Effect of solids on gas-liquid mass transfer in three phase systems

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Bubble columns are commonly used in industry as gas-liquid and gas-liquid-solid contactors. Chemical or biochemical reactive operations, as well as the separation of mixtures by rectification, absorption, and waste-water purification, can serve as examples of their application [1]. Recently, bubble columns have also gained increasing importance in the field of biotechnology [2]. In multiphase systems, appearing in mechanically agitated reactors and bubble columns, frequently gas-liquid mass transfer is the rate determining step for the overall process. Therefore, the knowledge of gas-liquid mass transfer rates characterized by volumetric gas liquid mass transfer coefficients (k_La) is needed for reliable design of such reactors [3]. Also a complete understanding of the effect of the operating parameters on each of the components of k_La - the liquid side mass transfer coefficient (k_L) and the interfacial area (a) - is needed. In three phase systems, the presence of solids is an important parameter that may benefit or may have an undesirable influence on the mass transfer process. Thus, the effect of solid characteristics such as size, loading and surface properties on gas-liquid mass transfer has been a challenging task for researchers. Several methods exist for measuring the interfacial area in gas-liquid systems, such as photographic, light attenuation, ultrasonic attenuation, double-optical probes and chemical absorption methods. But these methods are effective only under certain conditions [4]. In our work, photographic and subsequent image analysis techniques were used to determine the bubble characteristics such as superficial area, size and shape. Volumetric mass transfer coefficients were also obtained for different gas flow rates, solid loading and size. The system under study was the absorption of oxygen from the air into water, in a cylindrical column 84 mm in diameter and 600 mm high.

In the experiments with calcium alginate beads (d_p=1.2 mm) as solid phase, it was observed that k_La increases with gas flow rate and decreases when the solid loading increases (see Fig. 1). Similar behaviour was observed in experiments with calcium alginate beads (d_p=2.1 mm), ionic resin and PVC as solid phases.

From visualization experiments and after image treatment process, several bubble characteristics (superficial area, size, shape, etc) can be deducted. Bubble interfacial areas were obtained and then liquid side mass transfer coefficients were determined (Fig. 2).

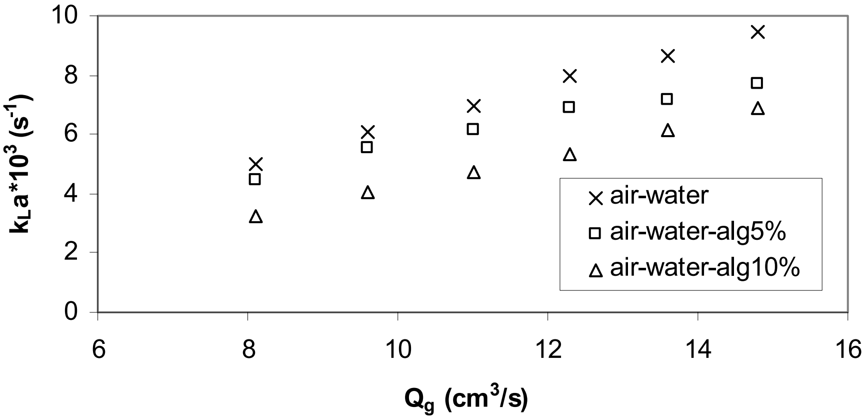


Fig. 1 - Dependence of k_La on gas flow rate for different calcium alginate concentrations (d_p=1.2 mm)

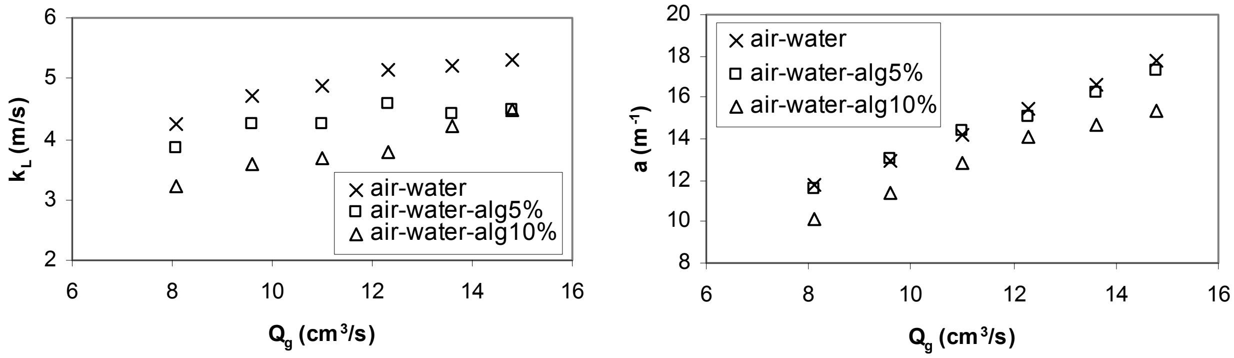


Fig.2 – Liquid side mass transfer coefficient and gas-liquid interfacial area

For the lowest solid concentration (5%v/v) there is a small decrease of k_La, which is due to a decrease on k_L, as interfacial area is not affected. For the highest solid phase concentration, the decrease on k_La is attributed not only to lower k_L but also to a decreasing of the gas-liquid interfacial area (see Figs 1,2). The enhancement of solids hold up causes an increase on bubble coalescence due to the diminishing of the flux area for the gas and liquid phases, which is reflected in a smaller gas-liquid interfacial area.

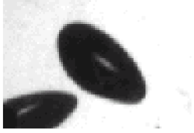
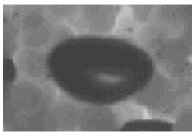
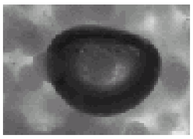
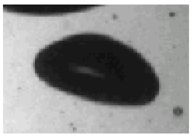
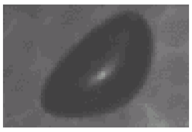
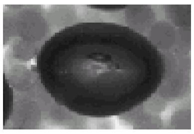
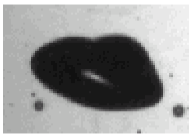
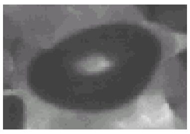
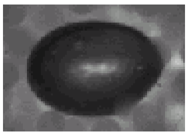
	%v/v Calcium alginate		
Gas flow rate (cm^3/s)	0	5	10
8.1			
12.3			
14.8			

Fig. 3 – Bubble examples for different gas flow rates and solid loadings

It was also found that the presence of calcium alginate beads (d_p=1.2 mm) influences the bubble shape and increasing solid loading bubbles tend to become rounder. As a consequence of an increase of solid loading, bubbles change progressively their shape from elongated spheroids to flattened spheroids (see Fig.3).

References

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