A Feasibility of a CFD simulation for an ECC Bypass

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1. Introduction

The direct ECC bypass fraction is strongly dependent on the relative ECC injection angle because the wake region of a hot leg has the characteristics of an ECC penetration due to the stagnant vortex behind the hot leg while the cold leg suction zone has the characteristics of an ECC bypass (Kwon et al., 2002, 2006). The recently developed CFD code version has a simulation capability of a two phase flow condition. Therefore, a CFD approach, if possible, is a very useful method to reduce the total costs during a conceptual developing period to investigate the effects of a DVI nozz`le location. In this study, a 3-dimensional fine mesh calculation of a direct ECC bypass was performed using the CFX code to investigate a feasibility of a CFD application for an ECC bypass of an air-water mixing in a downcomer. The effect of the azimuthal injection angle of the DVI nozzle on the direct ECC bypass has been numerically quantified. The numerical analysis results show that the CFX code has a capability to simulate the ECC bypass phenomena for an air-water flow mixing condition.

2. Experiment and Numerical Model

2.1 Air-Water Experiment

The relative azimuthal injection angle of an ECC nozzle from the broken cold leg is varied with 15 and 52 degrees. The experiment is performed using an air-water separate effect test facility (DIVA), which is a 1/5 linearly scaled-down model of the APR1400 nuclear reactor. The velocity of an ECC injection is fixed at 0.89 m/sec. The single nozzle injection of ECC-4(broken cold leg side) is considered for all test cases. The test conditions are summarized in Table 1. The relative azimuthal injection angle and the elevation tested are shown in Fig. 1.

Table 1 Experiment condition

Description	Condition
Cold leg Fluid(CL 1~3)	Air
Cold leg Velocity	5, 10, 15, and 20 m/sec
ECC Fluid	Water
Water Temperature	Room Temperature
ECC Flow for all	0.89 m/sec
ECC Injection Location	DVI-4 Only

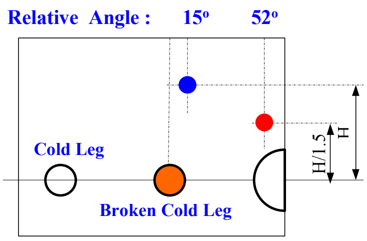


Fig. 1 DVI location

2.2 3-Dimensional CFX Model

The 1/5-scale reactor vessel downcomer is modeled as a simplified cylinder annulus having 4 cold leg nozzles, 2 hot leg blunt bodies, and 4 DVI nozzles inside the downcomer annulus. The flow field is assumed a two phase mixing condition of air and water with turbulence. The water level of downcomer was controlled as constant by a user control variable. The governing equations are for the continuity, momentum, turbulent kinetic energy, and turbulent kinetic energy dissipation. The uniform velocity distribution is applied at the inlet both the cold leg and the DVI. The pressure boundary condition is applied as an outlet boundary for the broken cold leg. The injection velocities for both the cold leg and DVI are applied in the same way as the air-water experimental conditions. The number of hexagonal volumes in a mesh generation is 434,000. The CFX geometrical model is shown in Fig. 2.

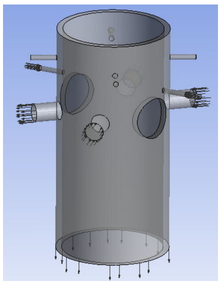
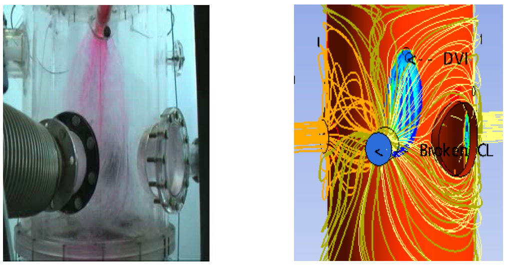


Fig. 2 Numerical model of downcomer

3. Results

The overall film shape of the ECC water near the broken cold leg is compared with the experimental results. Also, the ECC bypass fractions of the numerical result are compared with experimental data to quantify the overall accuracy of the CFD simulation for a two phase air-water mixing condition.

Fig. 3 shows the typical ECC spreading film shape near the broken cold leg of the APR1400. The ECC film is formed at near the suction zone of the broken cold leg. The ECC spreading shape of the CFX code simulation has the same as the experimental result. Fig. 4 shows the ECC bypass fraction. The ECC bypass fraction of the CFX result is well coincided with the experimental data in general trend for the case of the DVI-4 injection.



(a) Air-Water Experiment (b) CFX Calculation

Fig. 3 ECC spreading shape of current DVI (V(coldleg,air velocity)=20 m/s).

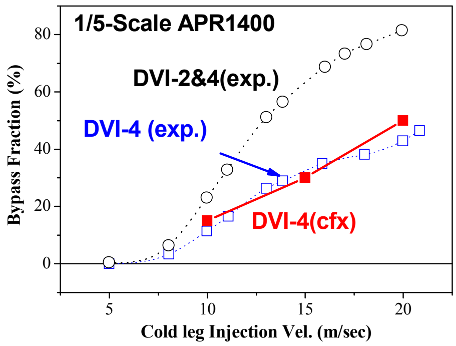
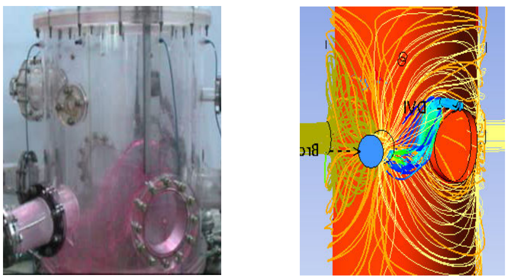


Fig. 4 Direct ECC bypass fraction



(a) Air-Water Experiment (b) CFX Calculation

Fig.5 ECC spreading shape of the shifted DVI (V(coldleg, air velocity)=20 m/s).

Fig. 5 shows that the ECC film is formed at the wake of the hot leg for the case of the shifted DVI to the hot leg from the broken cold leg. The film spreading shape of the CFX result has nearly the same shape as the experimental result. But, the film of the lower wake region disappeared in the CFX simulation. Fig. 6 shows the ECC bypass fraction for the shifted DVI. The ECC bypass fraction of the CFX code simulation is generally over predicted when compared to the experimental results at each cold leg velocity, respectively. The film breakup and its spreading in the CFX result are not strong near the hot leg wake. Therefore, the film is concentrated at a narrow path between the hot leg and the broken cold leg. This concentrated film pattern increases the direct ECC bypass fraction of the CFX simulation for the shifted DVI allocation.

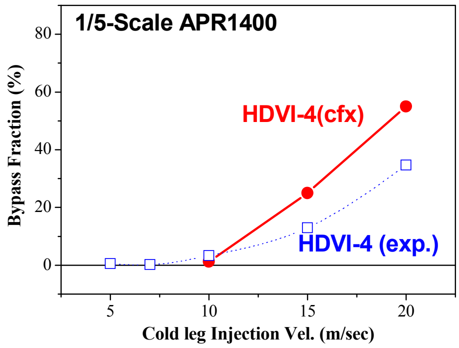


Fig.6 Direct ECC bypass fraction of the shifted DVI

4. Conclusion

The feasibility of a CFD fine mesh simulation has been tested to evaluate the accuracy of a CFX simulation. The test results show that the CFX model for two phase flow of an air-water mixing would partially be applicable for a qualitative study.

Acknowledgment

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