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Effect of gas holdup enhancement using aqueous solutions of electrolyte in taper bubble column

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Abstract : Experimental studies on gas holdup in tapered bubble column using electrolyte solutions have been reported. The effects of different operating variables such as liquid flow rate, bed height and concentration of electrolyte, etc. on the gas holdup were investigated. In our work distilled water and NaCl solution ware taken as continuous phase and bubbling air as discontinuous phase and flow was almost entirely heterogeneous. The hydrodynamic effects were investigated.

Keywords : Gas holdup; Newtonian liquid; Electrolyte; Tapered bubble column.

INTRODUCTION

A Bubble column is a device in which a gas phase is bubbled through a column of liquid to promote a chemical or biochemical reaction in the presence or absence of a catalyst suspended in the liquid phase. Gas–liquid bubble columns are becoming popular and are widely used in industry as absorbers, strippers, reactors and fermenters due to the absence of any moving parts, simple construction, good mixing and mass transfer capacity, temperature control, minimum maintenance, and low capital cost. Bubble coalescence, high pressure drop, considerable back mixing in both phases, short residence time of gas and complex hydrodynamics flow patterns are the main disadvantages of a bubble column. The bubble coalescence is one of the major disadvantages in the operation of bubble column. To get rid of this problem electrolyte can be used. Inorganic electrolytes are commonly known to reduce the degree of bubble coalescence and consequently the interfacial area increases. The salts are found to inhibit bubble coalescence by retarding the thinning of the intervening liquid film between bubble pairs. Marrucci et al.[1] analyzed this phenomenon by considering a constant volume element of the liquid film during the thinning process. The surface area of the element is increased during the thinning process. The higher salt concentration produces an increase in the surface tension of the film and hence a force develops opposite to the direction of flow at the gas-liquid boundary. This results in a significant increase in the thinning time of the liquid film during coalescence. Lee and Meyrick[2] measured the gas holdup and gas-liquid interfacial areas for dispersions of air in electrolytes solutions. Prince and Blanch[3] obtained expressions to calculate transition electrolyte concentrations for bubble coalescence. Thorat et al.[4] reported air-aqueous solution of electrolyte relatively less coalescing system.

The availability of literature using electrolyte are meager[2,4-10]. Literature review suggested that electrolyte can be grouped into two categories according to their function or affect the bubble coalescence insolutions. In first group the suppress bubble coalescence is moderate (NaCl and $MgSO_4.7H_2O$) and second group suppress bubble coalescence is very strong (Na_2SO_4 and $CaCl_2.2H_2O$)[8]. Syeda and Reza[10] reported that the addition of electrolyte changes the surface tension of the solution which is responsible for the enhancement of the gas holdup. Nguyen et al.[11] concluded that transition salt concentration for bubble coalescence and gas holdup depend not only on the salt properties, i.e., ion type and their combination, but also on the hydrodynamic conditions. The advantage of the tapered bubble column lies in the fact that the residence time of the bubble can be increased in comparison to the cylindrical or rectangular column, the flow is always developing in nature and bubbles coalesce to form bigger bubbles, structure of the bigger bubbles change continuously from circular to flat and rupture of the big bubbles to small bubbles[12]. Effects of electrolyte on the taper bubble column are not reported in literature. Hence the present experimental investigation reports the effects of bulk liquid property, gas flow rate, stagnant liquid height and electrolyte of different strength on gas holdup in tapered bubble column.

EXPERIMENTAL DETAILS

A schematic diagram of the experimental setup has been shown in Figure 1. It consists of tapered bubble column, manometers for pressure measurement, distributor (D) to distribute the air, compressor(C), pressure gauge (PG), rotameter (R_G) for flow measures and other accessories.

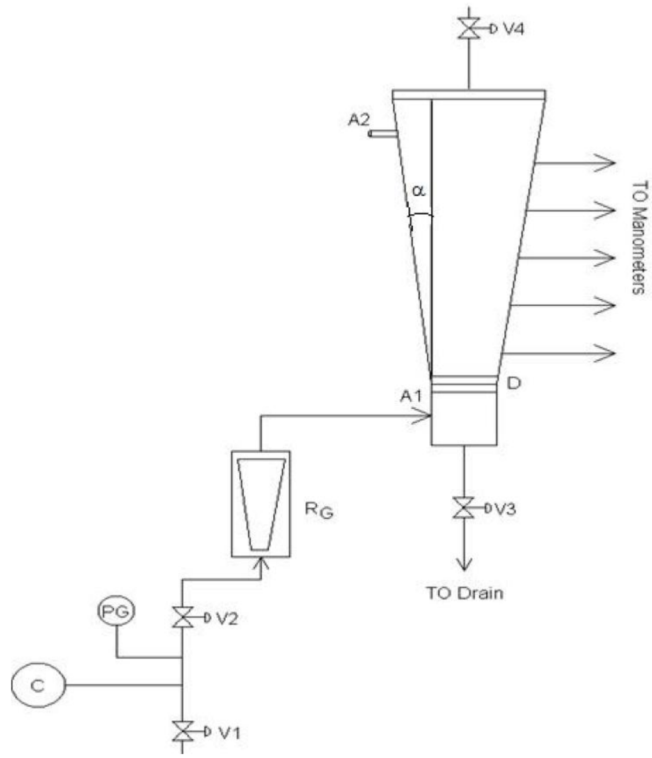

Figure 1 : Schematic diagram of experimental setup;A1: Air inlet; A2: Air outlet; Manometers; D: Distributor; C: Compressor; PG: pressure Gauge; R_G: Rotameter for gas; V1-V4: Control valves.

The tapered bubble column were made of thick perspex and square shaped. A perforated plate made of perspex of different hole diameter were used for air distribution and connected with the column by means of flanges. Air inlet would be provided at the bottom by means of nozzles of 4mm diameter and then distributed through the perforated plate and would enter into the column. Column was fitted to vertically by means of clamps to avoid any vibration. Detailed dimension of the column are shown in TABLE 1. The desired amount of NaCl was dissolved in distilled water. Four different NaCl concentrations, 0.05 - 0.4(M) NaCl were used for the experiment. The physical properties of the liquid are shown in TABLE 2. The liquid height used for the experiments were 1.12 m, 1.17 m and 1.22 m. The air at a pressure 1 kg/cm^2 gauge was introduced into the column, and under steady state condition, the height of liquid column was noted. Flow pattern was observed visually and it was homogeneous and heterogeneous according to the increasing air flow rate. Surface tension of water and

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TABLE 1 : Detailed dimension of tapered bubble column

Characteristic parameters	Taper bubble column
Thickness of Perspex sheet, m	0.0127
Height of column, m	1.83
Top plate area, m^2	0.1016×0.1016
Bottom plate area, m^2	0.0508×0.0508
Hole diameter of the air inlet and outlet, m	0.0127
Hole diameter of sieve plates used, m	0.004
Hole number of sieve plate	50
Taper angle, deg	0.86

TABLE 2 : Physical properties of water and NaCl solution of different concentration

Properties	Water	0.05(M)NaCl	0.1(M)NaCl	0.2(M)NaCl	0.4(M)NaCl
Density(Kg/m^3)	995.67	998.60	1001.52	1007.37	1019.07
Viscosity (Kg/m s)	8.007×10^{-4}	7.981×10^{-4}	7.821×10^{-4}	7.791×10^{-4}	7.602×10^{-4}
Surface Tension(N/m)	7.118×10^{-2}	7.408×10^{-2}	7.573×10^{-2}	7.922×10^{-2}	8.348×10^{-2}

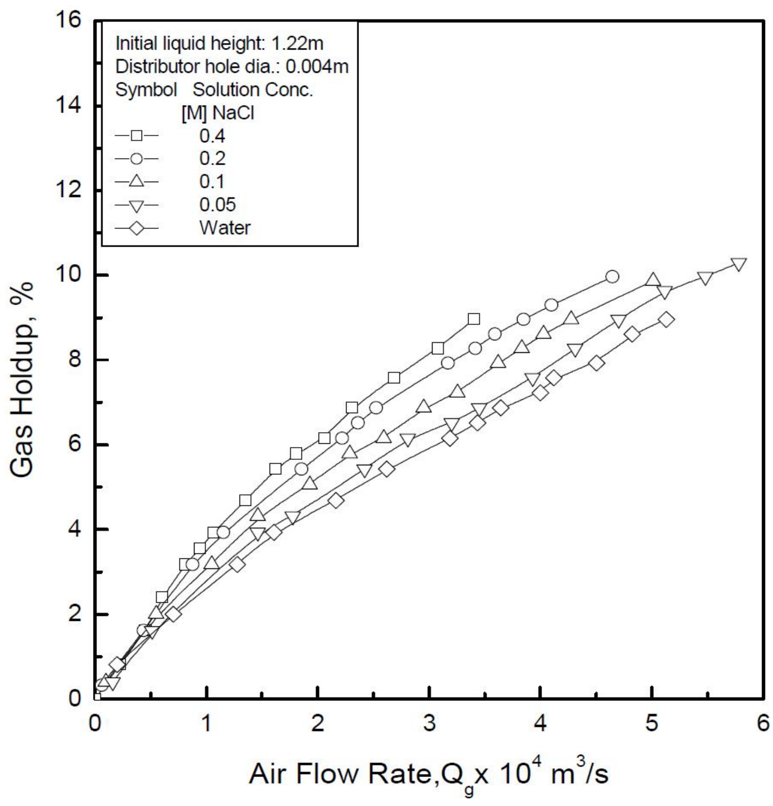

Figure 2 : Variation of gas holdup with gas flow rate at different electrolyte solution concentration

solutions are measured with DuNouy tensiometer. The experiments were repeated a number of times to ensure the reproducibility of the data. The temperature was maintained at atmospheric temperature30±2^{0}C. The overall value of gas hold up ratio was determined from this equation.

$$\varepsilon_g = \frac{V - V_o}{V} \quad (1)$$

Where V and V_o are volume of liquid in column with and without gas flow. The liquid volume in the tapered bubble column with respect to the height was calibrated before the experiment for each liquid used in the studies.

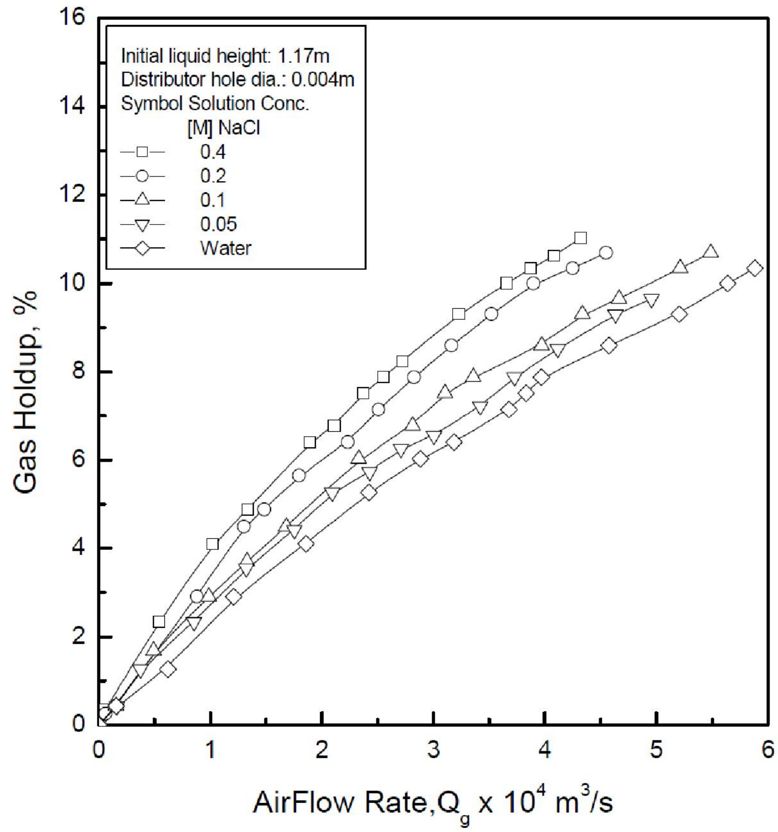

Figure 3 : Variation of gas holdup with gas flow rate at different electrolyte solution concentration

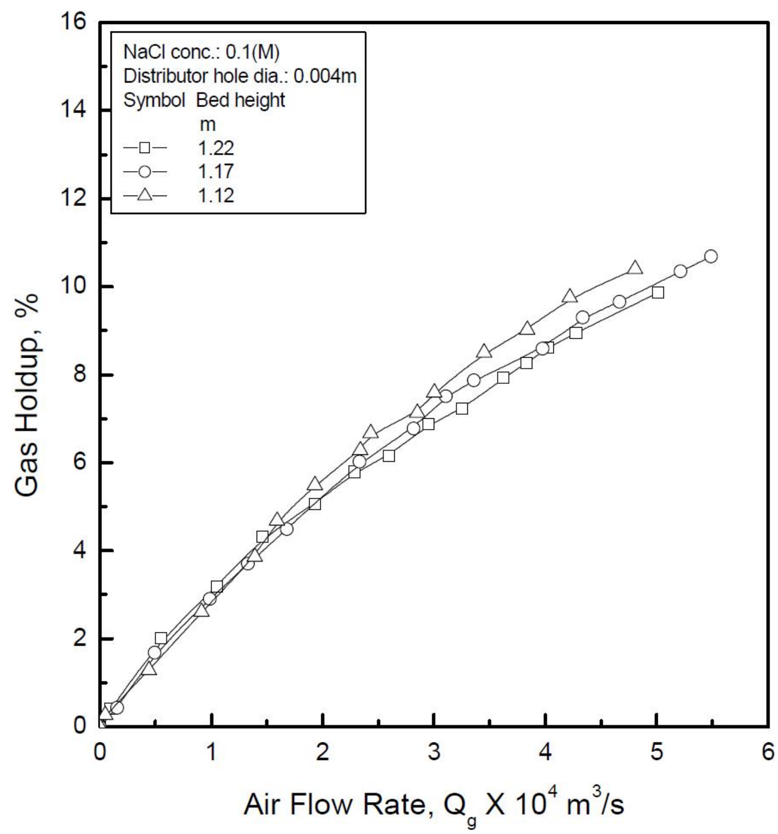

Figure 4 : Variation of gas holdup with gas flow rate at different clear liquid height

RESULTS AND DISCUSSION

Variation of holdup with gas flow rate at different NaCl concentrations

Figures 2-3 show that the variation of gas holdup with superficial air flow rate at constant bed height 1.17 m for water and four different 0.05 - 0.4(M) NaCl concentrations. It is clear that gas holdup increases with increasing air flow rate and NaCl concentrations. It is least in case of water. This is due to gas holdup in bubbling regime is strongly related to the coalescence tendency of bubbles in the respective gas-liquid system. As, inorganic salt dissolved in water should have a strong effect in reducing the size of bubbles. The action of the electrolyte is thus to prevent large bubble being reformed by inhibiting coalescence, the net effect being reduction of mean bubble size. Hence, the suppression of bubble coalescence leads to gas hold-up enhancement.

Variation of holdup with gas flow rate at different constant bed height

Figure 4 shows the variation of gas holdup with gas flow rate at different constant bed height for 0.1(M) NaCl solutions in the column. It is clear from the figure that the gas holdup increases with increasing gas flow rate at different constant bed height. As bed height increases the gas holdup decreases with increasing gas flow rate. Increase of the liquid height in the column, possibility of more coalescence and to form bigger size bubbles which rise quickly through the liquid by buoyancy force[12-15]. Hence, gas holdup decreases.

CONCLUSIONS

The experimental data of the effect of NaCl solutions on the gas holdup in tapered bubble column has been reported. The concentration was varied in the range of 0 - 0.4(M) NaCl solutions. The addition of electrolyte in water was found to cause enhancement in gas holdup. This is due to the enhancement of surface tension which affects the bubble coalescence character in the column.

Nomenclature

Q_g gas flow rate, m^3/s

Greek letters

ε_g gas hold-up, dimensionless

α taper angle (deg.)

Subscripts

g gas

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