Parametric Study for Interfacial Drag on Siphon break Phenomena in a Research Reactor

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1. Introduction

A pipe rupture of a primary cooling system (PCS) in an open-pool type research reactor, such as KiJang Research Reactor (KJRR), could lead to drainage of the coolant in a reactor pool through this pipe by siphon effect. As a consequence, the core could be exposed to the air. Therefore, this type research reactor is equipped with a siphon breaking system to maintain reactor pool water level above the required height during a loss of coolant accident (LOCA). In this study, numerical simulations are performed to access the effect of interfacial drag on siphon breaking phenomena using CUPID code.

2. Numerical Method

2.1 Numerical Model

The computational domain used in the present work was modeled to be nearly identical to siphon break test facility of POSTECH [1] as show in Fig. 1. This computational domain consists of a water tank, a main pipe, and an inverted U-tube shaped siphon break pipe. The computational meshes were generated about 200,000 in the numerical model.

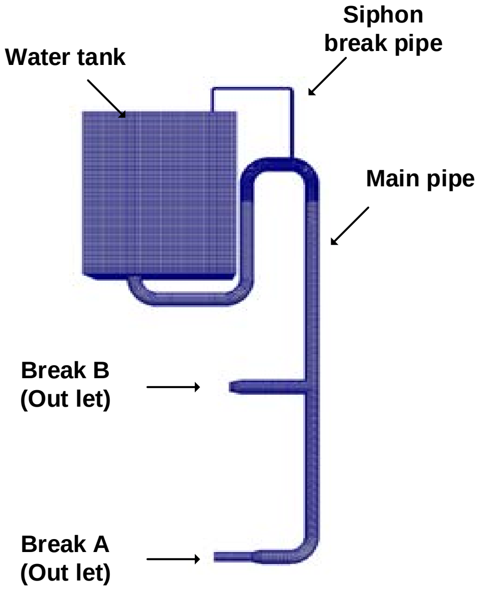

Fig. 1. 3-D computational domain and meshes

2.2 Numerical Method

Numerical simulations were carried out using a CUPID code. The siphon break phenomena involved a complex 3-dimensional transient two-phase flow was solved using two-fluid model in the CUPID code, and the algebraic turbulence model with a standard wall function was used to consider turbulence effect.

The topology concept suggested by Tentner [2] was applied to mathematically close the interphase transfer terms of the governing equations of the two-fluid model. Fig. 2 shows the interphase topology map. In this map, the configuration of the interface within the cell (mesh) can be represented by bubble, mist, and sharp interface flow (separated flow).

It is considered that the interfacial drag (F_{gl}) in the bubbly flow is the most influential parameter for the siphon break phenomena. Therefore, parametric study was performed to assess the effect of interfacial drag in the bubbly flow on the siphon breaking phenomena in this study.

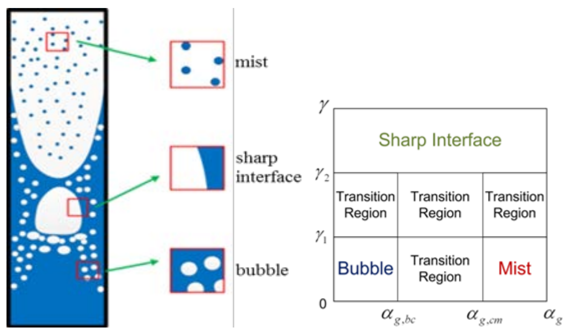

Fig. 2. Interphase topology map [2]

3. Results

Table 1 shows the simulation cases in the present work. Here, the diameter represents inner diameter of the siphon break pipe (SBP).

To assess the interfacial drag in the bubbly flow effect on siphon break phenomena, the interfacial drag, F_{gl}, was adjusted from 1,000 to 10,000 kg/m^{3}s. The effect of the interfacial drag in the bubbly flow seems to be important in determining the final water level in the water tank as shown in Fig. 3. CUPID result for simulation case 1 shows good agreement with experimental data when the interfacial drag in the bubbly flow is about 1,000~6,000 kg/m^{3}s. In this case, the air pocket forms in the inverted U-tube region of main pipe as air enters through the siphon break pipe, and then the break water flow through the main pipe is blocked by air pocket formed in the inverted U-tube region of main pipe.

However, CUPID code cannot predict final water level in the water tank when the interfacial drag in the bubbly flow has large value above than 6,000 kg/m^3s. This is because that the air taken in from the siphon break pipe is removed as soon as it appears due to the large interfacial drag. In this case, the entrained air from the siphon break pipe to the main pipe is dragged out by the water flow and the air pocket does not grow in the inverted U-tube region of main pipe.

Fig. 4 and 5 show comparison of water level transient with experimental data and CUPID calculation for all simulation cases. The CUPID results show that relevant interfacial drag to properly predict final water level in the water tank is dependent on the diameter of the siphon break pipe. The interfacial drag in the bubbly flow is proportion to the interfacial area concentration or the bubble size. The bubble (air) size initially introduced into the main pipe depends on the diameter of the siphon break pipe. Therefore, it is considered that the interfacial drag acts differently in the bubbly flow depending on the diameter of the siphon break pipe. The results also show that the interfacial drag acts differently depending on the break location. A detail review of these analysis results is ongoing.

Table 1: Simulation cases

Case #	Break location	Diameter (inch)
1	A	2.5
2		2.0
3		1.5
4	B	2.5
5		2.0
6		1.5

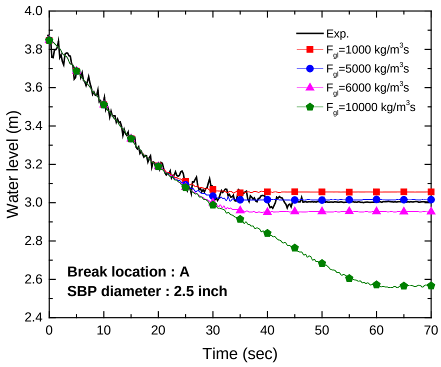

Fig. 3. Parametric study on interfacial drag in the bubbly flow for simulation case 1

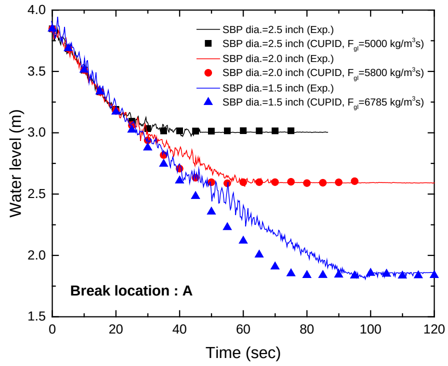

Fig. 4. Comparison of water level transient with experimental data and CUPID calculation: Simulation case 2 and 3

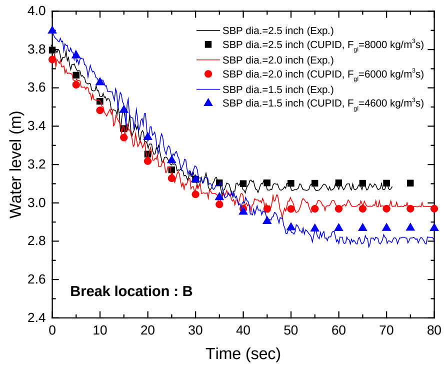

Fig. 5. Comparison of water level transient with experimental data and CUPID calculation: Simulation case 4, 5, and 6

4. Conclusions

The CUPID results indicated that siphonage break flow rate and initiation of siphon break are significantly affected by the interfacial drag. The calculated break flow rate and final water level in the water tank using CUPID code with relevant interfacial drag are good agreement with experimental data.

Acknowledgement

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