Fundamental validation of the SPACE code: basic hydraulics

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1. Introduction

The SPACE code is a system code for predicting the thermal-hydraulic behaviors of PRW nuclear power plants. KAERI has been in charge of the package development of physical models and correlations needed for each term in conservation equations. At present, a demo version of the code is on the edge of release in 2010. This study is to validate hydraulics-related models and correlations (flow regime maps and wall/interfacial drags). To this end, five hydraulic problems are simulated: U-shaped tube test, TPTF horizontal test, two-phase pressure drop test, ANL vertical air-water test, Wilson`s rising bubble test.

2. Test models and results

The models and correlations for flow regime maps and interphase/wall drags are described in Kim et. al. (2009a) and Kim et al. (2009). The simulation results are briefly dealt in this section.

2.1 U-shaped tube test

Figure 1 illustrates a schematic diagram of a U-shaped tube. At the initial state, sub-cooled water is filled in the tube, with different level between left and right pipes. For some length of time after the initial state, water exhibits oscillating motion by gravity and finally comes to a standstill by wall friction. A total of 12 cases are considered in this study, depending on the existence of wall friction, the type of interfacial frictions (drag-coefficient or drift-flux model), and three different sizes of tube diameter. The liquid motion for a small pipe with wall friction is plotted with respect to time in Fig. 2.

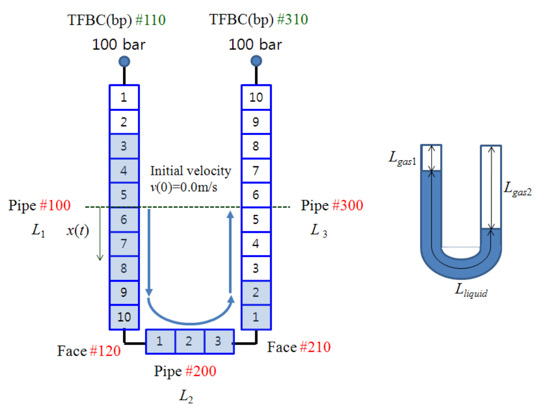

Fig. 1. Nodalization diagram of a oscillating manometer

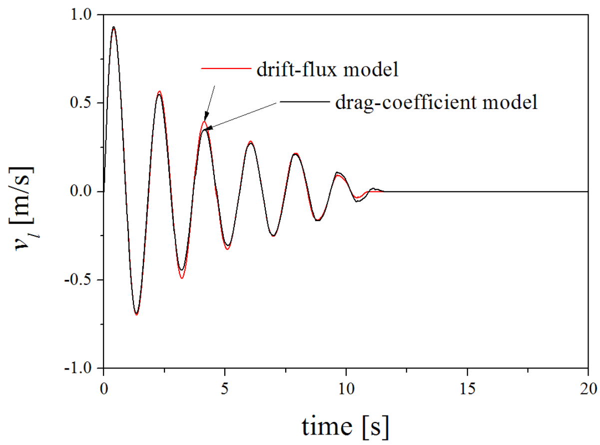

Fig. 2. Liquid velocity history for a small pipe

2.2 TPTF horizontal test

Kawaji et al. (1987) and Nakamura (1996) reported a large number of experimental data for cocurrent-horizontal flow at saturated conditions. This data is chosen due to the importance of horizontally-stratified flow in hot legs during LOCA accidents.

2.3 Two-phase pressure drop test

Ferrell & Bylund (1966) is considered as a reference experiment, in order to validate the capability to predict two-phase pressure drop. The working fluid is a mixture of steam and water. They measured the pressure drops of cocurrent-vertical two-phase flow in various conditions. The pressure drop profiles along the pipe are shown in Fig. 3 for 1A8 and 1B2 cases. From this, one can say that the SPACE code is able to predict accurately two-phase pressure drop.

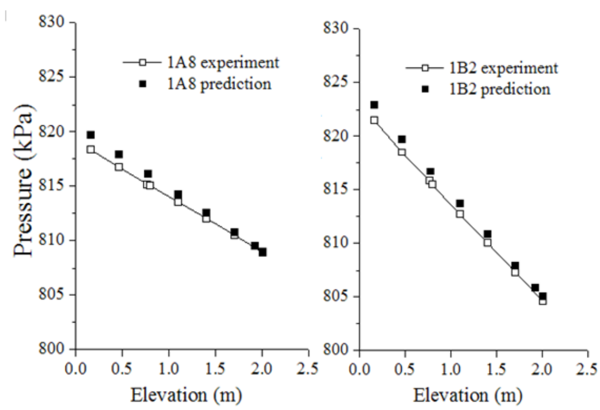

Fig. 3. Pressure drop profiles of 1A8 and 1B2 cases

2.4 ANL vertical test

Smissaert (1963) made hundreds of air-water experiments in a vertical pipe, as shown in Fig. 4. This report provides the void fraction and air and water velocities at position 3 for each case. Simulation results are summarized in Table I. Here, α_{drift} and α_{drag} are the void fractions obtained by the drift-flux model and the drag coefficient model, respectively. We can see from the table that the drift-flux model produces tolerance errors less than 0.032 void fraction, except for G-17 case.

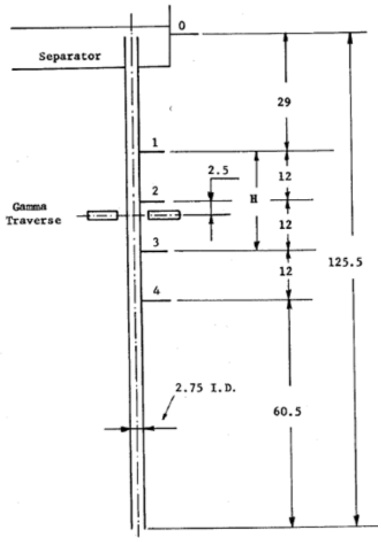

Fig. 4. Schematic of ANL vertical test

Table I: Simulation result

Run	Experiment			Simulation	
	J_L (m/s)	J_G (m/s)	α_{EXP}	α_{drift}	α_{drag}
A-1	0.0	0.875	0.597	0.605	0.730
A-5	0.0	0.637	0.553	0.563	0.634
A-9	0.0	0.210	0.339	0.371	0.445
B-5	0.03	0.796	0.559	0.580	0.663
B-12	0.03	0.341	0.419	0.443	0.501
B-16	0.03	0.032	0.067	0.087	0.109
G-4	0.244	0.677	0.425	0.455	0.517
G-10	0.244	1.628	0.589	0.614	0.725
G-17	0.244	4.676	0.709	0.787	0.882

2.5 Wilson`s rising bubble test

Wilson (1965) was to perform a series of steam-water tests to determine the void fractions in a bubbling two-phase mixture. The experimental apparatus is drawn in Fig. 5 and the simulation results are given in Table II.

3. Conclusions

Through five hydraulic problems, we can make a conclusion that the hydraulics-related model packages (flow regime maps and the wall/interfacial drags) work reliably and accurately in the SPACE code.

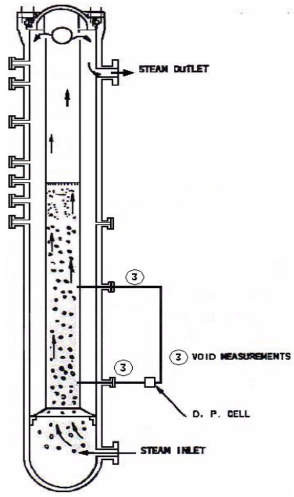

Fig. 5. Experimental apparatus (Wilson 1965)

Table II: Simulation result

Case	Experiment		Simulation	Error
	Pressure	α	α	Sim-Exp
1	4.137 MPa	0.260	0.275	0.015
2		0.501	0.549	0.048
3		0.592	0.649	0.057
4	6.895	0.315	0.345	0.030
5		0.576	0.604	0.028
6		0.813	0.751	-0.062
7	9.653	0.290	0.304	0.014
8		0.546	0.582	0.036
9		0.701	0.731	0.03
10	13.89	0.199	0.313	0.114
11		0.509	0.583	0.074
12		0.645	0.707	0.062

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