Effect of Surfactants on Gas Hold-Up in Baffled Column Reactor

Atheel Khairi Jabir

University of Nahrain , Chemical Engineering Department

Abstract:

The present work aims to study the performance of Baffled bubble Column Reactor on homogeneous flow regime .Experiments were carried out to investigate the effect a surface active agent (type and concentration) on Gas Hold-Up in Baffled bubble Column Reactor on with the border range of superficial gas velocity (0.001 -0.039 m/s). Ethanol and hexanol were used as surfactants in the present work. Also three types of baffles: perforated, circular and fin baffle were used. The results show that the gas hold up increases with increasing the concentration of the surfactants. The highest values of gas hold up were recorded in the presence of perforated baffle with 30% of ethanol-water and hexanol-water mixture.

Keywords: Baffled bubble column, surfactants, fractional gas hold up.

الخلاصة

يتضمن البحث دراسة تأثير تركيز كل من الايثانول والهكسانول(9%, 18%, 30%) على محتوى الغاز الحجمي في العمود الفقاعي بوجود الحواجز عند معدلات جريان للغاز مختلفة (0,001 -0.039 m/s). انواع الحواجز التي تم استخدامها هي الحلقي، المثقب ، والزعنفي.

اظهرت النتائج ان محتوى الغاز الحجمي يزداد بزيادة تركيز المواد الايثانول والهكسانول ، واعلى قيم لمحتوى الغاز الحجمي تم تسجيلها بوجود الحاجز من النوع المثقب مع تركيز 30% للايثانول والهكسانول.

1. Introduction:

Bubble column reactors are intensively utilized in chemical, petrochemical, biochemical and metallurgical industries. These reactors are often preferred because of simplicity of operation, low operating costs and ease with which the liquid residence time can be varied [1]. There are some important parameters, such as gas holdup, gas-liquid interfacial area, interfacial mass transfer coefficient, dispersion coefficient and heat transfer coefficient and so on, which are essential to characterize, scale up and design the bubble column reactors. For instance, the gas holdup gives the volume fraction of the phases present in the reactor. On the other hand, the gas holdup combined with knowledge of the mean bubble diameter allows determination of the specific interfacial area and the related volumetric mass transfer rates between the gas and liquid phase. Moreover, the gas holdup is usually used to identify the flow regime in bubble column reactors[14]. Extensive studies on the gas holdup have been carried out in several contexts, such as flow regime identification and factors that may influence the gas holdup in bubble column reactors, such as gas flow rate, liquid flow rate, geometry of the bubble column, operating conditions (such as pressure and temperature), physical properties of both phases, sparger type and so on [2].

Both the column characteristics and the liquid media have a strong effect on these parameters, but the liquid media effect seems more complex and is still disputed.

In fact, the bubble size strongly depends on coalescence behavior of the liquid, but the influence of the liquid properties on bubble coalescence and break-up remains difficult to quantify, especially in industrial complex media. The most analyzed liquid properties are viscosity and surface tension [3]. It is widely accepted that the presence of small amounts of surfactant additives largely affects a wide range of phenomena in a bubble column (i.e., production of more numerous bubbles, inhibition of coalescence) leading to higher gas holdup values. However, most studies deal with salt solutions, while little has been reported about the effect of organic surfactants on bubble column operation [4]. Surfactants are the materials containing both polar and non-polar parts (amphiphilic); these molecules locate their hydrophilic head groups in the aqueous phase and allow the hydrophobic hydrocarbon chains to escape from water phase [5]. These materials are widely using as antifoam agent, wetting agent, detergent, film coating, emulsifying agent, chemical and petrochemical productions [6]. In bubble columns, the surface tension effect is similar to what is observed for single bubbles: a decrease in surface tension decreases bubble size and bubble velocity [7] this induces higher gas holdup [8] and higher mass transfer coefficient [9].

Present work aimed to study the effect of a surface active agent (type and concentration)on Gas Hold-Up in Baffled Column Reactor on homogeneous flow regime (0.001 -0.039 m/s). Aqueous solutions of (9 %, 18 % and 30 %) hexanol-water and ethanol-water were used as the liquid phase . Also three types of baffles: perforated, circular and fin baffle were used.

2. Experimental Work:

The experiments were carried out in a QVF cylindrical bubble column of 0.15 m inside diameter and 2 m height. Perforated plate sparger was used as gas distributor consisted of 54 hole and 1mm diameter and free surface area to cross sectional diameter 0.24. Schematic diagram of experimental setup is shown in figure(1).

The air was compressed from the bottom of the column to a static mixture (water and surfactants) of height 45 cm. The gas flow rate was varied in the range of 0.001 - 0.039 m/s to cover homogeneous flow regimes. Aqueous solutions of (9 %, 18 % and

30 %) hexanol-water and ethanol-water were used as the liquid phase. Also three types of baffles: perforated, circular and fin baffle were used which were located at a distance of 10 cm from the bottom of the column (above the gas sparger); at each type the gas hold up was measured. Figure (2) shows the sketch of the three types of baffles . The gas hold up measured with the method of bed expansion. The baffles located from the top of the column and the surfactants added with various concentrations in the presence of these baffles. The properties of these surfactants are shown in detail in Table (1).

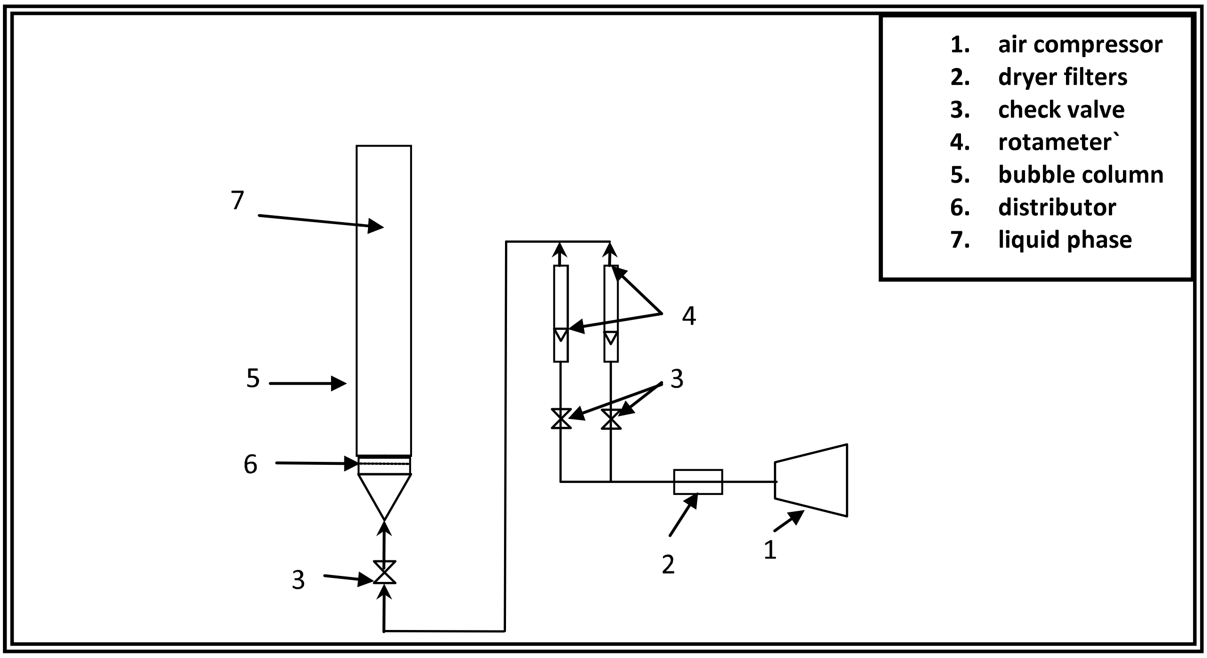


Fig.(1) Schematic diagram of experimental setup.

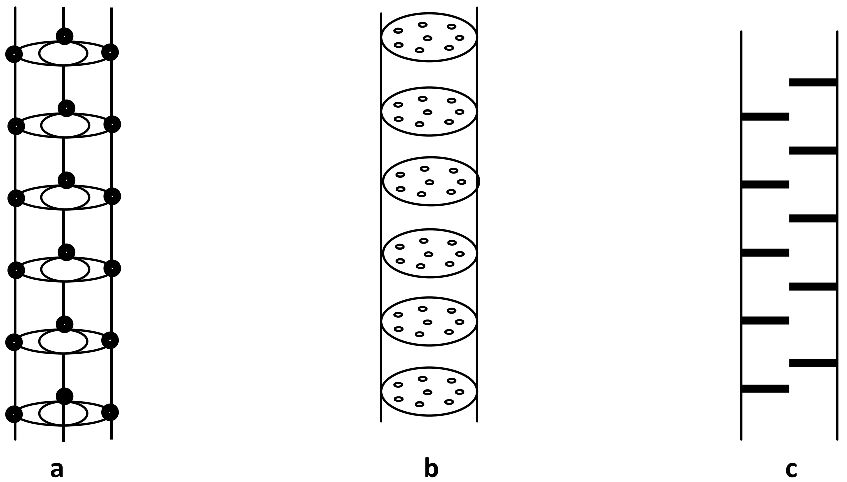


Fig. (2) Type of baffles: a. Circular

Table (1) Surfactants properties.

Surfactants	Solubility in water	Molecular formula	type	Viscosity (mP.s at 20 C°)	Surface tension (mN/m at 20C°)
Ethanol	Fully miscible	C_2H_5OH	grain alcohol	1.200	22.39
1-Hexanol	5.9 g dm^{-3}	$C_6H_{14}O$	Organic alcohol		18.43

Table (2) Experimental values of surface tension at each concentrations.

Mixture of water and Surfactants	Persanage of mixtures	Surface tension (mN/m)
Water + Ethanol	9%	38
	18%	40
	30%	43.7
Water +hexanol	9%	29
	18%	30
	30%	31

In order to analyze the surface tension effect in bubble columns, two mixtures of different surface tension are compared: water, which is a reference as its behavior is widely investigated with ethanol and water with hexanol.

3. Measurements:

3.1 Gas Hold-Up:

In these experiments the fractional gas hold-up was estimated from bed expansion:

$$\varepsilon_g = \frac{H_f - H}{H_f}$$

3.2 Bubble Rise Velocity:

In homogenous regime, bubble rise velocity can be estimated from the drift flux model Zuber and Findlay model [10]:

$$\frac{U_G}{\varepsilon_G} = C_0 U_G + C_1$$

The constants are given by the following equation:

$$C_0 = \frac{\langle \varepsilon_G U_G \rangle}{\langle \varepsilon_G \rangle \langle U_G \rangle}$$

$$C_1 = \frac{\langle \varepsilon_G \varepsilon_L U_S \rangle}{\langle \varepsilon_G \rangle}$$

Where the experimental data Ug/Eg are plotted against Ug then the bubble rise velocity can be from the intercept of Ug/Eg axis as shown in figures (3&4).

Table (3) shows the bubble rise velocity for different baffles and liquid concentrations.

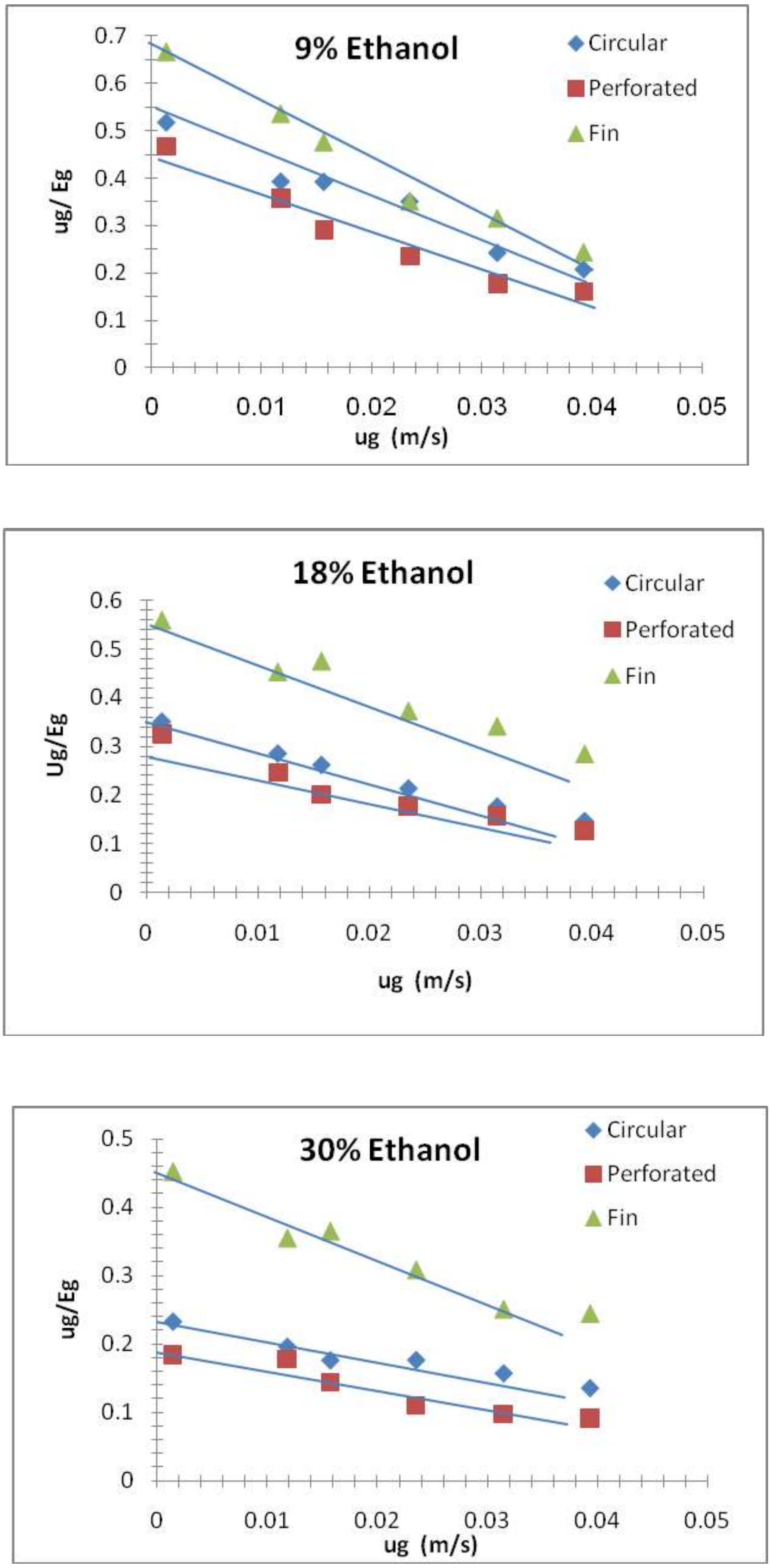
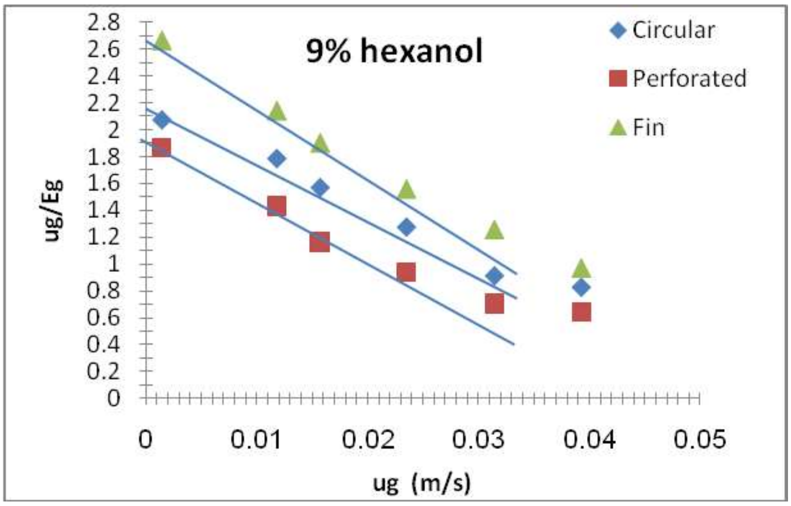
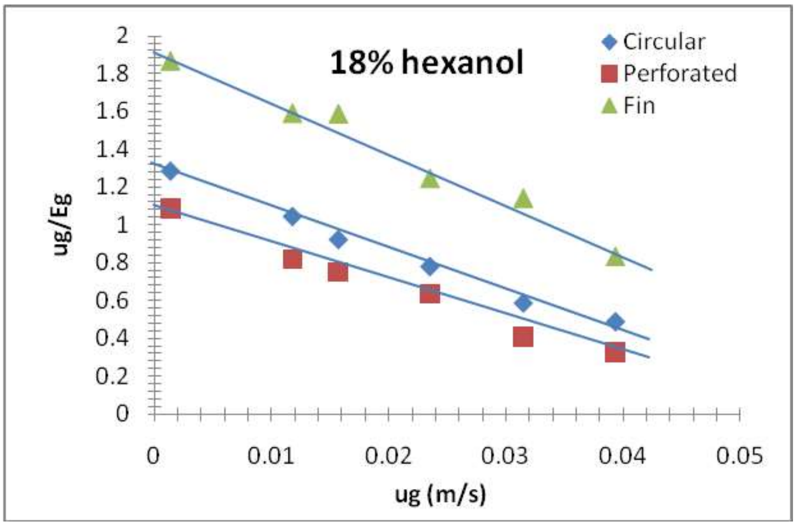


Fig.(3) effect of ethanol concentration on gas holdup and bubble rise velocity.





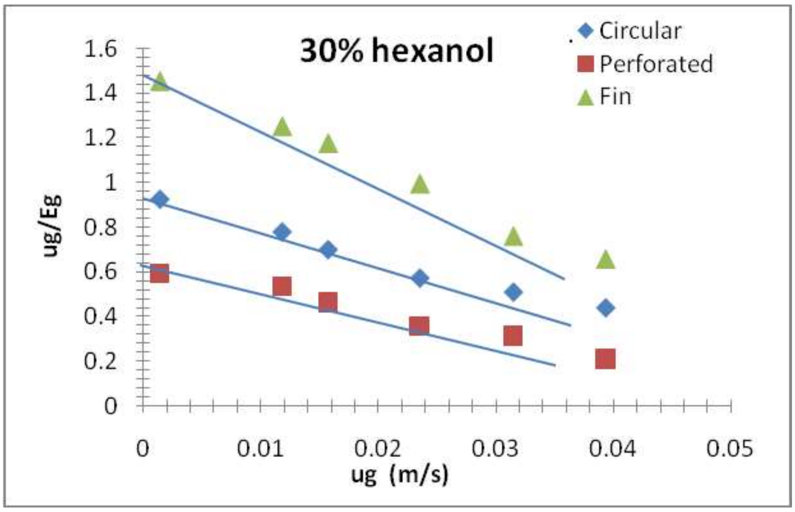


Fig.(4) effect of hexanol concentration on gas holdup and bubble

Table (3) bubble rise velocity for different baffles and liquid concentrations.

Concentration	Fin baffle	Circular baffle	Perforated baffle
9% Ethanol	0.675	0.53	0.415
18% Ethanol	0.586	0.325	0.299
30% Ethanol	0.457	0.23	0.153
9% Hexanol	2.58	2.11	1.85
18% Hexanol	1.96	1.22	1.05
30% Hexanol	1.48	0.922	0.678

3. Results and Discussion:

3.1 Effect of baffles Type:

Figures (5&6) show the effect of baffles type on gas hold up at different ethanol and hexanol concentrations respectively . From these figures it can be seen that the gas hold up for perforated baffle are higher than the gas hold up when circular and fin baffles were used .This is attributed to the diminishing in the bubble coalescence frequency : the bubbles are then smaller , slower (i.e. low bubble rise velocity see Table (3) and also more spherical [11] therefore the bubbles will accumulated for along time under the baffle plate . Table (3) shows the bubble rise velocity for different baffles and liquid concentrations.

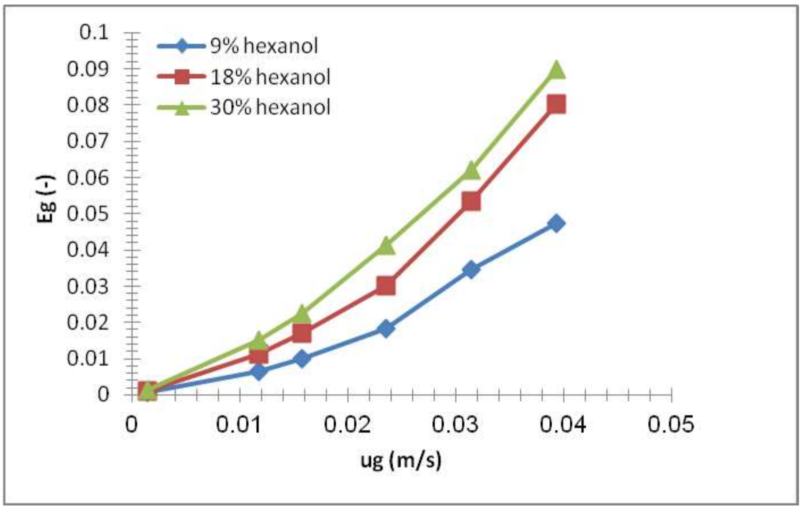
3.2 Effect of Surfactants Concentration (Ethanol, Hexanol):

Figures (3&4) and Table (2) show the effect of ethanol and hexanol concentration on gas holdup and bubble rise velocity respectively. It can be seen from these figures that an increase of alcohol concentration resulting in a higher gas holdup. When the concentration increases the solution will be so viscous and this will increase the rate of breakage in the bubbles. And also presence alcohol in water will reduce the surface tension of the mixture which caused a suppression of the coalescence tendency of small bubbles where making liquid mixture non-coalescing [13]. The average bubble size and bubble rise velocity decreases in non-coalescing liquid mixtures and as a consequence, the gas holdup will be increased [11]. Krishna et al [13], explain the mechanism of the suppression of the coalescence tendency of small bubbles as follows: when alcohol dissolved in water, it strongly adsorbed at the interface. They behave as hydrophobic materials and that to be rejected from the bulk of the solution to the interface. They accumulate around the bubbles forming a “protective” monolayer and consequently the coalescence between the bubbles will be hindered. When a bubble moves through in a liquid adsorbed surface active material is pushed to the back of the bubble this causes a surface tension gradient which opposes the tangential shear stress. This phenomenon increases the drag on the bubble and consequently the rise velocity is reduced .

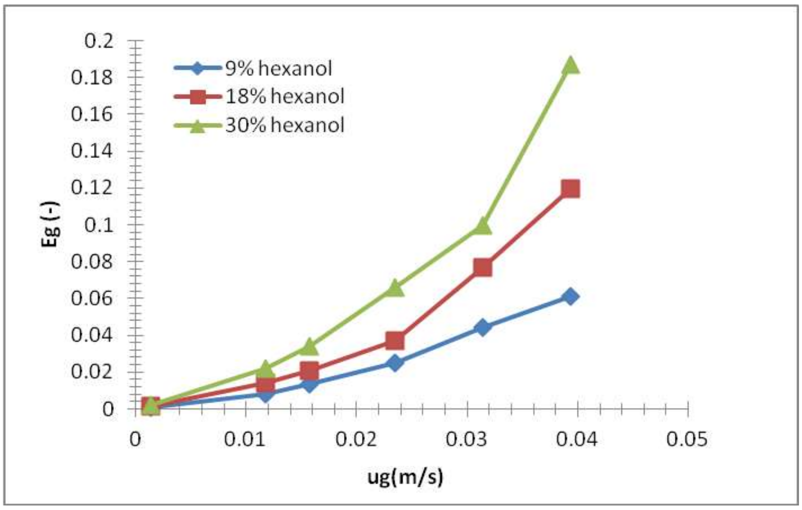
3.3 Effect of Superficial Gas Velocity:

Figures (5,6) show the effect of superficial gas velocity on the gas holdup as a function of alcohol concentration for different baffle type. It can be seen that, the gas holdup increases with increasing superficial gas velocity.

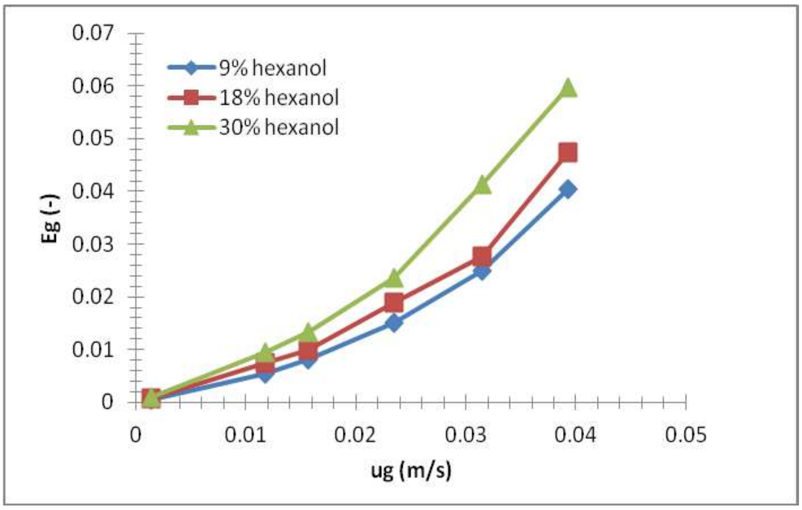
This is attributed to the fact that the rate of breakup of bubbles increased. In addition, increasing superficial gas velocity gives smaller bubbles. The smaller bubbles with lower rising velocity lead to form large residence time and consequently higher gas holdup [13, 12].



(a)

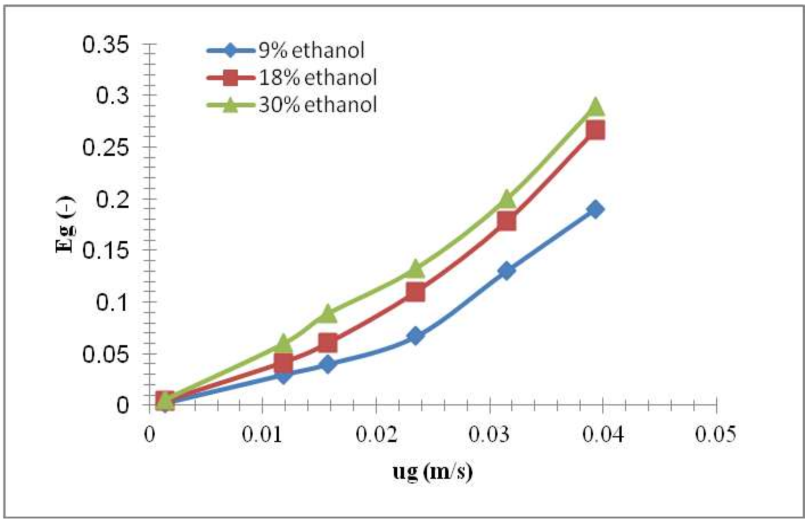


(b)

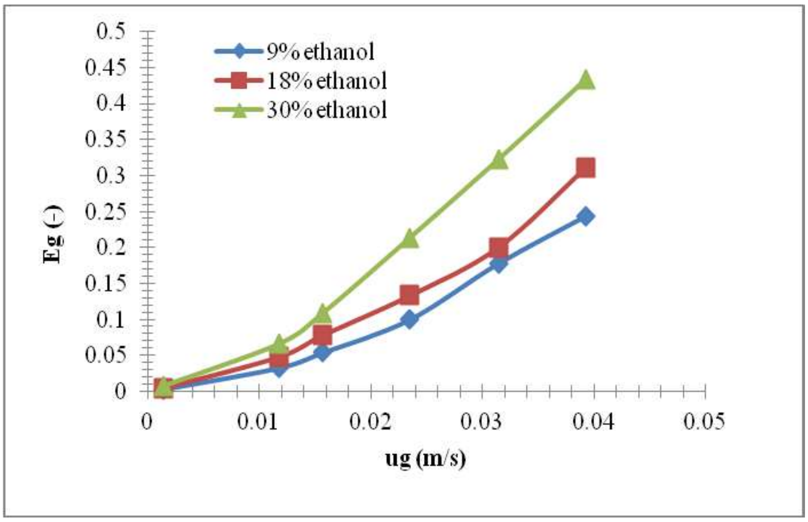


(c)

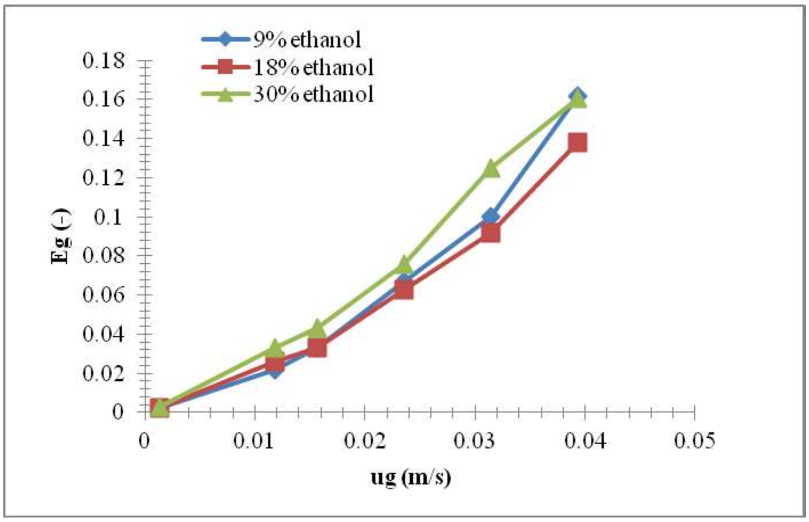
Fig.(5) Effect of superficial gas velocity on gas hold-up at different hexanol concentration in thepresence of:(a) circular baffle, (b) perforated baffle, (c) fin baffle.



(a)



(b)



(c)

Fig.(6) Effect of superficial gas velocity on gas hold-up at different ethanol concentration in the presence of:

4. Conclusions:

1. From experimental data and the plotted figures (5,6); it can be concluded that the best type of baffles in performance is the perforated one, this is due to the small surface area of this baffle and also the large number of holes which produce high amount of small bubbles that accumulated under the surface of the baffle so the residence time will be longer and this leads to increase the gas hold-up.
2. At higher concentrations of surfactants the surface tension causes a remarkable increment in gas hold-up.

Nomenclature:

Hf : Aerated liquid height, (m)

H : Clear liquid height, (m)

Ug : Superficial gas velosity, (m/s)

Co : Distribution coefficient in liquid, (-)

Ubr : Bubble rise velosity, (m/s)

Greek Letters

εg : gas hold-up, (-)

References:

1. Y. T. Shah, B. G. Kelkar, S. P. Godbole, and W. -D. Deckwer. Design.
2. parametersestimations for bubble column reactors. AIChE Journal, 28(3):353–379, 1982.).
3. Shah et al.,1982; Heijnen and Van't Riet, 1984; Deckwer and Schumpe, 1993.
4. Kantarciet al., 2005; Ribeiro Jr. and Lage, 2005; Shaikh and Al Dahhan, 2007;(Joshiet al., 2008).

3. Deckwer, W.D., Bubble Column Reactors. Wiley, New York,Dhotre, M.T., Ekambara, K., Joshi, J.B., 2004. CFD simulation of spargerdesign and height to diameter ratio on gas hold-up profiles in ubblecolumns reactors. Experimental Thermal and Fluid Science 28, 407– 421. 1992.

5. N.A. Kazakis, A. Anastasiou, A.A. Mouza, S.V. Paras, Effect of surfactant.
6. additives on holdup in bubble columns equipped with fine pore sparger.

5. Shaw, D., 1992. Surface activity and micelle formation. Modified by T. Corcoran, 2002.

6. Porter, M.R., Hand book of Surfactants, Blackie, and London 1994.

7. Camarasa, E., Vial, C., Poncin, S., Wild, G., Midoux, N., Bouillard, J., Influence of coalescence behaviour of the liquid and of gas sparging On hydrodynamics and bubble characteristics in a bubble column. Chemical Engineering and Processing 38, 329–344 1999.

7. Kantak, M.V., Hesketh, R.P., Kelkar, B.G., Effect of gas and liquid properties on gas phase dispersion in bubble columns. The Chemical

Engineering Journal 59, 91–100 1995.

8. Krishna, R., Dreher, A.J., Urseanu, M.I., Influence of alcohol addition on gas hold-up in bubble columns: Development of a scale up model 2000. International Community of Heat and Mass Transfer 27 (4), 465–472.
9. Zuber, N. and Findly, J.D., J.Heat Transfer Trans. ASME Ser. C, 87, 453- 468, 1965.
10. U. ParesuVeera, Kamal L. Kataria, J.B. Joshi, "Gas hold-up profiles in foaming liquids in bubble columns", Chem. Eng. J., 84, (2001), 247-256.
11. Paras, S.V., Dalakoglou, G.K. and Mouza, A.A., Chem. Eng. Sci., 60, 1465-1475, 2004.
12. R. Krishna, M.I. Urseanu, A.J.Dreher, "Gas hold-up in bubble columns: influence of alcohol addiction versus operation at elevated pressures", Chem. Eng. And Processing, 39, (2000), 3.
13. Amir Sheikhi, Rahmat Sotudeh - Gharebagh, Reza Zarghami, Navid Mostoufi, Mehrdad Alfi "Understanding bubble hydrodynamics in bubble columns" , Experimental Thermal and Fluid Science, Volume 45, February 2013, Pages 63-74.