Gas fraction and bubble dynamics in structured slurry bubble columns

Nasim Hooshyar*, Peter J. Hamersma, Robert F. Mudde, and J. Ruud van Ommen
Delft University of Technology, Julianalaan 136, 2628 BL, Delft, the Netherlands

Summary
In this paper we study the effects of structuring column on the hydrodynamics of slurry bubble columns. The overall aim of our research is to reduce backmixing to achieve a higher efficiency. We apply a special needle sparger in a 2D and 3D column. We are investigating the gas fraction and bubble dynamics using a four-point optical probe in a three-phase G/L/S system. Experimental results for air-water-glass beads (d_p=78 μm, U_{sg}=0-1 m/s) show that reduction in the vortical structures can be achieved and the homogeneous flow regime can be extended beyond 30% gas fraction. Increasing the solids concentration decreases the gas fraction and widens the bubble velocity distribution.

Keywords: slurry bubble column, four-point optical probe, bubble dynamics, structuring

Introduction

Slurry bubble columns are widely applied for chemical and biochemical processes. However, the scale-up and design is difficult due to the complexity of the hydrodynamic behavior of these three-phase systems. Depending on the superficial gas velocity, the hydrodynamics in a slurry bubble column can be characterized by two different flow regimes, namely, the homogeneous and heterogeneous regimes. To obtain a sufficiently high throughput, many industrial columns are operated in the heterogeneous flow regime. However, one of the disadvantages of working in this flow regime is that the degree of backmixing cannot be controlled. To reduce the backmixing we have used a special gas injection system to provide a uniform inlet flow to the column. The needle sparger system we have used, gives the ability to generate a narrow bubble size distribution while extending the homogeneous flow regime to higher superficial gas velocities. Gas holdup and bubble dynamics were locally measured in various positions in the column by using a four-point optical probe[1, 2]. In comparison to a dual optical probe this probe allows discriminating between bubbles rising upward or under an angle with the probe.

Experimental

Experiments are carried out in both a 2D and 3D setup. The 2D column (length×width×height=240×40×1000 mm) consists of a gas injection system with 95 needles each with an inner diameter of 0.8 mm. The needles are placed in a triangular pattern with a pitch of 6 mm[1, 3]. The 3D setup has an inner diameter of 150 mm and is equipped with a needle sparger with 559 needles of which the upper tip is located 5 mm above the column bottom. Application of such a sparger gives the ability to have a dynamic control on gas injection system[3]. The columns are filled with the water as liquid phase and air is injected from the bottom. Glass beads with a mean diameter of 78 μm and a specific density of 2500 kg/m^3 are used as solid phase in our studies. Optical probes are used to measure the gas holdup and bubble dynamics. Optical probes in our study are working on the principle of light refraction. The gas holdup and bubble dynamics are obtained by analyzing and processing the response from the probes.

Results and Discussion

Using a needle sparger, the transition from homogeneous to heterogeneous regime for an air-water system can be delayed from U_{sg}=0.04 m/s to 0.06 m/s (see Figure 1). From measuring the radial gas fraction profile in a 3D setup with single point glass fibers it follows that at a gas velocity less than 0.06 m/s vortical structures and backmixing are absent and a uniform flow exists in the column. At higher gas velocity the wall region has the lowest gas fraction. It supports the visual observation of that a downward motion of the liquid, driving bubbles away from the wall. Note that some of the bubbles which are going downward have a smaller probability of being pierced by the probe. Figure 1 shows that near the center of the column the gas fraction still increases with U_{sg}.

* Corresponding Author: E-mail address:n.hooshyar@tudelft.nl, Tel: +31 15 278 4753; Fax: +31 15 278 5006;

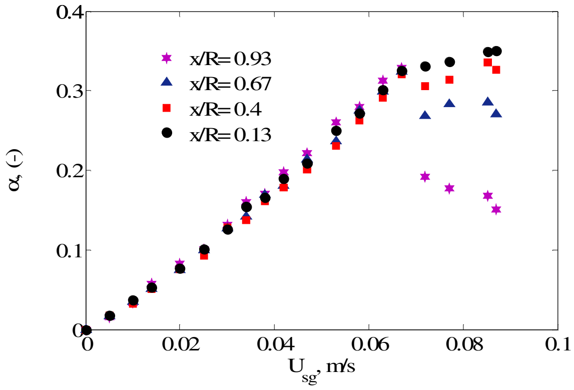
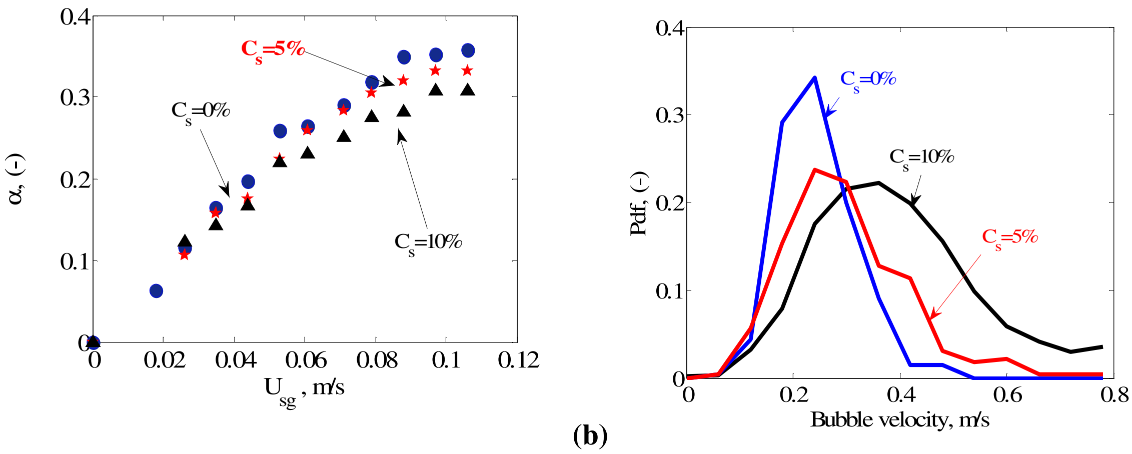


Figure 1. Local radial gas fraction for an air-water system in a 3D column.



(a) **(b)**

Figure 2. Effect of solids concentration on (a) gas fraction and (b) bubble velocity distribution (U_{sg}=4.4cm/s), in the centre of a 2D column.

For the bubble velocity measurement in the three-phase system a four-point optical probe was used. Figure 2(a) and 2(b) show the effect of solid concentration on the gas holdup and bubble velocity distribution in the 2D setup. Adding glass beads to the system results in a lower gas holdup and a wider range of bubble velocities in comparison to the air-water system. Presence of the solids enhances the bubble coalescence resulting in higher rise velocities. A change in the density of the slurry phase helps the bubbles to rise faster and indeed the gas holdup decreases. Moreover, increase in solid concentration, which promotes the internal liquid circulation, results in an earlier transition to the heterogeneous regime i.e., from $U_{sg,trans}$=0.06 m/s to 0.04 m/s. Visual observations, especially in the 3D case, indicates that by adding 10% of solids some large bubbles are formed, although there are still many small bubbles present in the column.

Conclusions

In this work, by using optical probes, it is shown that the use of a more structured system in a 2D and 3D column results in a shift of the transition point to higher superficial gas velocities. Furthermore, for superficial gas velocities higher than U_{sg}=0.06 m/s the gas fraction still increases continuously. With the aid of a four-point optical probe we could show that the bubble velocity distribution in a three-phase slurry system is strongly affected by the presence of the solids i.e. the distribution becomes wider and its maximum occurs at higher bubble velocities. Adding 10% solids to the system affects the density of the slurry phase and enhances the bubble rise velocity which is in agreement with the experimental results.

References

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