231a Validation Study of Bubble-Column Simulations for Uniform and Non-Uniform Aeration Conditions

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In our previous work (Monahan et al., 2005), we showed that flow-regime predictions of air-water bubble columns are highly dependent on the momentum-transfer model formulation, which includes drag, virtual-mass, lift, rotation, and strain forces, and Sato's bubble-induced turbulence (BIT) model. Numerical simulations were performed with CFDLib, a cell-centered, finite-volume code developed by Los Alamos National Laboratory. The code utilizes an Eulerian two-fluid model, which includes closures for effective stress and interphase momentum exchange.

We report on a validation study of our results against those of the experimental research group at Delft University of Technology. Their recent work has focused on large-scale flow structures in cylindrical bubble columns for gas volume fractions ranging from 5% to 50%. Additionally, they have utilized a rectangular pseudo-two-dimensional column with width 24.3 cm in order to study the dynamic behavior more closely. Experiments for the Delft rectangular column include one uniform aeration pattern and six non-uniform aeration patterns (Harteveld et al, 2004). Fully resolved CFDLib simulations of the Delft rectangular column are carried out on a uniform grid with cell spacing of 0.243 cm in the horizontal and vertical directions.

In the model formulation, bubble Reynolds number Re is controlled by bubble diameter and volume fraction □ is controlled by the inlet gas flow rate. We present flow maps to identify the regions in Re-□ space where flow profiles exhibit a particular behavior and to clearly illustrate where flow transitions occur. The maps reflect a strong dependence on the model parameters applied, and show that if the BIT model and all force models are used as discussed in Monahan et al. (2005), the CFD simulations agree qualitatively with the Delft experiments for uniform aeration.

Non-uniform aeration yields flow instabilities in the Delft experiments. If the non-aerated section near the column walls is small (less than 22%), large-scale structures are not observed, or such structures are present in a fixed position. An increase in the non-aerated section to 28% gives rise to dynamic large-scale structures with periodic behavior. Non-aeration in the center of the column results in circulation cells near the sparger (Harteveld et al, 2004). We present both qualitative and quantitative CFD results for these cases and compare the observed flow phenomena with those reported in the experiments. Quantitative analyses examine liquid axial velocity profiles across the column width, liquid axial velocity as a function of time, volume fraction profiles across column width, and axial normal stress as a function of column height.

References:

Harteveld, W. K., Julia, J. E., Mudde, R. F., and van den Akker, H. E. A. (2004). Large scale vortical structures in bubble columns for gas fractions in the range 5%-25%. Proc. 16th International Conference on Chemical and Process Engineering, Prague, Czech Republic, 2004.

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