International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.5., 2015
(Sept.-Oct.)

RESEARCH ARTICLE

ISSN: 2321-7758

HYDRODYNAMIC STUDIES IN THREE PHASE STIRRED BUBBLE COLUMN REACTORS WITH MULTIPLE IMPELLERS

K.CHANDRAMOHAN[1], A.S.PERIASAMY MANIKANDAN[2]
Kongu Engineering College, Perundurai, Erode, TN, India

ABSTRACT

Bubble column is widely used in chemical and petroleum industries. It plays a vital role where gas liquid contact is significant. It is particularly suitable where higher interfacial area between phases is desirable. It has high heat and mass transfer coefficient and higher residence time. It has no moving parts and operates at low cost, has low power consumption and needs little maintenance. Stirred bubble column reactors promote significant liquid hold up and long liquid residence time. In three phase bubble columns the gas phase provides energy for generating intense turbulent flow in the liquid phase. The liquid motion imports energy to the solid phase by which they can remain in suspended condition. The solid phase act as a catalyst, undergoes a chemical reaction, or may remain inert. For the effective utilization of bubble columns, the solid phase needs to remain in suspended condition. For this purpose a minimum value of superficial gas velocity is needed.

Modified bubble column reactors such as loop multistage and down flow bubble columns are used in chemical industries for carrying out gas –liquid (two phase) and gas- liquid-solid (three phase) processes.

This study focuses on gas hold up in three phase bubble column reactors fitted with multiple impellers. The gas hold up was found by visual observation method. The effect of stirrer speed and air flow rate on gas hold up for three phase reactor was studied for different particle size and concentrations. Impact of electrolyte addition was also studied. The experimental data indicated that gas hold up was found to increase with increase in stirrer speed and flow rate. Solid loading decreased the gas hold up considerably. Addition of electrolyte enhance the gas hold up.

Keywords: Stirred bubble column reactor, Electrolyte, multiple/dual impeller, Gas hold up

INTRODUCTION

A bubble column reactor consists of a vertical cylinder filled with liquid and a gas distribution arrangement at the bottom. The contents of the cylinder can be thoroughly mixed with the help of the impeller(s) driven by an electrical motor. The ratio between length and diameter of the reactor varies in the range from 3 to 10.The liquid phase is normally water and the reactor may be operated in batch or continuous mode (either concurrently or counter currently). The gas phase, normally air, is distributed with the help of a sparger located at the bottom of the column. Solid particles in the form of beads or spheres suspended in the liquid phase constitute the third phase.

The rising gas bubbles entrain an amount of liquid with them. The large bubbles along with the entrained liquid tend to rise up through the center of the column. The fluid returns down the column close to the wall transporting smaller bubbles with them forming a characteristic circulating fluid flow pattern. Large bubble swarms also rise in a helical fashion towards the top of the column. This circulation pattern was found to be transient and vanishes over a period of time. Mean liquid axial velocity profiles are relatively stable. A transient radial cross exchange of fluid elements is super imposed on the axial circulation pattern yielding a high degree of radial mixing.

Bubble column reactors are used in diverse application such as absorption, catalytic and bio reactions and coal liquefaction [2]. These reactors offer many advantages over other kinds of multiphase reactors: simple construction, no mechanically moving parts, good heat and mass transfer properties, high thermal stability, good mixing, low power requirements and hence low construction and operating cost [3].

When a column filled with a liquid is sparged with gas, the bed of liquid begins to expand "homogeneously" and the bed height increases almost linearly with the superficial gas velocity. This regime of operation in a bubble column is called the homogeneous bubbly flow regime. As the gas velocity is increased, the gas hold up, εg increases and at a certain gas velocity, $U_{transition}$, coalescence of the bubbles takes place to produce first fast-rising "large" bubble. The appearance of first large bubble changes the hydrodynamic picture dramatically [5]. The regime of operating for superficial gas velocity exceeding $U_{transition}$ is commonly referred to as heterogeneous or churn turbulent regime [7-9]. This regime is of importance in industrial reactor operation [10].

Gas hold up is one of the most important parameters characterizing the hydrodynamics of bubble columns [11]. It can be defined as the percentage by volume of the gas in the two or three phase mixture in the column. Gas hold up depends mainly on the superficial gas velocity and stirrer speed [1].

Materials and Methods

Experimental Setup:

The bubble column is of 2 m height, 5 mm thickness and 0.14 m ID made of acrylic material. The bottom of the column is fitted with a sparger. The sparger is very vital as it is responsible to distribute the air. It is placed in between the bottom end of the column and a sparger vessel. The sparger vessel is of 3 mm thickness and made up of mild steel. The vessel has provision for manometer tapping, air inlet and drainage. A compressor supplies the air needed for sparging the column. A rotameter of 50-500 lpm range is used to measure the flow rate of air. Manometer is used to measure the pressure drop across the collector. An agitator with Rushton type impeller along with Pitched-blade impeller is used for agitating the contents of the column. The compressed air from the compressor is metered through a rotameter. The pressure drop across the column is measured using U-tube manometer. The rotational speed of the impeller is controlled by an auto transformer connected to a D.C. motor. The fractional gas hold up is measured by visual observation. The accuracy of the results was ensured by repeating the experiments 3-4 times.

Methodology Used:

In this study visual observation method is used for finding the gas hold up. Gas hold up is found by equation given below.

$\varepsilon_G = (H_G - H)/ H_G$ ----------------------------- (1)

Where, ε_G - Gas hold up

H_G – Final Height of liquid in mm

H- Initial Height of Liquid in mm

Experimental Procedure:

The initial height of water, which is retained inside the column stagnantly, is measured. Air is bubbled from the bottom of the column. The final height is noted down. The gas hold up was calculated from the equation 1.

RESULTS AND DISCUSSION

Effect of Superficial velocity on Gas hold up

Effect of Newtonian fluid velocity in gas hold up was studied at a stirrer speed of 10-100 rpm with different concentration of solids. The Superficial velocity was increased from 0.15 to 0.9 m/s. It was found that the gas hold up increased with the increase in superficial velocity for a particular solid concentration. The gas hold up was found to be higher for a dual impeller system compared to that without impeller. As the solid concentration increased the gas hold up decreased. However, for a particular concentration the gas hold up increased with increase in flow rate. This observation was good for system with and without impeller.

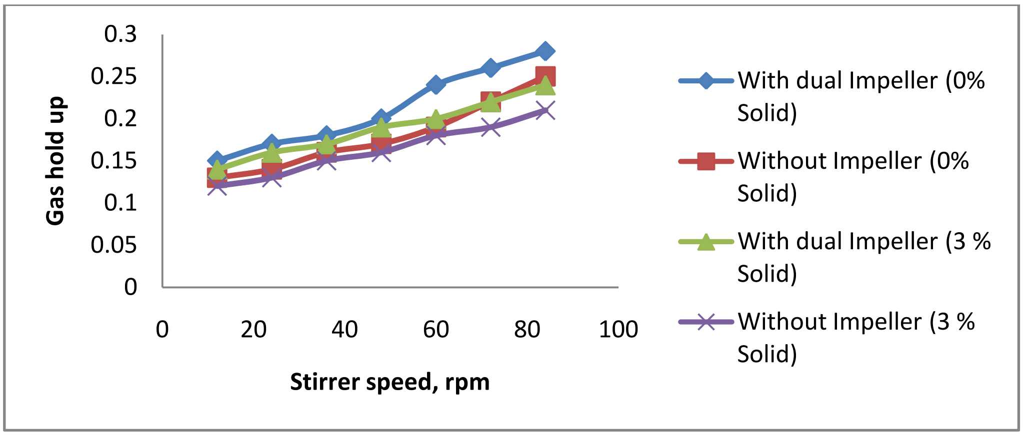

Figure 1: Effect of superficial gas velocity on Gas hold up with and without impeller

Effect of Stirrer speed on Gas hold up

Stirrer speed plays an important role on the gas hold up. The stirrer speed was varied from 10 to 100 rpm. If the stirrer speed is increased, large amount of small bubbles will be created, hence the gas hold up increases. It was found that the gas hold up increase with stirrer speed up to a stirrer speed of 80 rpm. The gas hold up with dual impeller was found to be higher compared to that without impeller.

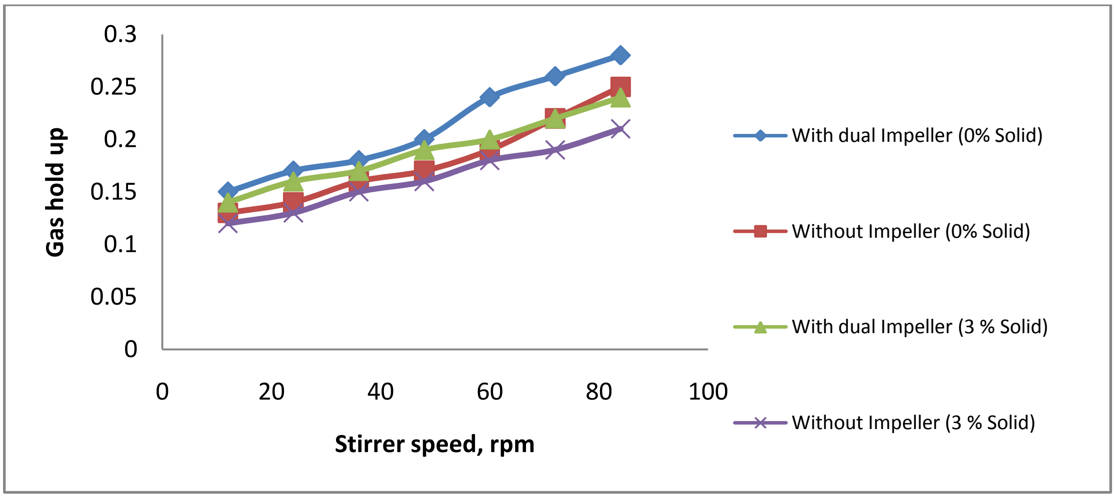

Figure 2 Effect of stirrer speed on Gas hold up with and without impeller

Effect of electrolyte addition on Gas hold up

The effect of electrolyte addition on gas hold up was observed.

The bubble coalescence results in the formation of more bubbles causing more dispersed phase of bubble. This is due to addition of electrolyte. The addition of electrolyte increases gas hold up initially, but further electrolyte addition in excess electrolyte concentration does not affect the gas hold up considerably because in drag force exerted over the bubbles by, the incremental amount of ionic component in the solution. This causes the bubbles to coalescence very slowly. So the gas hold up does not vary after the increased concentration. Here, Sodium carbonate is used as electrolyte.

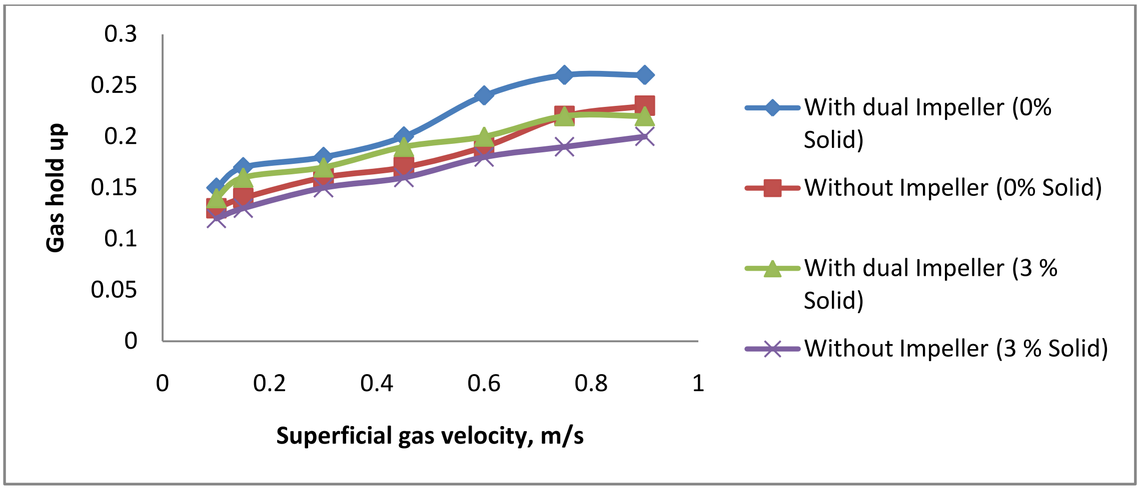

Figure 3 Effect of Electrolyte addition on Gas hold up with and without impeller

Conclusion

Gas hold up is an important parameter in mass transfer studies. The gas hold up in bubble column for three phase (water-air-polypropylene solids) systems was studied. It was observed that the gas hold up increases as the flow rate of Newtonian fluid was increased. It was found that the gas hold up values with dual impeller was higher compared to that without impeller. The stirrer speed for the three phase system was changed from 20 to 100 rpm. The gas hold up was found to increase with increase in stirrer speed. Similar findings were obtained on addition of electrolytes for systems with and without impellers.

References

[1]. A.A.Rafiei and et.,al.,(2011), 'Gas hold up and single bubble velocity profile', International Journal of mineral processing, 268; pp. 16

[2]. Yuanxin,W., Chen One,B., Al-Dahhan,M.H.: Predictions of Radial Gas Hold up Profilesin Bubble Column Reactors, Chem. Eng. Sci., 56 (2001) 1207-1210.

[3]. Xukun,L., Lee,D.J., Lau,R., Yang,G., L.S. Fan,L.S.: Maximum Stable Bubble Size andGas Hold up in High Pressure Slurry Bubble Columns, AIChE Journal, 45 (1999) 665-679

[4]. Hikita,H., Asai,S., Tanigawa,K., Segawa,K., Kitao,M.: Gas Hold-Up in Bubble Columns,Chem. Eng. J., 20 (1980) 59-67.

[5]. Krishna, R., Van Baten, J.M., Urseanuy, M.I., Ellenberger, J.: A Scale up Strategy ofBubble Column Slurry Reactors, Catal. Today, 66 (2001)199-207.

[6]. Behnoosh Moshtari, Ensieh Ganji Babakhani, Jafar Sadegh Moghaddas 'Experimental study of gas hold-up and bubble behavior in gas –liquid bubble column' Journal of Petroleum & Coal 51(1) 22-28 (2009).

[7]. Degaleesan S, Dudukovic M, Pan Y. Experimental study of gas induced liquid-flow structures in bubble columns. AIChE J 2001;47:1913–31.

[8]. Shah YT, Godbole SP, Deckwer WD. Design parameters estimations for bubble column reactors. AIChE J 1982;28:353–79.

[9]. Michele V, Hempel DC. Liquid flow and gas holdup-measurement and CFD modeling for two-and-three-phase bubble columns. Chem Eng Sci 2002;57:1899–908.

[10]. Behkish A, Men Z, Inga RJ, Morsi BI. Mass transfer characteristics in a large-scale slurry bubble column reactor with organic liquid mixtures. Chem Eng Sci 2002;57:3307–24.

[11]. Tang C, Heindel TJ. Time-dependent gas holdup variation in an air– water bubble column. Chem Eng Sci 2004;59:623–32.

[12]. Veera UP, Kataria KL, Joshi JB. Effect of superficial gas velocity on gas hold-up profiles in foaming liquids in bubble column reactors. Chem Eng J 2004;99:53–8.