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COALESCENCE AND BREAK-UP IN DENSE BUBBLY FLOWS

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Summary

A combined experimental and computational study has been performed on the effect of coalescence and breakup in bubbly flows. A pseudo-2D bubble column with a special needle sparger has been constructed to obtain well-defined inlet conditions at the gas distributor. An advanced digital image analysis technique has been developed to determine the Bubble Size Distribution (BSD) as a function of position and superficial gas velocity. Most experimental studies of the size distribution have thus far concentrated on bubbly flow at relatively low void fractions. In the present study the column is operated in the regime of dense bubbly flow, where the individual bubble or a cluster of bubbles can be characterized, leading to the construction of the size distribution.

Keywords

Bubble column, bubbly flow, coalescence, break-up.

Introduction

Bubbly flows are characterized by the existence of the interfaces between the gas and liquid phases and the discontinuities of associated properties. In bubble columns, the gas-liquid mixture may distribute in a variety of ways, which characterize the flow regime. The particular regime one observes depends on the flow parameters of the phases, the fluid properties and the column size or orientation. The regimes are divided in: homogeneous, transition, heterogeneous and slug flow regimes. Industrial bubble columns are operated in the heterogeneous regime, where the bubbly flow is very dense.

One of the key parameters in bubbly flow is the bubble size distribution, since the specific interfacial area determines the rate of exchange of mass, momentum and energy between the phases. In the absence of heat and mass transfer, the evolution of the size distribution is described by the destruction and creation of the bubble population due to coalescence and breakup of bubbles. To study this phenomenon, a pseudo-2D bubble column is employed, facilitating the usage of a non-invasive optical measuring technique to obtain the bubble size distribution.

Some experimental work on the bubble size distribution using image analysis has been done by Bröder & Sommerfeld [1], who measured the bubble sizes within a lab-scale 3D column with an average gas volume fraction between 0.5 - 5.0 % and a mean bubble diameter ranging between 2 - 4 mm. Mena et al. [2] measured the bubble size distribution in a mass transfer system with a lab-scale 3D column and low superficial gas velocities of 2.8 mm/s. Above mentioned previous work are one of the many experimental studies with the focus on bubbly flow with low void fractions.

In the present study, measurements are performed in a pseudo-2D bubble column with superficial gas velocities exceeding 1 cm/s up to the limit, where individual bubbles are non-detectable through image analysis.

Experimental setup

For the experiments the air-water system was used and a pseudo-2D bubble column, with dimensions 0.2 x 0.03 x 1.0 m (see Figure 1). Gas is dispersed through a needle sparger with 20 inlets at the center of the bottom of the column with a pitch of 1 cm. Using a high speed camera still images of the bubbly flow were obtained and processed through a number of digital filters to yield some characteristics of the bubbly flow e.g. bubble size distribution (see Figure 2). By capturing two consecutive images, PIV (particle image velocimetry) is employed to calculate the velocity flow field.

Computational model

For the simulations a deterministic Euler-Lagrange model described by Darmana et al. [3] was used with appropriate models to account for the coalescence and break-up of bubbles. Within this approach, the bubbles are followed through the turbulent flow field along their trajectories (see Figure 3). Experimental results are used to validate the numerical model.

References

[1] D. Bröder & M. Sommerfeld, Planar shadow image velocimetry for the analysis of the hydrodynamics in bubbly flow, Meas. Sci. Technol. 18 (2007) 2513–2528.

[2] P.C. Mena, M.N. Pons, J.A. Teixeira, F.A. Rocha, Using image analysis in the study of multiphase gas absorption, Chem. Eng. Sci. 60 (2005) 5144 – 5150

[3] D. Darmana, N.G. Deen and J.A.M. Kuipers, Parallelization of an Euler-Lagrange model using mixed domain decomposition and a mirror domain technique: Application to dispersed gas-liquid two-phase flow, Journal of Comp. Phys. 220 (2006) 216-248

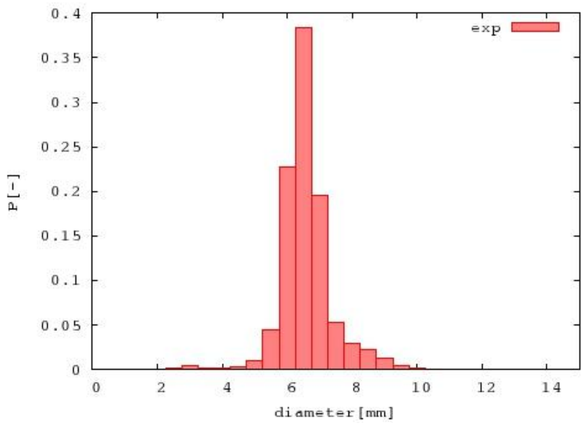

Figure 2. Example of a bubble size distribution for individual bubbles (approximately 20 % void fraction) at a superficial gas velocity of 1 cm/s

Figure 1. Simulation snapshot of the pseudo-2D bubble column

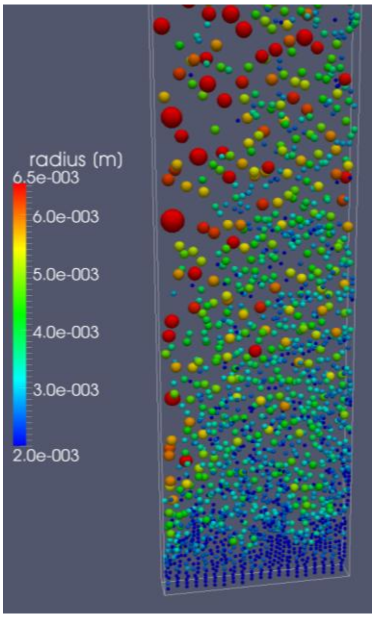

Figure 3. Simulation snapshot of the pseudo-2D bubble column