Chapter - 5

Hydrodynamics Using Electrolyte

This chapter deals with the experimental studies on gas holdup in tapered bubble column using electrolyte solutions. The effects of different operating variables such as liquid flow rate, bed height, concentration of electrolyte, etc. on the gas holdup were investigated using larger tapered bubble column (TB2). In this work distilled water and dilute NaCl solutions ware taken as continuous phase and bubbling air as discontinuous phase and flow was almost entirely heterogeneous in nature.

5.1 Introduction

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. (1967) 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 (1970) measured the gas holdup and gas-liquid interfacial areas for dispersions of air in electrolytes solutions. Prince and Blanch (1990) obtained expressions to calculate transition electrolyte concentrations for bubble coalescence. Thorat et al. (1998) reported air-aqueous solution of electrolyte relatively less coalescing system.

The availability of literature using electrolyte are meager (Lee and Meyrick, 1970; Hikita et al., 1980; Jamialahmadi and Muller-Steinhagen, 1991; Zahradnik et al., 1995; Thorat et al., 1998; Ribeiro and Mewes, 2007; Orvalho et al., 2009; Syeda and Reza, 2011). 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 $CaCl_2.2H_2O$) (Ribeiro and Mewes, 2007). Syeda and Reza (2011) 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. (2012) 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. 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.

5.2 Experimental procedure

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 5.1.

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 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.

5.3 Results and discussion

5.3.1 Variation of holdup with gas flow rate at different NaCl concentrations

Fig. 5.1 shows 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.

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

Fig. 5.2 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 (Wallis, 1969; Viogt and Schugerl, 1979; van Baten and Krishna, 2002). Hence, gas holdup decreases.

5.4 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.

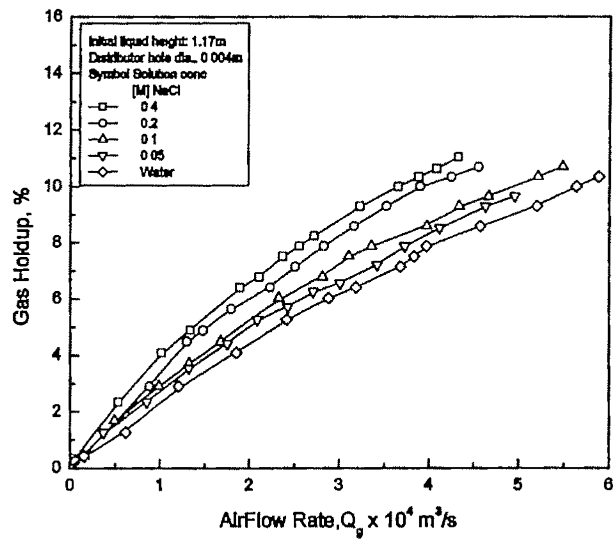

Fig. 5.1 Variation of gas holdup with gas flow rate at different electrolyte solution concentration

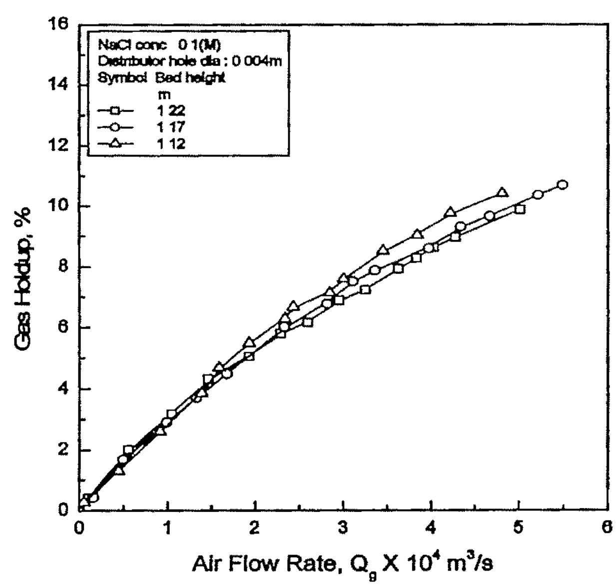

Fig. 5.2 Variation of gas holdup with gas flow rate at different clear liquid height

Table 5.1 Physical properties of water and NaCl solutions 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}

NOMENCLATURE

D_c	:	Diameter of column (log mean), m
D_n	:	Distributor hole diameter, m
g	:	Acceleration due to gravity, m/s^2
H_m	:	Gas-liquid mixture height in column, m
H_0	:	Initial liquid height in column, m
K	:	Consistency index, Ns^n/m^2
n	:	Flow behaviour index
N	:	Total number of data set
N_{pl}	:	Liquid property group ($N_{pl} = \frac{\mu_{eff}^4 g}{\rho_l \sigma_l^3}$), dimensionless group.
ΔP_f	:	Frictional pressure drop, N/m^2
Δp_h	:	The column hydrostatic head, N/m^2
Δp_T	:	Total pressure drop, N/m^2
Δp_a	:	Pressure drop due to accelerative effect, N/m^2
ΔP	:	Pressure drop, (dimensionless)
Q_g	:	Gas flow rate, m^3/s
R	:	Cross-correlation coefficient (dimensionless)
Re	:	Reynolds number, dimensionless
TB1	:	Smaller tapered bubble column
TB2	:	Larger tapered bubble column
V	:	Volume of liquid in column
x	:	Experimental value (dimensionless)
y	:	Predicted value (dimensionless)
ΔZ	:	Distance between two pressures tapping over which the pressure drop has been measured, m

μ_{eff} : Effective viscosity

μ_l : Viscosity of liquid

μ_g : Viscosity of gas

Greek letters

α : Taper angle (deg.)

ε_g : Gas hold-up, dimensionless

ρ_l : Density of liquid, Kg/m^3

ρ_g : Density of gas, Kg/m^3

σ : Standard deviation (dimensionless)

σ_l : Surface tension, N/m

θ : Taper angle, (rad.)

Subscripts

a : Accelerative

eff : Effective

f : Frictional

g : Gas

h : Hydrostatic

l : Liquid

m : Mixture

o : Without gas flow

T : Total