CHAPTER-1

INTRODUCTION

CHAPTER-1

INTRODUCTION

Bubble column is frequently used as a gas-liquid contactor and find applications as chemical reactors [Shah et al. (1982), Rollbusch et al. (2015)] and bioreactors [Kantarci et al. (2005)]. Shah et al.(1982) has reviewed several applications of bubble columns as chemical reactions. Some of these are chlorination, hydrogenation, absorption, catalytic slurry reactions, coal liquefaction etc. Bubble columns also find application in biochemical applications and wastewater treatment. In a bubble column, gas is dispersed in form of bubbles into liquid by sparging it though a distributor. Due to bubble-induced liquid motion, mixing of liquid and gas phases is achieved without having any moving parts.

1.1 Introduction to the Problem

The mixing in a bubble column is induced by motion of bubbles, therefore, the performance of bubble columns are closely related to bubble behviour. Size, shape, bubble formation at the sparger, bubble coalescence and bubble breakup etc. are some of the aspects which depend upon each other. The bubble surface is influenced by fluid mixing and hence the bubbles do not have a rigid surface. They keep on being deformed continuously. At low gas velocity, bubble coalescence and bubble-breakup may be absent. Thus, bubble-induced turbulence is a complex phenomenon. Hydrodynamic parameters used to specify the bubble behaviour are primarily gas holdup, bubble size and shape, bubble velocity, bubble coalescence and bubble breakup phenomena [Jasima et al.(2019)]. Flow regimes maps are used to understand performance of bubble columns under various operating conditions, since inter-relationship between different properties of bubbles depend upon the kind of the flow. The average bubble diameter may be estimated from bubble size distribution (BSD) in the column. Knowledge of bubble size is important as it may be used to estimate interfacial area and mass transfer rate as discussed elsewhere [Verma (2014), Zhang et al. (2016)].

Study of the specific interfacial area, a_i, is important as it is used to estimate volumetric mass-transfer coefficient. BSD in cases other than uniformly distributed bubble columns can be used not only to measure Sauter-mean bubble diameter, d_{32}, and estimate a_i, but may also be useful in characterizing flow regimes through statistical analysis. Sharaf et al. (2016) have shown that group of small and large bubbles can be identified from the BSD data. Experimental studies on BSD, d_{32}, gas holdup, ε_g, and a_i were recently carried by using appropriate techniques, to study the effect of temperature and pressure on these parameters [Feng et al. (2019)]. These parameters are significantly affected by the aspect ratio of the column (height-to-diameter ratio) and sparger geometry [Besagni et al. (2018)]. One of the solutions to include the effect of these parameters on performance of bubble columns may be to use ratio of column diameter-to-sparger diameter as a dimensionless group in correlation [Anastasiou et al. (2013)].

Photographic technique is a direct method of measurement of bubble size. Due to image processing tools available today, it has become a rapid and accurate technique to measure BSD, bubble shape, gas holdup, Sauter-mean bubble diameter, interfacial area. It can also be used to study flow transition, bubble coalescence and bubble breakup phenomena.

Volumetric mass transfer coefficient is product of mass-transfer coefficient and specific interfacial area. Latter is easily and accurately measured by photographic method. A suitable model for mass transfer is required to measure volumetric mass transfer coefficient.

Studies on use of image processing technique to measure bubble-properties are limited. Suitable image processing technique to detect overlapping of bubbles, detection of individual bubble in a group of bubble flock, identification of various bubble shapes, estimation of bubble velocity, effect of fluid properties and distributor on bubble properties are some of the areas requiring more studies. Understanding the effect of bubble properties on gas-liquid mass-transfer coefficient is also a challenging task.

1.2 Aims and Objectives

The present work is aimed at measurement of measuring bubble properties using photographic method and suitable image processing techniques. Variation of *ai* with operating is not available. It may help in understanding mass-transfer rates in bubble columns. From BSD, values of d_{32} and a_i may be estimated. The effect of fluid properties on BSD, d_{32} and a_i will be studied using CMC solution in addition to water. The objective of the present study is as following:

1. Using photographic method, BSD will be determined.
2. From images extracted from a video, expanded bed height will be measured.
3. The periodic behavior of fluctuating top surface of the air-liquid dispersion will be measured
4. To estimate gas holdup from BSD.
5. To estimate d_{32} and a_i from BSD.

6. To study effect of superficial gas velocity, U_g, and static bed height, H_s on d_{32} and a_i. The latter is using photographic techniques is not reported earlier.
7. To study the effect of viscosity by making measurement in CMC solution.
8. To develop a model for volumetric mass-transfer rate, ($k_L.a_i$), and express it terms mass-transfer coefficient, k_L, and a_i.
9. To develop a methodology to use the correlations for non-Newtonian fluids.

1.3 Organisation of the Thesis

The organisation of this thesis is as following:

The Literature relevant to the present problem is presented in Chapter-2. It covers topics related to hydrodynamics of the bubble column, bubble size and shape, gas holdup, specific interfacial area, mass transfer coefficient and model for mass transfer rate.

Details of experimental setup, properties of the systems used, experimental procedure to perform the experiment and image processing technique to analyse video recording is in Chapter-3.

The variation of BSD, d_{32} , gas holdup and a_i with superficial gas velocity and static bed height is presented in Chapter-4 under the heading of 'Results and Discussion'. A model for mass-transfer rate and a methodology to determine apparent viscosity of non-Newtonian fluid are also presented.

Conclusions based on present findings and suggestions for future are presented in Chapter-5.

All the data on BSD, estimated values of the parameters are given in appendices. It also includes essential 'MATLAB' code.