MARS Code Assessment for the CCFL in the Nearly Horizontal Pipe

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1. Introduction

CCFL is the limiting condition where the gas or liquid flow rate cannot be increased further when the gas or liquid flow rate increases in a countercurrent flow system. It is very important phenomenon in analyzing the safety of the nuclear power plant because the steam generated from the core could partly or totally inhibit the injected water for the safety back down when an accident occurs.

There have been many researches to predict the onset of CCFL both experimentally and analytically. In the experimental studies, CCFL correlations were developed in various conditions. In the theoretical studies, CCFL models have been developed. And in the numerical studies, the capability of the thermal hydraulic system analysis codes such as RELAP was improved using developed correlations and models. From those researches, CCFL phenomena could be analyzed in various conditions. However, the simulation of CCFL in the inclined pipe has received little attention compared with the vertical or horizontal cases.

In this study, in order to assess the capability of MARS code to the prediction of the onset of CCFL in the nearly horizontal pipe, numerical study was performed. From the simulation results, it was found that the standard MARS code overestimated the onset of CCFL in the nearly horizontal pipe. Therefore MARS code was modified by applying the CCFL model in the horizontal volume and then the sensitivity tests were performed to evaluate which correlation predicted well the onset of CCFL.

2. CCFL Experiment in the Nearly Horizontal Pipe

In order to validate the availability of the standard MARS code on the CCFL phenomena in the horizontal pipe, Choi's experiment in KAIST was used [1]. Figure 1 shows the schematic diagram of the CCFL experiment.

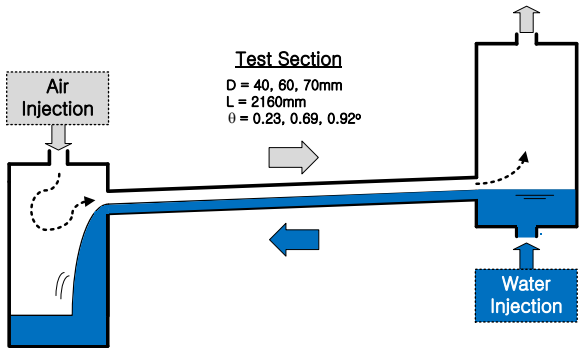

Fig. 1. CCFL experiment in the nearly horizontal pipe

The experiment was performed in the facility with the length of 2160 mm, and with three different inner diameters of 40, 60, and 70mm, and with the various inclination angles of 0.23˚, 0.69˚ and 0.92˚. In this experiment, increasing the air flow rate for the fixed water flow rate in the air-water countercurrent flow, the onset of CCFL was measured.

3. MARS Code Modeling

3.1 MARS Code Nodalization

MARS nodalization is developed for the simulation of the CCFL experiment as shown in Fig. 2.

Water is injected into the test section (Pipe100) from the bottom of air tank (Pipe370) and air is injected from the top of water tank (Pipe270). Flow boundary conditions of water and air are modeled as time dependent junction, TDV315 and 215, respectively. Water is drained into the water tank (Pipe270). Air flows out to the air tank (Pipe370) and then air is vented to the time dependent volume (TDV390) that is modeled as a pressure boundary.

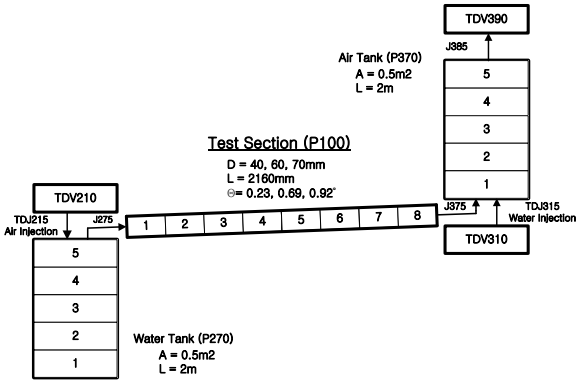

Fig. 2. MARS nodalization of the CCFL experiment

3.2 Determination of the Onset of CCFL

MARS calculation is performed as follows. Water flow is injected as a fixed value where a given flow rate is corresponding to the dimensionless superficial liquid velocity of the experimental data. Simultaneously, air flow is injected as a fixed value where a given air flow rate does not disturb the water flow rate. The procedure allows the liquid flow to settle down into a steady state before increasing the gas injection rate. And then the air flow rate is increased slowly from t=200 sec until the onset of CCFL is observed.

In MARS calculation, the onset of horizontal CCFL is determined by the sudden change of water flow rate,

water level in the air tank, pressure and void fraction. Figure 3 shows the onset of CCFL. At the onset of CCFL, water flow rate starts to decrease suddenly because the water flow injected to the test section is limited by the air flow. Using these results, the dimensionless superficial gas velocity is determined as the value at the time when the CCFL occurs.

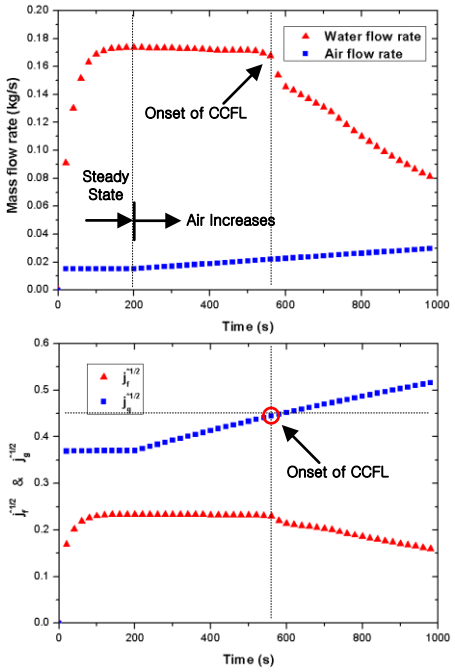

Fig. 3. Prediction of the onset of CCFL using MARS code

4. Simulation Results using MARS Code

4.1 Simulation Results using Standard MARS Code

From the simulation results using the standard MARS code, it is found that the air flow rates, which lead to CCFL for given water flow rates, are not in good agreement with the experimental results. The predicted air flow rate is much higher than that measured in the experiment by the CCFL model. The comparison results are shown in Fig. 4.

4.2 Simulation Results using Modified MARS Code

CCFL model is only applied into the vertical volume in the standard MARS code. Therefore, the present study extended the CCFL model for the vertical volume to the horizontal volume using the method suggested by Heo [2]. And then the sensitivity tests for the various horizontal CCFL correlations, shown in Table 1, were performed to evaluate which correlation predicted well the onset of CCFL. Figure 4 and 5 show the comparison of results for θ=0.23˚ and 0.92˚, respectively. From the results in Fig. 4, it could be concluded that the modified MARS code using Kim's correlation [3] predicts well the onset of CCFL. However, in Fig. 5, it is found that the modified MARS codes do not predict well the onset of CCFL as the inclination angle increases.

Table I: Horizontal CCFL Correlations

CCFL Correlations		
1	Kim	$j_g^{*0.5} + 0.614 j_f^{*0.5} = 0.635 - 0.00254\left(\frac{L}{D}\right)$
2	Richer	$j_g^{*0.5} + j_f^{*0.5} = 0.7$
3	Krolewski	$j_g^{*0.5} + 0.78 j_f^{*0.5} = 0.53$

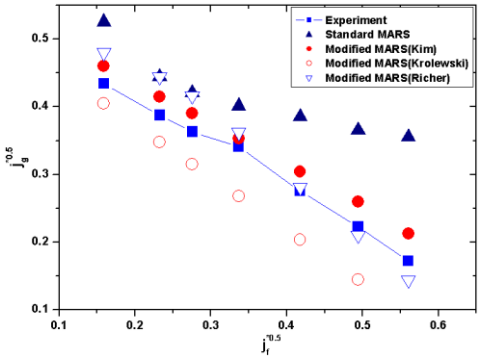

Fig. 4. Comparison of results (D=70mm, θ=0.23˚)

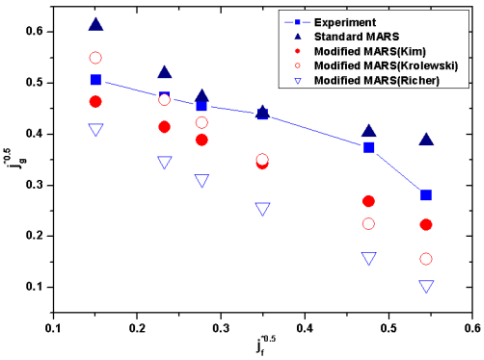

Fig. 5. Comparison of results (D=70mm, θ=0.92˚)

6. Conclusions

In this study, numerical simulations of the CCFL phenomena in the nearly horizontal pipe were performed using the MARS code. From the results, it is found that the onset of CCFL could be predicted well when the CCFL model using the appropriate correlation is applied into the horizontal volume. Therefore it is concluded that the standard MARS code should be modified to include the CCFL model in the horizontal volume as well as in the vertical volume. And it is required to develop the CCFL correlation considering the inclination angle.

REFERENCES

[1] K. Y. Choi, H. C. No, Experimental Studies of Flooding in Nearly Horizontal Pipes, Int. J. Multiphase Flow, Vol.21 (3), pp. 419-436, 1995.
[2] S. Heo, H. C. No, Improvement of the CCFL Models of the RELAP5/MOD3.2.2B Code in a Horizontal Pipe, Proc. 8th International Conference on Nuclear Engineering, Baltmore, USA, 2000.
[3] H. T. Kim, H. C. No, Assessment of RELAP5/MOD3.2.3r against flooding database in horizontal-to-inclined pipes, Vol. 29 (7), pp. 835-850, 2002.