Prediction of Gas Holdup and Transition Velocity in Countercurrent Bubble Column

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Highlights

- Extension of liquid circulation model for non-zero gas holdup at the wall.
- Prediction of gas holdup for homogeneous and heterogeneous regimes.
- Prediction of gas velocity and gas holdup at transition.
- Simulation of radial profile of axial liquid velocity.

1. Introduction

Bubble column reactors are commonly used in process industries owing to high heat and mass transfer rates. Bubble columns (BC) are operated with the liquid phase in batch or cocurrent or countercurrent mode. Majority of the studies have focused on the hydrodynamics of BCs in batch mode. Studies on hydrodynamics of countercurrent BC (CCBC) are very limited [1]. Most of the attempts to predict gas holdup in CCBC are empirical. In the present work a methodology is developed to semi-empirically predict the gas holdup in the homogeneous and heterogeneous regimes along with the transition gas velocity.

2. Methods

Hydrodynamic experiments were conducted in a pilot scale CCBC using porous plate distributor. Gas holdup was measured using pressure drop, for different gas and liquid velocities. The gas velocity for transition from homogeneous to heterogeneous regime was determined using the swarm velocity method. The phenomenological model proposed by Molerus and Kurtin [2] was used to model the homogeneous regime with bubble diameter as the model parameter. For the heterogeneous regime, the liquid circulation model proposed by Ueyama and Miyauchi [3] was extended to account for non-zero gas holdup at the wall. The extended model was used to predict the holdup in the heterogeneous regime with the apparent slip velocity as the model parameter. The simultaneous solution of both the models gave the gas velocity and gas holdup at the regime transition point.

3. Results and discussion

The gas velocity at which the homogeneous regime becomes heterogeneous decreases with increase in liquid velocity due to the advancement of instability. The gas holdup along this regime transition boundary however increases with liquid velocity. Similar to batch BC, the gas holdup increases with gas velocity. Increase in liquid velocity increases the gas holdup due to increased drag of down-flowing liquid.

The bubble diameter which was fitted as a parameter of the Molerus and Kurtin model in the homogeneous regime shows a decrease with increase in liquid velocity probably due to increased turbulence. The apparent slip velocity which was fitted as a parameter of the extended Ueyama and Miyauchi model increases with both gas and liquid velocity. An empirical correlation is proposed for the apparent slip velocity. The two models with the two fitted parameters were solved simultaneously to get the gas velocity and holdup at the transition point. The gas holdup predicted by the models in the respective regimes and the transition gas velocity and holdup compares satisfactorily with the experimental data.

The extended Ueyama and Miyauchi model is used to simulate the effect of gas and liquid velocity on radial profile of axial liquid velocity and average liquid circulation velocity. The radial profile and the average circulation velocity are determined by the relative magnitude of the gas induced liquid circulations and the downflowing external liquid.

4. Conclusions

Gas holdup data in CCBC show that, the homogeneous to heterogeneous transition is advanced with increase in liquid velocity and the gas holdup increases with velocity of both the phases. A methodology has been developed to predict semi-empirically the gas holdup in a CCBC by employing two existing models in the literature. The effect of phase velocities on the model parameters viz. bubble diameter and apparent slip velocity has been studied and empirically correlated. The methodology predicts the experimental gas holdup and transition velocity satisfactorily. Simulated radial profiles of liquid velocity show that a liquid upflow region as observed in the core of BC can be absent in a CCBC.

References

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Keywords
Countercurrent bubble column; gas holdup; flow regime; apparent slip velocity.