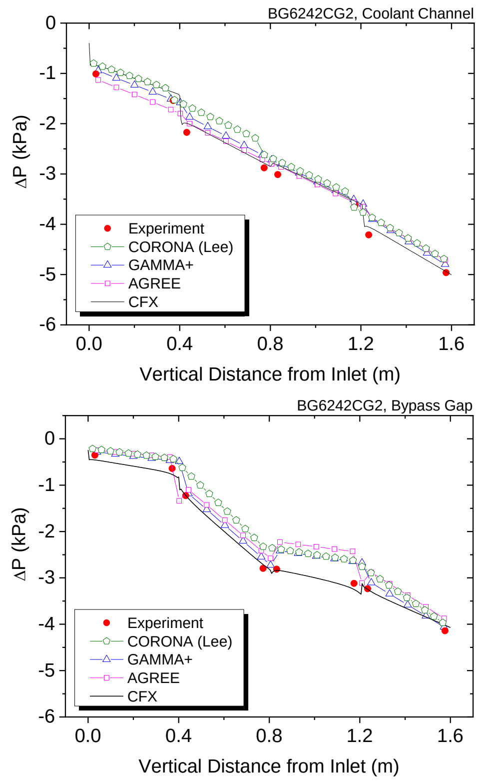

Fig. 4. Comparison of pressure drop: BG6242CG2 (Experiment, CORONA, GAMMA+, AGREE, CFX)

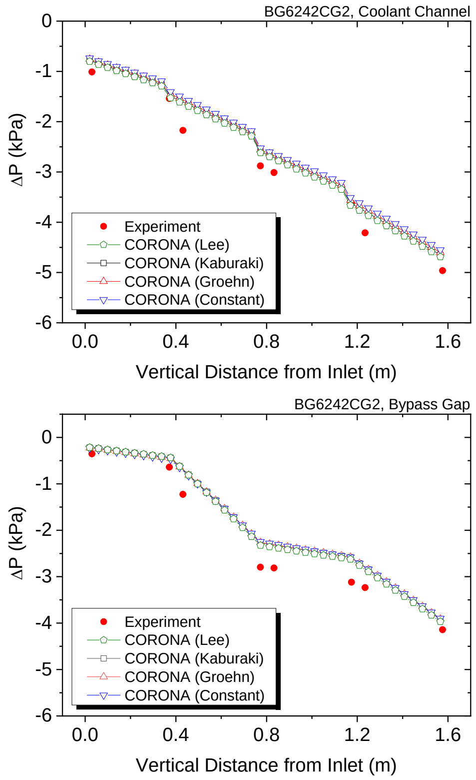

Fig. 5. Cross flow model sensitivity test results (Lee, Kaburaki, Groehn, Constant)

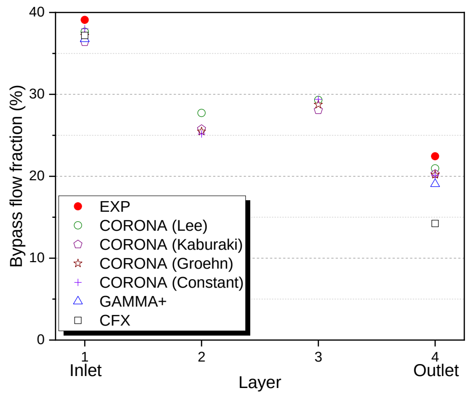

Fig. 6. Comparison of bypass flow fraction: BG6242CG0 (CORONA, Experiment, GAMMA+, CFX)

3.3 BG62420CG2

In BG62420CG2 case, bypass gap at the transition layer was set to 0 mm which leads to whole bypass flow at the third layer from the top goes through the cross gap so that the effect of cross flow can be emphasized. The measured gap size and geometrical information were provided in Table IV. The prediction results of CORONA show good agreement with experimental results and calculation results of GAMMA+, AGREE, and CFX as seen in Fig. 7. In addition, the flow stagnation at the bottom bypass gap was well captured in the code. Fig. 8 presents the comparison of the cross flow models and no significant difference was observed in pressure drops between the models even the cross flow was emphasized. Fig. 9 shows the comparison of the bypass flow fraction. Even GAMMA+ slightly under predicts bypass flow fraction (4.8%p), considering the uncertainty of the experiment, the results are quite reasonable.

Table IV: Geometrical information of bypass gap for each layer: BG62420CG2

Layer	Bypass gap (mm)	Hydraulic diameter (mm)	Flow area (mm^2)
4	6.15	12.5	650
3	2.64	5.31	276
2	4.71	9.55	596
1	2.65	5.34	278

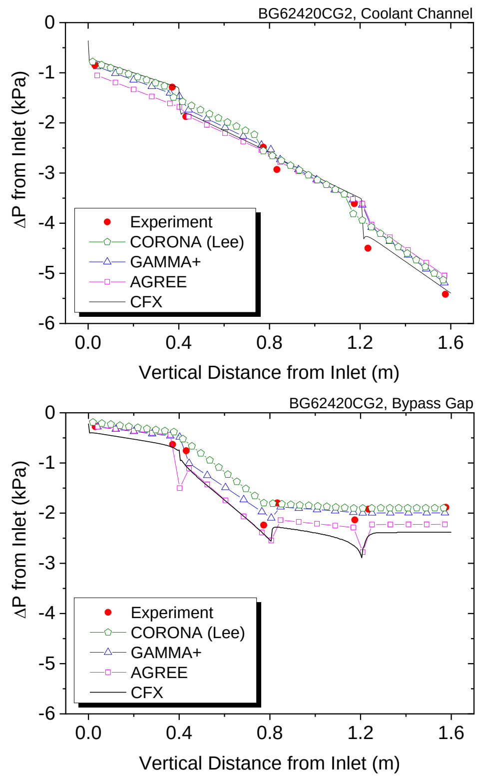

Fig. 7. Comparison of pressure drop: BG62420CG2 (CORONA, Experiment, AGREE, GAMMA+, CFX)

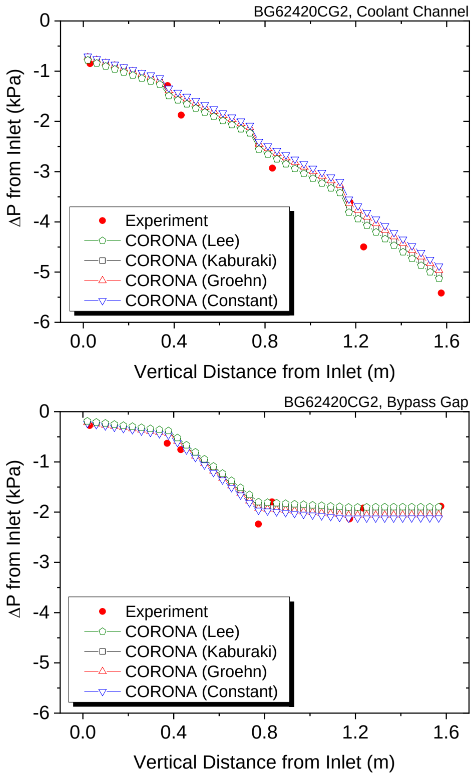

Fig. 8. Cross flow model sensitivity test results (Lee, Kaburaki, Groehn, Constant)

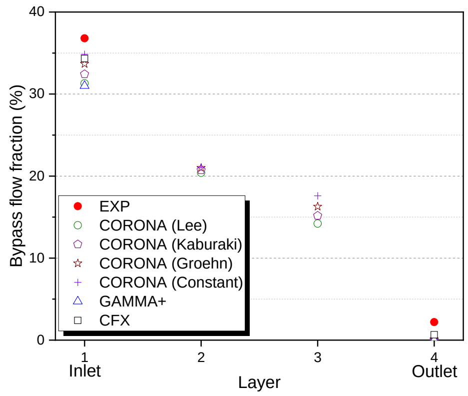

Fig. 9. Comparison of bypass flow fraction: BG62420CG0 (Experiment, CORONA, GAMMA+, CFX)

4. Conclusions

In this study, CORONA was validated with SNU experimental data and compared with other flow analysis codes. Overall pressure drop results were all in good agreement. In addition, as a results of the sensitivity test of the cross flow models, it was confirmed that all models were applied properly and no significant difference in results was found between the models. Therefore, from this study, it is concluded that CORONA can predict the flow distribution of the core of the block type HTGR and expected that the code can contribute to design core of HTGR by reliably predicting the flow distribution.

Acknowledgements

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