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Effects of Core Cavity on a Flow Distribution

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1. Introduction

The mixing behaviors in a downcomer and core depend on a geometrical condition. The mixing intensity in the core region is enhanced by wall shear and flow unbalances between flow channels. However, the former mixing tests were performed under the free (no) core condition. The axial pressure drop is removed in the free core condition, But the actual core has lots of fuel bundles and mixing vanes to the flow direction. The axial pressure drop induces flow uniformity. In a uniform flow having no shear stress, the cross flow or cross flow mixing decreases. The mixing factor is important in the reactor safety during a Steam Line Break (SLB) or Main Steam Line Break (MSLB) transients. And the effect of core cavity is needed to evaluate the realistic core mixing factor quantification.

The multi-dimensional flow mixing phenomena in a core cavity has been studied using a CFD code. The 1/5-scale model was applied for the reactor flow analysis. A single phase water flow conditions were considered for the 4-cold leg and DVI flows. To quantify the mixing intensity, a boron scalar was introduced to the ECC injection water at cold legs and DVI nozzles. In addition, to study the effect of asymmetric flow condition, 3-pump and 4-pump running conditions were assumed at the cold legs, separately.

2. Test Model

The reactor vessel and internal structures of ACOP test facility is 1/5 linear scale model of an APR+ reactor. Figure 1 shows the reactor vessel and cold legs.

The CFX version 15 was applied for a steady-steady calculation. Figure 1 shows the fluid model for CFD simulation. In this model, tetra mesh was applied. The prism layer was applied both for the near wall zone and multi-hole perforated plate of the reactor internals. The inlet velocity distribution at 4 cold legs was assumed to be uniform and constant.

A pressure boundary condition was applied for the outlet and the no-slip condition was applied to the wall boundary. The heat transfer and phase change were not considered. To simulate the equivalent boron worth conditions both for CLI and DVI modes, the boron scalar factors for the inlet boundary conditions of cold legs and DVI nozzles were set as following;

Boron scalar factor for CLI mode :

- CL1A : (CL flow rate)/(DVI flow rate)
- The other CLs : 0

Boron scalar factor for DVI mode :

- DVI1 : 1
- The other DVIs : 0

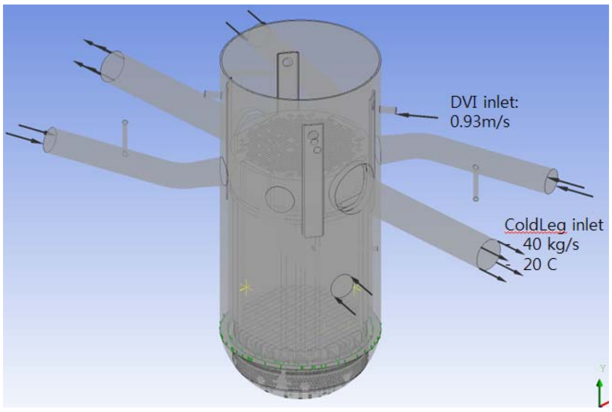
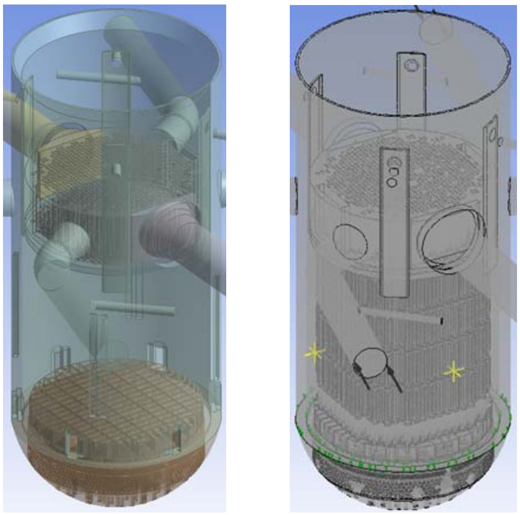
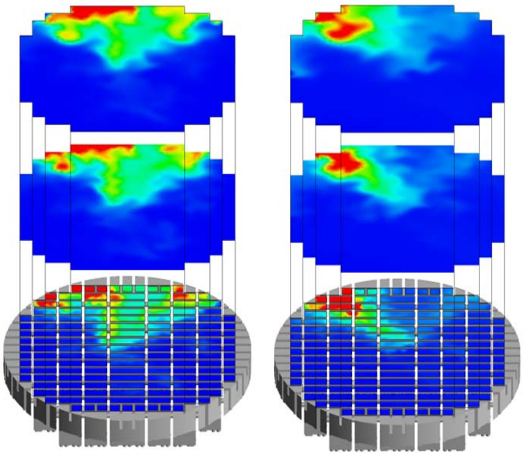


Fig. 1 1/5-Scale model and boundary conditions

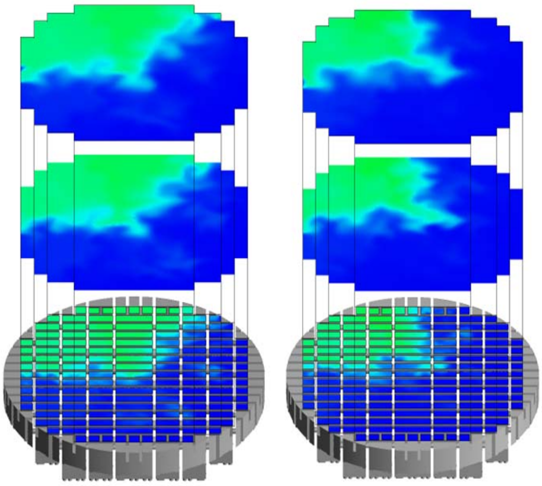
To study the core cavity effects on the boron mixing, two core configurations were considered as shown in Fig. 2. Figure 2(a) is a model for the case of no core structure. The core structures were removed in the analysis model. Figure 2(b) shows a core simulator model and a core was replaced by 257 core simulators that preserved the scaled axial pressure drop and cross flow characteristics.



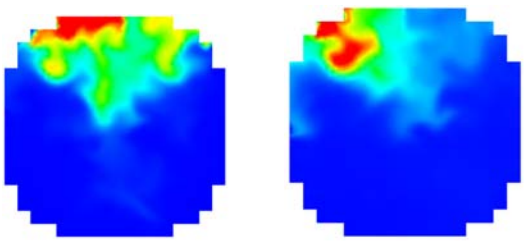
(a) No core model (b) Core simulator model
Fig. 2 Core flow model



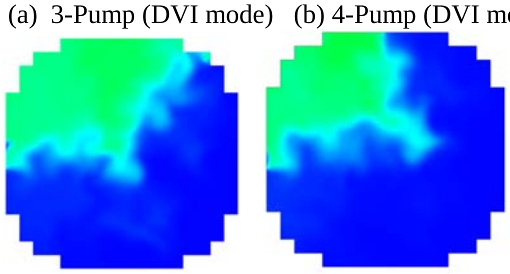
(a) 3-Pump running (b) 4-Pump running
Fig. 3 Mixing phenomena for DVI mode



(a) 3-Pump running (b) 4-Pump running
Fig. 4 Mixing phenomena for CLI mode



(a) 3-Pump (DVI mode) (b) 4-Pump (DVI mode)



(C) 3-Pump (CLI Mode) (d) 4-Pump (CLI mode)
Fig.5 Mixing pattern at the core top

3. Results

Figures 3 and 4 show the boron mixing at the core for DVI and CLI modes in the core simulator model, separately. Figures 3(a) and 4(a) represent the results for the 3-RCP running conditions while Figs. 3(b) and 4(b) represent the boron mixing for the 4-RCP running conditions, separately. The flow spreading patterns in the core are shown. The overall flow distribution is shifted to the direction of the stopped RCP by the running RCP flow forces. Figure 3 shows the more concentrated boron distribution due to the DVI duct for the DVI mode when compared to that of CLI. Figure 5 shows the mixing pattern at the core top.

4. Conclusion

The present CFD pre-study was performed to quantify the effects of core structure on the mixing phenomena. The quantified boron mixing scalar in the core simulator model represented the effect of core cavity on the core mixing phenomena. This simulation results also give the information for sensor resolution to measure the boron concentration in the experiments and response time to detect mixing phenomena at the core and reactor vessel.

Acknowledgments

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