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Experimental Determination of Bubble Size in Solution of Surfactants of the Bubble Column

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Abstract

This paper focuses on the effect of surfactants on the bubble size. Bubble size in SDS/water system were investigated at various superficial gas velocities (0.13, 0.26 and 0.5 cm/s). On the other hands, Bubble diameter were determined for different values of SDS surfactant concentration. Surfactant concentration in water were 0.05, 0.02 and 0.1 vol.

Index terms— bubble column, surfactant, bubble size.

1 Introduction

ubble column reactors are widely used in chemical and biochemical processes such as oxidation, chlorination, polymerization, hydrogenation, synthetic fuels by gas conversion processes, fermentation and wastewater treatment. Bubble columns can be employed in many mass transfer processes [3].However, the lack of a more complete knowledge on the bubble column fluid dynamic behavior in its various regimes causes several operational difficulties and design uncertainties, which include poor predictions of the mean bubble diameter, gas hold up and interfacial area [2,14]. A bubble column reactor is basically a cylindrical vessel with a gas distributor at the bottom [12]. The interfacial area available for mass transfer is the most important design parameter defined by gas holdup and bubble size which in turn are affected by the operating conditions, the physic-chemical properties of the two phases, the gas sparger type and the column geometry [5]. Bubble column are preferred to be two-phase contactors for their ease of operation, maintenance and absence of moving parts, yet they have complex hydrodynamics characteristics [21]. Knut [13] studied dynamic simulation of 2D bubble column and shown that two dimensional dynamic simulation of the flat bubble column is feasible, applying state-of the art dynamic turbulence models. Surfactant designates a substance that exhibits some superficial or interfacial activity. Different methods have been employed for bubble dimension evaluation [9]. Gas bubbles in transparent fluids can be photographed and measured, usually using image-analysis [16]. This is the simplest technique but cannot be used with opaque media 2 such as those found in fermentation systems. Statistical models [6] are required to calculate bubble -size distributions from the measured chord lengths. Several authors studied bubble size and interfacial phenomena in different types of bubble column reactors. Colella et al. [7] studied the interfacial mechanisms focusing on the coalescence and breakage phenomena of bubbles in three different bubble columns. They investigated the influences of gas superficial velocity and different hydrodynamic configurations on bubble size distribution in the bubble columns. Lehr and Mewes [15] evaluated the bubble sizes in two-phase flows. They predicted the bubble size distribution in bubble columns including the formation of large bubbles at high superficial gas velocities. Schäfer et al. [20] discussed the influence of operating conditions and physical properties of gas and liquid phase on initial and stable bubble sizes in a bubble column reactor under industrial conditions. Akita and Yoshida [1] determined the bubble size distribution using a photographic technique. The gas was sparged through perforated plates and single-orifice using various liquids (water, aqueous and pure glycol, methanol, and carbon tetrachloride). It has been reported in the literature [11] that with increase in surfactant concentration, coalescence time increases. Sardeing et al. [19] reported that in superficial gas velocities between 1.5×10^{-4} - 2×10^{-4} m/s, bubble diameter was in surfactant solutions between 1mm-8mm. In these studies we have also analysed the influence of SDS surfactant concentration and the gas flow-rate upon the bubble diameter in bubble column. On the other hand, the bubble size distribution has been studied in ionic, nonionic and zwitterionic surfactants on the bubble column.

ii.

2 Experimental Setup and Technique

The schematic diagram of the modified bubble column is shown in]. The gas from the compressed air line passed through calibrated rotameter. The photographic method, used in this study to determine the bubble size of the two-phase mixture, has been developed using a rectangular bubble column (20cm× 5cm× 120cm). The liquid column heights during the operation were 45cm. To determine profiles of ellipsoid, bubble was monitored over distance ca. 1m and was using professional video recorder. The photographs were taken by a digital camera (Casio Exilim (EX-F1)) taken along the height of the column, from bottom to top. The digital photographs were processed and enhanced by using Image Processing MATLAB Software that enabled to distinguish clearly the bubble boundaries. The diameters of the bubbles were determined from photographs of the operating column, 5, 20, 30 and 40 cm above the gas distributor. The images were taken at three axial positions for different operating conditions. The 2d picture shapes of the bubbles were approximated by ellipsoid [17,18] whose maximum and minimum axes were automatically computed by the software program used for image analysis. The third dimension was calculated with the assumption that the bubbles are symmetric around the minimum axes. From the known values of maximum and minimum axes, an equivalent ellipsoid bubble diameter was calculated by the following equation [8]:

(1)

Where d b, max and d b, min are the maximum and minimum bubble diameter of bubble. The distributions were obtained by sorting the equivalent diameters of bubbles into different uniform classes. At a particular operating condition, the bubble picture taken from different locations of the column are shown in Fig. 2. The Sauter mean bubble diameter (d vs) is defined as the volume-to-surface mean bubble diameter [4]:(2)

Where n i is the number of bubbles of diameter d Bi .

Between 1000 and 3000 bubbles were counted for determination of the size distribution, using 30 photographs.

3 Bubble Size Distribution

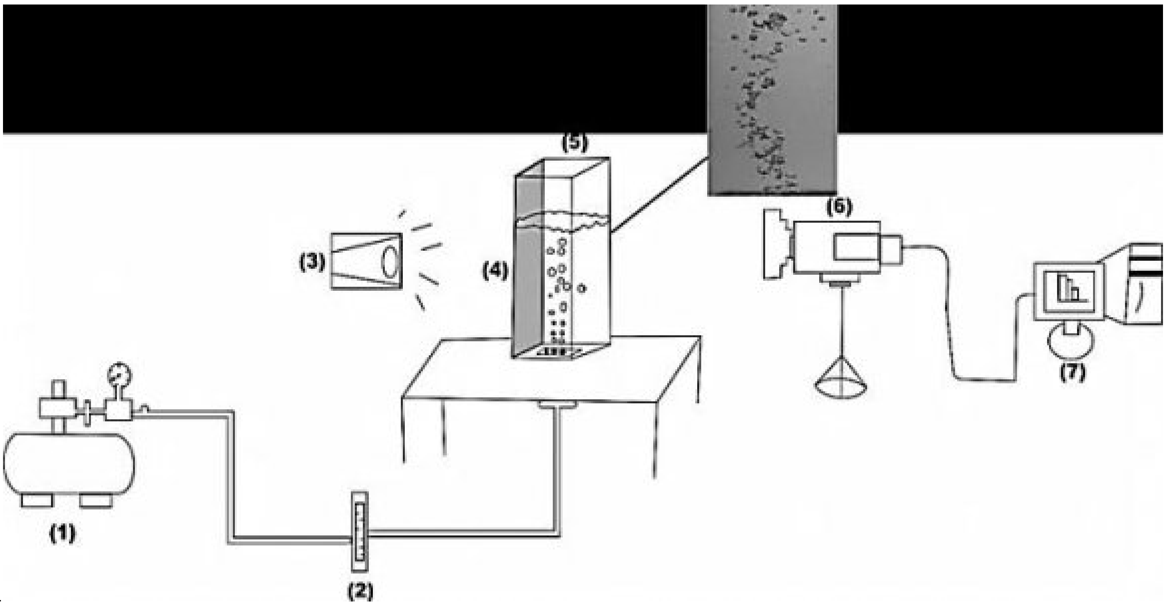
Bubble coalescence and breakup play a significant role in determining bubble size distribution. Coalescence was found to take place when more than about a half of the projected area of the following bubble was overlapped with that of the leading bubble at the critical distance. In contrast, the breakup occurred in the case the overlapping was less than about a half of the projected area of the following bubble. Thus, when the leading bubble is larger than the following one, the latter has a tendency to coalesce. In contrast, in the case of the smaller size of the leading bubble, the following bubble tends to breakup. Coalescence is significantly influenced by the physical properties of the liquid. Analysis of bubble size in bubble columns must distinguish between bubble-size distribution just after bubble formation at the sparger and size distribution further away from the distributor [17]. Two basic methods -photography and probe techniques -exist for determining bubble size, however; they do not lead to identical results. Both methods are subject to certain limitations in view of the marked bubble selection that may occur (i.e., not all bubble sizes can be detected). In particular, any measurement method only leads to realistic results if the flow is homogeneous (i.e., a narrow bubble-size distribution is found). As yet, no method can be recommended for the measurement of large bubbles in the heterogeneous flow regime. Results and Discussion a) Effect of superficial gas velocity upon bubble size in SDS +water system First, there is general observation that applies to all solutions. For example, regardless of type and presence of chemical added, the average bubble radius decreases as gas flow rate. Fig. **??** show bubble size distribution for SDS-water system in regions A and D. As the gas flow rate increases the gas holdup and kinetic energy increases which increase turbulent intensity, bubble-bubble interactions, velocity of bubbles and the probability of coalescence which is because of as increasing collision frequency between bubbles with increase in gas flow rate. The probability of coalescence is higher in region D but the bubble size decreases with increasing superficial gas velocity in A and D location. This is due to bubble break-up with increasing gas flow rate. Also as the superficial gas velocity increases, the Sauter mean bubble diameter decreases (Fig. **??**). For u g greater than 0.13 cm/s smallest bubbles are obtained in solution of lowest static surface tension. The rate of coalescence decreases with the gas flow rate increasing. One of the parameters that effect bubble size, is surfactant concentration. Effect of various SDS concentrations (0.02, 0.05 and 0.1%vol) at u g =0.13cm/s on bubbles diameter is shown in Figure **??**. SDS addition to pour water decreased the bubbles diameter. Further, surfactant concentration enhancement decreased the of bubbles diameters by decreasing the surface tension and buoyancy force. Sardeing et al. [19] used various surfactants and investigated that bubbles diameter decreased about 30% (as an average value). The bubble size distribution in an emulsification processes is a result of the competition between opposite processes, bubble breakage and bubble-bubble coalescence. It was shown experimentally that the bubble size rapidly decreases with an increase of SDS concentration [10]. Sample photographs of the bubble populations shown in Fig. **??**. They clearly showed that as the SDS concentration increases, the bubble populations will become smaller in size. Sauter mean bubble diameter (d vs) decreases due to SDS concentration increasing (Fig. 7). Presence of surfactants has a great effect on the bubble diameters. The bubble size distribution was obtained in four axial locations A (of height 0.05 m), B (of height 0.2 m), C (of height 0.3m) and D (of height 0.4m) from the bottom of the column (Fig. 2). Typical results for these four locations are presented in Fig. **??**. It is seen that the bubble size in location D are greater than location A , B and C (Fig. 2). The average bubble size in location C and B are almost the same. All calculations regarding goodness of fit have been performed by MATLAB software. Bubble diameter increased with increasing the distance from the bottom of the column due to the coalescence of smaller bubbles. The coalescence bubbles of location A go up due to their buoyancy and accumulate in location B, C and D. Also the bubble number flux varies in different locations due to the same reason. That bubble number flux decreases in location C and D over location A and B is result of an increase in bubble size due to coalescence. As shown in Fig. **??**, there is no significant variation of bubble size in location B and C. The bubble size in location A is much smaller than other locations due to a break-up.

4 Conclusion

Effect of surfactant on the bubble size in rectangular bubble column has been studied. In order to obtain bubble size distribution about 1000-3000 bubbles were analyzed. The evaluation of bubble size distribution in different location of the column and the influence gas flow rate and SDS concentration were pointed out. The measurements were done using photographic techniques. The bubble size in bubble column increased with increasing distance from the bottom of the column due to coalescence. The bubble diameter in SDS+ water system were bigger than other system. When gas flow rate increase (SDS +water system), an increase in the number of small bubbles was also observed, and Sauter mean bubble diameter also decreased due to breakage bubbles. The Sauter mean bubble diameter decreases, when SDS concentration increasing. [1]

1

Figure 1: Fig. 1 .



1

Figure 2: Fig. 1 :

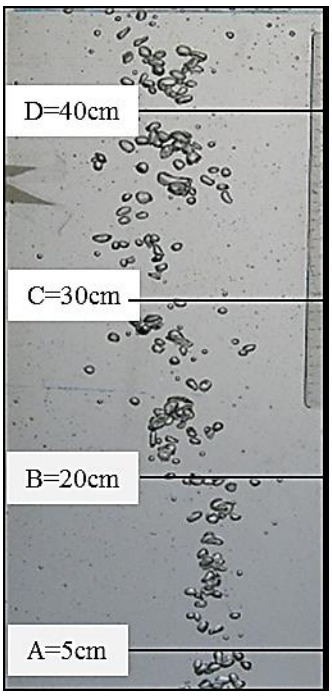


Figure 3: ©

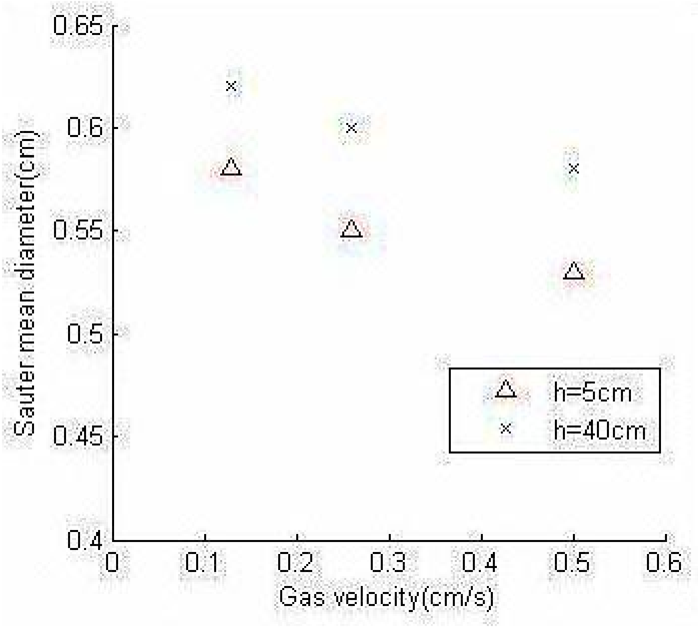


Figure 4:

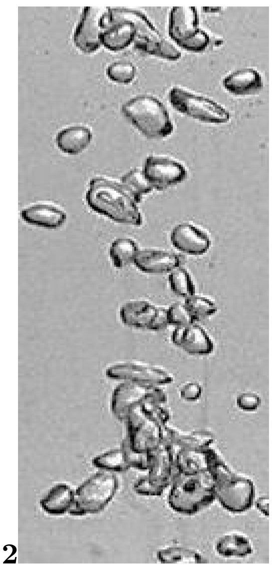
2 

Figure 5: Fig 2 :

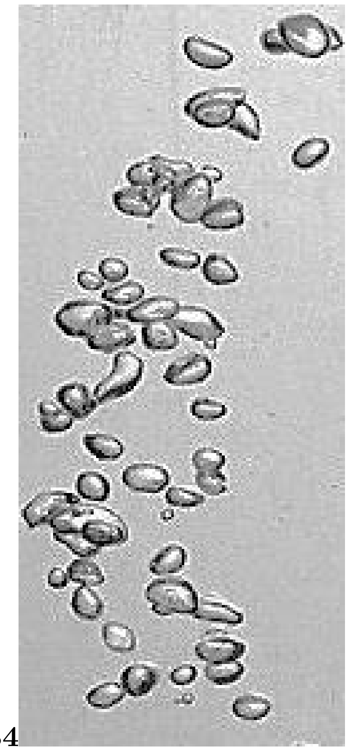
34

Figure 6: Fig 3 :Fig 4 :

5668

Figure 7: Fig 5 : 6 Fig 6 : 8 Fraction

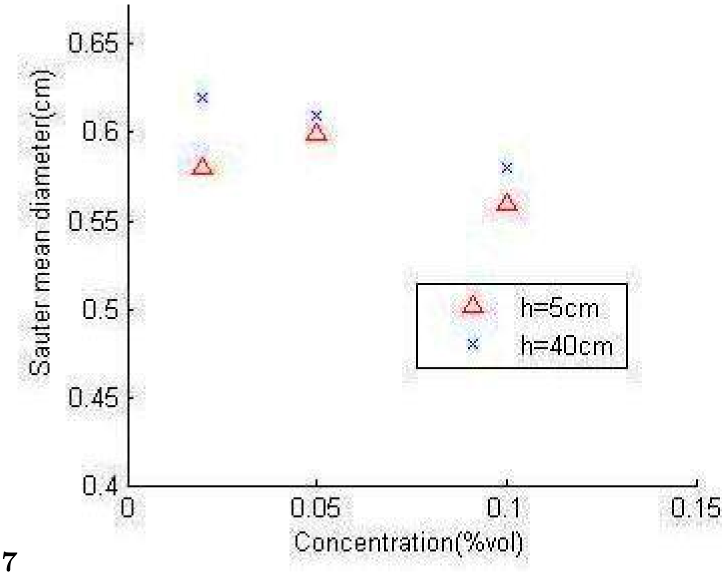


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Figure 8: Fig 7 :

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Figure 9: Fig 8 :Fig 8 .

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Figure 10: Fig 9 :

Figure 11:

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