Bubble Column Fluid-Dynamics: Experimental and Numerical Investigations

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Motivations

Bubble columns are widely used as chemical reactors. The global and local flow properties are related to the prevailing flow regime. The correct design and operation of bubble column reactors rely on the understanding of the global fluid dynamics, the local flow phenomena and the bubble properties. At present,, there is a lack of studies concerning:

i. large-diameter and large-scale bubble columns (bubble column diameter larger than 0.15 m);
ii. the influence of working fluids other than air-water;
iii. the influence of bubble column design (i.e., internals, sparger design and bubble column aspect ratio);
iv. the influence of bubble column operation (i.e., counter-current operation mode);
v. rReliable CFD approaches to predict the bubble column fluid dynamics.

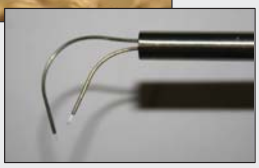
Experimental methods

We have built a counter-current large-diameter (0.24 m inner diameter) and large-scale (5.3 m height) bubble column and we have applied the following experimental techniques, which considers the “*reactor-scale*” and the “*bubble-scale*”:

i. Gas holdup
ii. Gas disengagement
iii. Image analysis
iv. Optical probe

Bubble column design tested:

i. Pipe sparger;
ii. Spider sparger;
iii. Two porous plates;
iv. Needle sparger;
v. Vertical internals;
vi. Different aspect ratios.

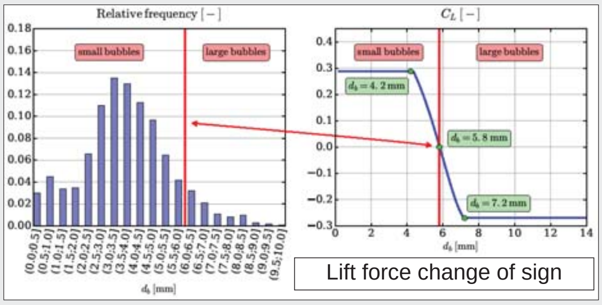


Liquid phases tested:

i. Air-Water
ii. Air-Water-NaCl
iii. Air-Water-Ethanol
iv. Air-Water-Monoethylen glycol

Numerical methods

We have used the Euler-Multi fluids (3-D, transient) approach(ANSYS FLUENT), where the phases are implemented as in penetrating continua coupled by a set of interfacial forces. Different approaches for the characterization of the dispersed phase and the small and large bubbles (accordingly with the lift force change of sign) have been tested. The numerical results have been validated using the experimental datasets.



We have compared our results with the HZDR baseline model (ANSYS CFX). The HZDR model has been tested in its coalescence and break up formulation.

Experimental results

These results would help in the design, operation and scale-up multiphase reactors

- The changes in the liquid phase properties mainly influence the bubble properties at the interface, thus resulting in a change of the bubble size distribution, and, therefore, affecting the regime transition and the gas holdup curves.
- The counter-current mode has turned out to increase the gas holdup, destabilize the homogeneous regime and reduce the bubble rising velocity.
- The aspect ratio, up to a critical value, has turned out to decrease the gas holdup and destabilize the homogeneous regime. The critical value of the aspect ratio depends on the bubble column operation and liquid phase properties.
- The sparger design highly influence the bubble column fluid dynamics, depending on the diameter of the openings. The vertical internals have a limited influence on the global bubble column fluid dynamics.

Numerical results

These results would help in the simulation and prediction of multiphase reactors performance

- The bi-dispersed approach is required for the accurate prediction of the homogeneous regime, given the polydispersity nature of the bubbly flows investigated. On the contrary, a mono-dispersed approach is unable to predict the bubble column fluid dynamics.
- The bi-dispersed Eulerian approach is able to account for both the stabilizing and destabilizing effects of small and large bubbles.
- The results demonstrated the necessity of a population balance model able to capture the bubbles coalescence and breakup phenomena for the correct prediction of the pseudo-homogeneous and the heterogeneous regimes.
- Our approach (ANSYS FLUENT) performed similarly to the HZDR baseline model (ANSYS CFX) and is a promising method for the simulation of bubble columns

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