ABSTRACT

Experiments and model predictions were performed for studies on two-phase flow behavior at low- and high-pressure conditions. 35 and 81 tests were conducted using nitrogen and water in a test loop of 106.4 mm diameter pipe with inclination angles 0°, 1°, and 3° at 592 kPa and 2060 kPa, respectively. The measured parameters included gas and liquid flow rates, pressure and temperature, differential pressure, and liquid holdup. The flow pattern of each flow condition was determined by interpreting visual observations and liquid holdup signals. Effects of the inclination angle and pressure on the flow pattern, liquid holdup and pressure drop were evaluated on the basis of the experiment data.

Based on the experimental data, the mechanistic model was developed incorporating transition criteria for eight flow patterns, and individual flow models for estimating liquid holdup and pressure drops.

For transition to dispersed-bubble flow, the critical bubble size mechanisms are applicable at low and high pressures to predict its region. It was confirmed with the data that only the criterion for bubble distortion $d_{\max}=d_{CD}$ can effectively discriminate between them, and the liquid holdup calculated by the slip model matches the experimental data better than the non-slip model.

For prediction of stratified and non-stratified flow transition, sequential application of the Taitel-Dukler and Bendiksen-Espedal criteria can correctly identify at all conditions, and for the liquid holdup evaluation, the Lockhart and Mattinelli correlation based on the superficial shear stresses is much best estimator.

The intermittent flow pattern is subdivided into elongate-bubble, slug, and froth flow based on the experimental data. For model predictions of these three flow patterns and transition from annular to intermittent flow, we proposed new transition criteria based on experimental data. The mass balance and global force balance along the slug unit were used for the liquid holdup and pressure drop evaluation, respectively. Suitable friction factor correlations were used according to flow conditions.

For the pressure drop prediction of annular flow, new correlation for the liquid-wall frictional factor at bottom and top was proposed using different Reynolds numbers for liquid-wall friction factor in stratified flow, and was found more effective to improve accuracy.

The flow pattern prediction results were plotted on flow pattern maps for both low- and high-pressure conditions using superficial gas and liquid velocities as coordinates. Predicted results showed good agreements with experimental data.

The results predicted by the individual models demonstrated excellent agreements with the experimental data for each pressure and each inclination angle. The overall performance of the new mechanistic model was evaluated against the total 348 experimental data for liquid holdup and 938 data for pressure drop. The model predicted liquid holdup and pressure drop within 9.50 % and 14.38 % absolute average errors, respectively.