Flow regime, gas holdup and volumetric mass transfer coefficient in slurry bubble column with different liquids and solids: An experimental study

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Highlights

- Experimental investigation of flow regime, α_g and $k_l a$ is done in slurry bubble column.
- Effect of solid size, concentration and liquid properties on α_g and $k_l a$ is reported.
- Empirical correlations for α_g and $k_l a$ with varying physical properties are proposed.

1. Introduction

Slurry bubble column reactors find extensive application across biochemical, chemical, petrochemical, and metallurgical sectors [1]. These reactors exhibit advantages such as streamlined geometric design, refined temperature regulation, effective heat dissipation, elevated mass transfer rates, minimized operational and maintenance expenditures, and prolonged catalyst durability [2]. Hydrodynamics and mass transfer phenomena holds significant importance in the design and development of a slurry bubble column. The hydrodynamics and mass transfer characteristics are influenced by the flow regime, liquid and solid physical properties, liquid to solid proportion and solid concentrations [3-4]. Therefore, an experimental investigation of flow regime transition, gas holdup, volumetric mass transfer coefficient with respect to different proportion of solid concentration (5% - 20%) in distinct liquids such as ethanol, glycerol is reported in this study. An empirical correlation with different liquid properties is proposed using regression approach over a wide range of operating conditions of experiments.

2. Methodology

The gas holdup and volumetric mass transfer coefficient are calculated by assuming liquid and solid phases as slurry phase or pseudo-homogeneous phase in a slurry bubble column. Slurry phase physical properties such as density and viscosity are varied under different operating conditions. A slurry bubble column of diameter of 0.1 m and height of 1.2 m is used in this experimental study and presented in Figure 1. Compressed air is used as the gas phase with the superficial velocities range 0.01 – 0.6 m/s to explore the flow regimes. Water, ethanol, and glycerol are used as the liquid phase whereas hydrophilic glass beads of different size range 75 – 212 µm are considered as the solid phase. The gas to liquid mass transfer coefficient is measured by the oxygen desorption method. An optical probe is employed to gauge the oxygen concentration in slurry at a height of 0.25 m above the gas distributor. The α_g is measured by the liquid bed expansion expressed in Eq. (1) and $k_l a$ is investigated by Eq. (2).

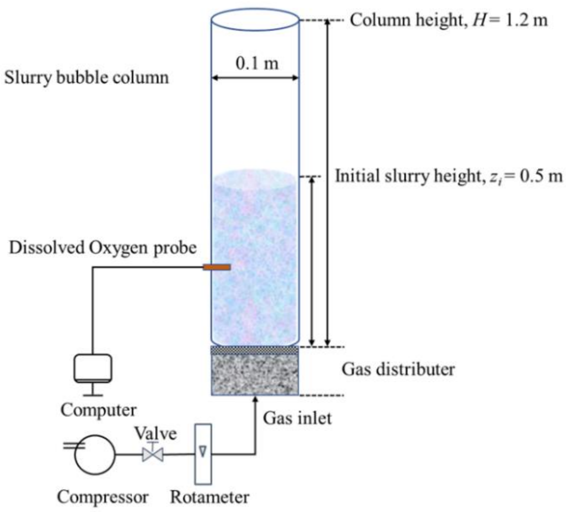

Figure 1. Schematic presentation of experimental set-up

$$\alpha_g = \frac{z_f - z_i}{z_i} \tag{1}$$

$$ln\left[\frac{C*_{O_2} - C_{O_2}(t)}{C*_{O_2} - C_{O_2}(t=0)}\right] = k_l a t \tag{2}$$

3. Results and discussion

The investigation of gas to liquid $k_l a$ is performed for two different conditions. Figure 2 represents the variation of $k_l a$ with respect to three different solid concentration in slurry liquid. $k_l a$ is found as increasing with increase in gas superficial velocity for each solid concentration. Although, as the solid concentrations are increased, $k_l a$ is decreased due to decrease in gas holdup. Further, slurry physical properties are varied by adding 5% (v/v) ethanol, glycerol and 20% solid concentration to know the effect of liquid properties on gas holdup and $k_l a$. Figure 3 represents the variation of $k_l a$ for ethanol and glycerol. The $k_l a$ is observed as decreasing for glycerol compared with ethanol due to density and viscosity of prepared slurry solution.

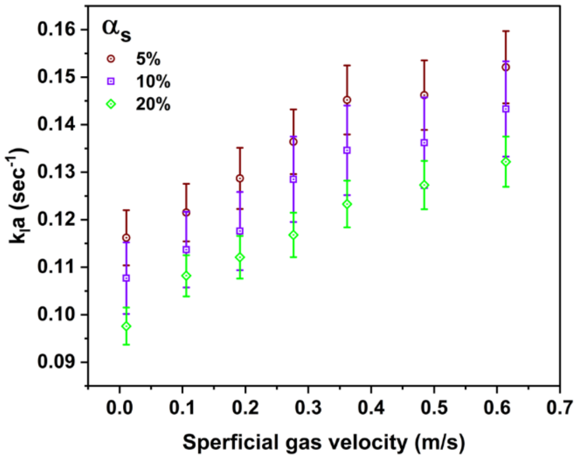

Figure 2. Comparison of $k_l a$ for different α_s

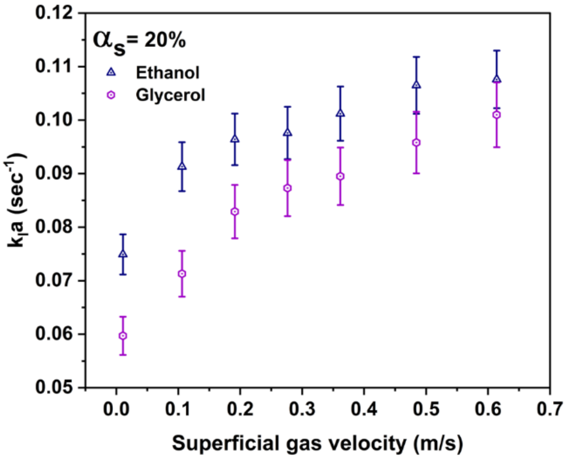

Figure 3. Comparison of $k_l a$ for different liquids

4. Conclusions

Experimental investigations become imperative for the purpose of technology design and scale-up. These experiments delve into key factors such as flow regime, α_g and $k_l a$ in slurry bubble column with different slurry physical properties. The outcomes of these experiments contribute vital insights of slurry phase bubble column design for respective commercial application.

References

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Keywords

Slurry bubble column; flow regime; gas holdup; volumetric mass transfer coefficient