SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Effect of Swirl Gas Injection on Bubble Characteristics in a Bubble Column

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ARTICLE INFO

Article history:
Received 7 August 2022
Received in revised form 23 December 2022
Accepted 2 January 2023
Available online 23 January 2023

Keywords:
Swirl gas injection; bubble characteristics; bubble detection technique

ABSTRACT

Swirling gas injection is a well-known technique to improve mass transfer in bubble columns. It can be used to create small bubbles with a high surface area-to-volume ratio, which is beneficial for mass transfer. Swirl gas injection can also be used to create a more uniform bubble size distribution and improve the mixing of gas and liquid in the column. This study aims to determine the impact of swirl gas injection on bubble properties, including bubble shape, size, and velocity. A bubble detection approach has been developed for quick and precise determination of bubble size distributions in gas-liquid systems. Advanced digital image processing, including edge detection and bubble edge recognition, is used in this method. The experiment is conducted in a bubble column at a height of 57 cm and 61 cm. The column had a ring sparger and was made of Plexiglas. Tap water was used as the liquid, while air from an air compressor was utilized as the gas phase. The shape, size, population, and velocity of the bubble are measured using a high-speed digital camera. According to this study, the average bubble size reduced as the impeller speed increased, while the population of bubbles increased when the sparger rotation speed increased from 30 to 150 rpm.

1. Introduction

In a few decades, the motion of bubbles rising in liquids has been paying attention of researchers because of the bubble’s fascinating variety of motion patterns and instabilities [1]. Bubbly flows consist of gas bubbles (dispersed phase) within a carrier liquid (continuous phase) [2,3]. In two-phase bubbly flows, bubbles have the shape of spheres, ellipsoids, or spherical caps, which they rise in rectilinear, spiraling, zigzagging, or rocking motion depending on the characteristics of the system such as bubble diameter and the properties of the liquid [4,5]. At the point where gas is injected into a stagnant liquid, bubbles are formed and rapidly move upward due to buoyancy force [6]. As the bubble size increases, the bubble shape changes from spherical to ellipsoidal and after that to a spherical cap. There is three component cause bubble to break up, for example, instabilities of larger bubbles, detaching the edges of larger bubble, and collisions between bubbles [7].

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https://doi.org/10.37934/arfmts.102.2.155165

The bubble will either reduce or increase in size due to coalescence or break up as it rises through the column [8]. A few factors can affect the shape of the bubbles, such as fluid density, fluid viscosity, surface tension, terminal gas velocity, gravitational acceleration, etc. This change in bubble size occurs when the bubble is subjected to these external factors until the forces balance at the gas-fluid interface.

Gas diffuser or sparger is another important device for developing multiphase flow as dramatically dominates bubble size distribution and bubble rising velocity in the reactor [9]. The swirling flow of gas and liquid is a well-known technique to improve mass transfer in bubble columns [10]. Swirling flow can be generated by a variety of methods, such as injecting the gas through a cyclone, spinning the column, or using a specialized nozzle [11]. Swirl gas injection is an effective way to improve the hydrodynamics of a bubble column by introducing vorticity into the system. This can have a significant effect on bubble characteristics, such as bubble size, shape, and residence time. The introduction of a swirl, can help to reduce the bubble coalescence rate, decrease the gas holdup, and increase the overall mass transfer efficiency. The swirling motion of the gas injection is also beneficial, as it creates a more uniform distribution of the reactants and products throughout the reactor, promoting better reaction efficiency. Finally, the dispersed nature of the bubbles in the reactor allows for further homogenization of the reaction mixture, leading to improved reaction selectivity.

In the experiments described herein, a high-speed camera was used to obtain the temporal evolution of the flow fields in bubbly flows. The dispersion of gas into a liquid relies upon the bubble size, and the distribution of the bubble possibly coalesces or breakup [12]. Bubble size can be increased through coalescence, in which two or more bubbles come together. There are three mechanisms of bubble coalescence such as bubble coalesce because of turbulence; different bubbles' sizes toward each other, and one of the bubbles being drawn into the wake of a preceding one [7,13]. Buwa and Ranade [14] presented experimental data similar to that of Mudde (1997) *et al.,* [15] on the dynamics of gas-liquid flows using different sprayer configurations and different liquids. Their results suggested that the bubble size distribution is the key parameter that controls the dynamic characteristics of the bubble column. Hibiki *et al.,* [16] and Sun *et al.,* [17] developed a double sensor probe based on the concept of interfacial area concentration, gas velocity and bubble Sauter mean diameter in a 3-D bubble column.

The aim of this research is the characterization of the bubble in bubbly flow under the presence of swirl sparging, i.e., presence of various rpm of sparger rotation in the range 30 to 150 rpm. Achieving these objectives required the development of measurement techniques for bubble surface oscillations; characterization of bubble interactions, and evaluation of the effect of gas sparging rate and rotating speed. This required development of appropriate image processing techniques.

2. Methodology

This study was conducted in a 0.57 m diameter bubble column that was filled with water to a depth of 0.50 m. The experimental setup is illustrated in Figure 1 and it consists of a ring sparger, which was used to inject air into the column. The ring sparger has 190 holes with a diameter of 1mm, and a thickness of 0.5mm. The column was operated at room temperature and the airflow rate was varied from 0.063 g/s to 0.316 g/s.

Descriptions, development, and validation of methods are presented for techniques created or adapted to characterize the bubble motion. The technique involves measuring the size and diameter of bubbles, providing accurate data for analysis. This method is useful for a range of applications such