CAP Code Validation of Two-Phase Flow Pressure Drop

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1. Introduction

The CAP (Containment Analysis Package) code has been developed for the analysis of containment thermal hydraulic behaviors including pressure and temperature trends and hydrogen concentration. As the CAP code version was upgraded to 3.0, pipe component, interfacial heat & mass transfer model, and interfacial drag model were implemented for the improvement of two-phase analysis in the pipe [1]. However, there is not enough validation for the CAP 3.0, so more validations are required. In order to assess the prediction capability of the CAP 3.0 for the two-phase pressure drop, this study performed the validation simulations GE (General Electric) test [2] of pressure drop. The analysis results of the CAP 3.0 were compared with experimental data and MARS-KS1.4 [3] prediction results.

2. GE Test

GE Test was conducted by General Electric to measure the pressure drop occurring under adiabatic conditions. The Ge Test was designed as shown in Fig. 1 to measure the pressure drop of the vertical upward flow, horizontal flow, and vertical downward flow at a time.

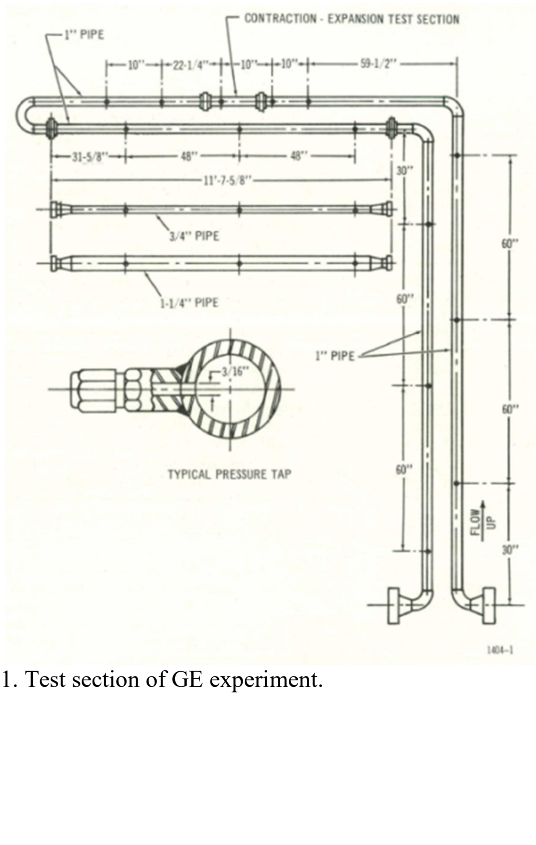


Fig. 1. Test section of GE experiment.

This test performed in rectangular channels (1/4in ×1-3/4in, 1/2in ×1-3/4in) and circular channels (0.742, 0.954, and 1.268 in). GE test covers below conditions.

- Pressure: 41.4, 68.9, and 96.5 bar
- Mass flow: 0.15 ~ 0.63 kg/s
- Quality: 0.0 ~ 0.9 (Thermodynamic)

3. Code Analysis

This study simulated 116 experiments performed on circular channels with diameters of 0.954 in and 1.268 in using the CAP 3.0 and MARS-KS1.4.

The pressure drop in the MARS and CAP is calculated using the method suggested by Lockhart & Martinelli [4].

$$\left(-\frac{dp}{dx}\right)_{2\varphi} = \varphi_g^2\left(-\frac{dp}{dx}\right)_g = \varphi_f^2\left(-\frac{dp}{dx}\right)_f \quad (1)$$

$$X^2 = \frac{\varphi_g^2}{\varphi_f^2} \quad (2)$$

$$\varphi_f^2 = 1 + \frac{C}{X} + \frac{1}{X^2} \quad (3)$$

$$\varphi_g^2 = X^2 + CX + 1 \quad (4)$$

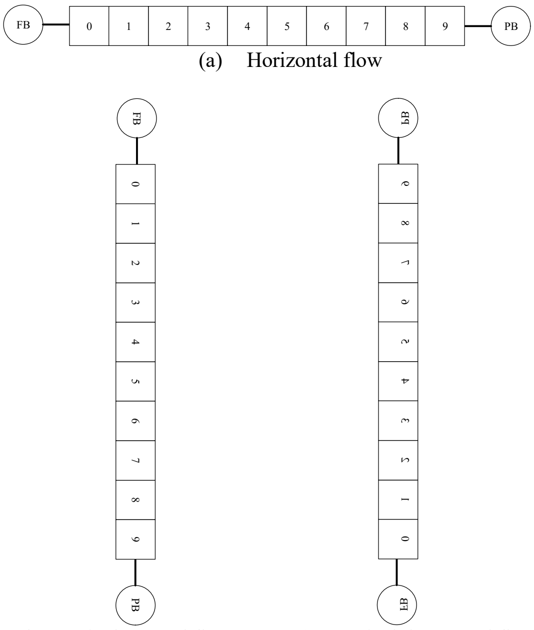
In equation 3 & 4, C is generally calculated from the H.T.F.S. model [5], but in the annular flow, it is calculated through the Wallis model [6].

3.1 The CAP & MARS code modeling

Figure 2 shows the nodalization of GE test. It consists of one pipe and inlet and outlet boundary. The length of the pipe is about 3.5m, and consists of identical 10 cells.

3.2 Analysis Results

Figure 3 shows the comparison results between the CAP 3.0 pressure drop and the MARS-KS1.4 pressure drop. The two codes have significantly similar predictive performance, but it can be seen that there are errors of up to 20% in some conditions. Figure 4 shows the comparison between pressure drop of the CAP 3.0 and that of the GE test, and 88 data out of a total of 116 data are included within an error of 30%.



(b) Vertical upward flow (c) Vertical downward flow

Fig. 2. Modeling of the CAP & MARS codes.

Figs. 5 to 8 show the comparison results the predicted pressure drop by two codes (CAP 3.0 and MARS-KS1.4) and the experimental pressure drop. Figs. 5 and 6, where the mass flow rate is relatively high (m=0.63 kg/s), show the predicted pressure drops by two codes (CAP 3.0 and MARS-KS1.4) are quite similar to that of the experiment. On the other hand, in case of mass flow rate is low (Figs. 7 and 8), the two codes under-estimate pressure drop than experiment.

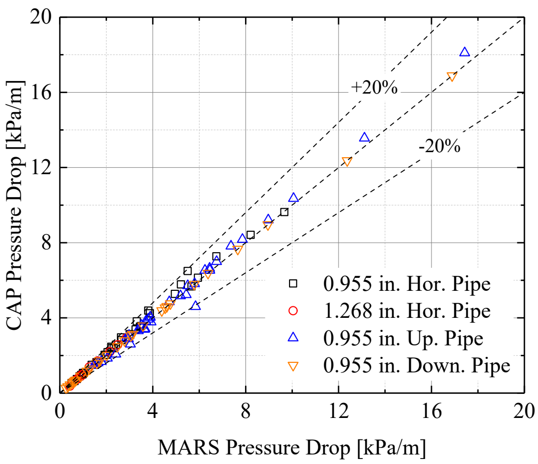


Fig. 3. Comparisons of pressure drop predicted by MARS and CAP.

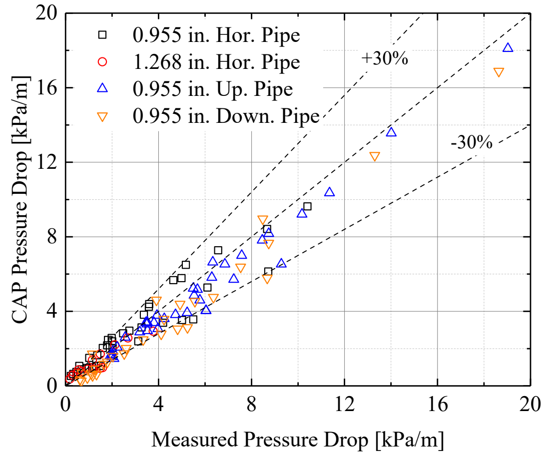


Fig. 4. Comparisons of pressure drop predicted by CAP and experimental data.

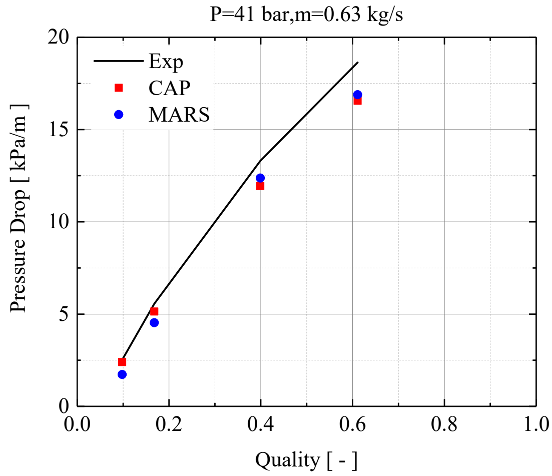


Fig. 5. Comparisons of pressure drop in vertical upward flow (0.955 inch pipe, P = 41 bar, m = 0.63 kg/s).

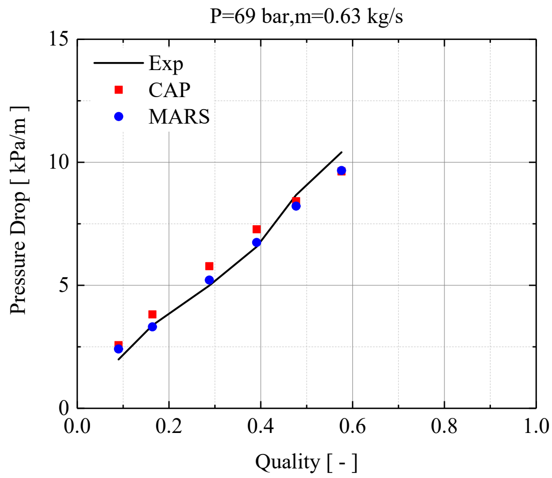


Fig. 6. Comparisons of pressure drop in horizontal flow (0.955 inch pipe, P = 69 bar, m = 0.63 kg/s).

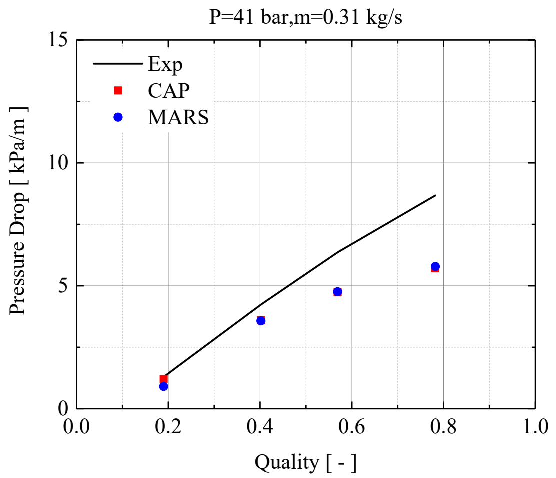


Fig. 7. Comparisons of pressure drop in vertical downward flow (0.955 inch pipe, P = 41 bar, m = 0.31 kg/s).

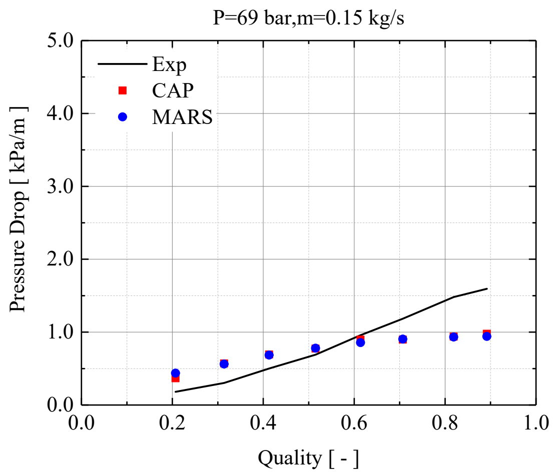


Fig. 8. Comparisons of pressure drop in horizontal flow (1.268 in pipe, P = 69 bar, m = 0.15 kg/s).

4. Conclusions

GE test was simulated using the CAP 3.0 and the MARS-KS 1.4 codes, and the calculated pressure gradients were compared with experimental data. It can be seen that the two-phase pressure drop prediction performance of the CAP 3.0 is similar to the MARS-KS1.4. In addition, CAP predicted 88 experimental data out of a total of 116 data within a 30% error range. However, the CAP 3.0 under-predicts the pressure drop as the mass flow rate is lowered, so further study is required.

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