Effect Of Solid Catalyst On Bubble Rise Velocity And Gas-Drift Flux In Three-Phase-Columns

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Abstract

The bubble rise velocity and drift flux were measured in 0.051 m i.d glass column with ethanol as the liquid phase, cobalt catalyst as the solid phase in concentration varying from (1.0 to 0.4) vol % in three phase column.
Gas superficial velocity (U_g) was varied from (0.02 to 0.1) m/s.
Experimental results show that the gas-holdup and gas flux decreases with the increasing of catalyst concentration but increasing bubble rise velocity.

Key words: slurries, Gas holdup, Bubble column, mass transfer coefficient

الخلاصة

تم في البحث قياس وايجاد سرعة ارتفاع الفقاعة وتدفق الغاز في الاعمدة ثلاثية الطور (سائل-غاز-صلب) باستخدام الايثانول كطور سائل والكوبالت كطور صلب بتركيز (١% - ٤%) حجما , لمعــدلات تدفق الهواء (الطور الغازي) لقيم تتراوح (٠,٠٢ – ٠,١) متر / ثانية .
التجارب اثبتت انه بزيادة تركيز العامل المساعد سيؤدي إلى تقليل نسب احتجاز الغاز وتدفق الغاز ولكن وبالتالي يزيد من قيم سرعة ارتفاع الفقاعة خلال العمود.

1. Introduction:

Three phase bubble columns are widely used in industry for carrying out a variety of chemical reactions such as hydrogenation, chlorination and oxidations. There is currently a great deal of academic and industrial interest in conversion of remote natural gas to liquid transportation fuels. (1)

The superficial gas velocity (U_g) depending on the catalyst activity and the catalyst concentration in the slurry phase(2).

In practice the volume fraction of catalyst in the slurry phase is of the order (0.15 – 0.3) (3).

At these high slurry concentrations the gas dispersion consists of fast-rising-large bubbles (4).

Vandu. et.al (5) studied rectangular slurry reactor with ($C_9 – C_{11}$) paraffin oil as liquid phase, air as gas phase and varying volume fractions of porous catalyst (Alumina catalyst as solid phase).He found that increasing slurry concentration ,gas holdup significantly decreased due to enhanced bubble coalescence.

Krishna. et. al (6) studied the gas hold-up and volumetric mass transfer coefficient in slurry bubble columns, he found that increasing catalyst concentration decrease the gas holdup and volumetric mass transfer coefficient.

A.A. Mouza (7) studied effect of liquid properties on the performance of bubble column with fine pore spargers. He proposed a new correlation based on dimensionless

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groups for gas holdup and bubble size.

Koops,K.[(8)] studied large bubbles size , large bubble rise velocity in rectangular column. He found that increasing slurry concentration reduced gas holdup ,small bubbles reduced in number.

2. Experimental setup and procedure

The experiments were carried out in a glass bubble column of 0.05m i.d. Glass distributor for gas (air) was of (3mm) thick with an average pore size of 70μm as shown in figure (1).

To control the air flow into the column, rotameter was connected with the air line, where gas velocity was estimated from:

$$U_g = \frac{Q}{A} \quad \ldots\ldots\ldots(1)$$

where:

$U_g =$ Gas superficial velocity (m/s).
Q = Volumetric gas flow (m^3 /s)
A = Cross – sectional area of column (m^2)

Air was used as the gas phase with (density = 1.3 kg/m^3) (viscosity = 1.7 x 10^{-5}pas)[(9)].

Ethanol used as liquid phase (density = 798 $kg/m^{3)}$, viscosity = 0.00127 pas, surface tension = 0.023 nm^{-1} passivated Raney cobalt catalyst particles (bulk density) = 1177$kg/m^{3(9)}$, mean diameter= 25.4 μm, with almost uniform size distribution) .Catalyst particles are suspended into liquid phase in varying concentrations. Volume fraction of catalyst C_s = 0.01 (=3.6 wt% catalyst) and C_s = 0.04 (=13.4wt% catalyst).

The pore volume of the particles which is liquid filled during the experiments is assumed to be part of the solid phase. The catalyst particles are held in suspension due to the liquid circulations caused by the rising gas. Air was sparged to the column at a certain flow rate controlled by the rotameter connected with.

After reaching the steady state, the new liquid level was recorded.

Gas holdup was estimated from bed expansion (Shah et al 1984 [(10)]):

$$E_g = \frac{H - H_0}{H} \quad \ldots\ldots\ldots\ (2)$$

where:

E_g = gas hold-up
H = column dispersion height.
Ho = ungassed column height.

Table (1) shows the values of ($E_{g)}$ at different solid concentrations.

3. Experimental results and discussion

Bubble rise velocity in homogenous and heterogeneous flow regime can be estimated from drift flux model of Zuber and Findley [(11)], as follows (Mouza et al 2005 [(7)]):

$$\frac{U_g}{E_g} = Co.\ Ug + U_{br} \quad \ldots..\ (3)$$

where:

Co = distribution coefficient.
U_{br} = bubble rise velocity (m/s).

A plot of U_g/E_g vs. U_g, U_{br} can be found from the intersection of U_g/E_g – with y-axis. Table (2) shows U_g/E_g for different solid concentrations.

Drift flux (J) can be found from (shah 1984[(10)]):

$J = U_g (1 - E_g)$ …………..(4)

where:
J = gas drift flux in (m/s)

Fig (2) shows the effect of slurry concentration on the gas holdup at different gas velocities. The gas velocities cover both the homogenous and heterogeneous flow regions. It is observed that an increase in the volume fraction of solid catalyst decrease the gas holdup.

This decrease is due to the increased coalescence of small bubbles to from larger bubbles. Besides, the maximum value in the holdup curve for C_s = ٠ vanishes with increasing slurry concentrations.

This maximum value denotes a shift in the regime from homogenous bubbly flow to churn-turbulent flow. With the addition of catalyst particles, the coalescence of small bubbles is promoted and the dispersion consists only to large sized bubbles .These results are in agreement with the results of Krishna et al 1999(2) and 2004(6).

Fig (3) shows the relation between (U_g /E_g) vs. (U_g) to find the bubble rise velocity for different catalyst concentrations.

Increasing catalyst concentration will make faster transition from bubbly flow to heterogeneous flow, that means fast coalescence of small bubbly to from large bubbles bearing a higher rise velocity and leading to relatively lower gas holdup values.

Fig. (4) shows the transition regime for different solid concentration using drift flux model. Drift flux (J) which represents the gas flux through a surface moving at the average velocity of the mixture. From this figure it can be noticed the change in the slope of the curve indicates the transition from the homogenous to the heterogeneous regime. Increasing solid concentrations will reduce gas holdup, therefore increase the bubble rise velocity, this is due to faster transition from bubbly flow to churn turbulent flow. These results are in agreement with the results of Mouza et al (7).

4. Conclusion

The gas hold-up was measured and bubble rise velocity, gas flux were calculated in air-ethanol slurry system with three different slurry concentrations (C_s =0 **,** C_s = 0.01 , C_s = 0.04).

Increasing solid concentration tends to decrease (E_g), this decrease is due to the increased coalescence of small bubbles to form larger bubbles.

Increasing gas flow rate increases bubble collision probability resulting in greater bubble size increase bubble rise velocity and decrease gas hold-up in column, so transition from bubbly flow to churn flow will be faster.

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Table (1) Values for gas holdup at different Gas velocities & different solid

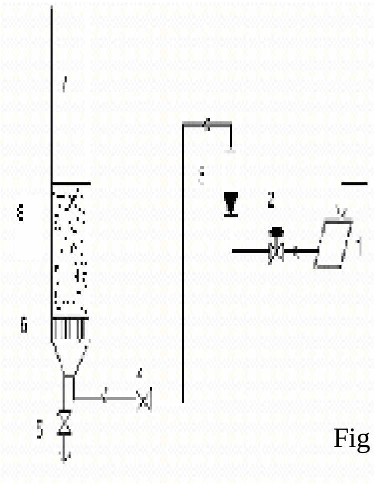
U_g m/s	E_g C_s = 0	E_g C_s = 0.01	E_g C_s = 0.04
0.02	0.125	0.125	0.09
0.04	0.20	0.175	0.125
0.06	0.211	0.19	0.160
0.08	0.22	0.21	0.175
0.10	0.23	0.22	0.20

Table (2) Values for the ratio of gas velocity to gas holdup at different gas velocity & different solid concentrations

U_g m/s	U_g /E_g C_s = 0	U_g/E_g C_s =0.01	U_g /E_g C_s = 0.04
0.02	0.16	0.16	0.22
0.04	0.20	0.228	0.32
0.06	0.28	0.315	0.375
0.08	0.36	0.381	0.457
0.10	0.43	0.454	0.50

Table (3) Gas fluxes at different gas velocities & different solid concentrations

Ug m/s	J C_s = 0 (m/s)	J C_s = 0.01 (m/s)	J C_s = 0.04 (m/s)
0.02	0.0175	0.0175	0.0182
0.04	0.032	0.033	0.035
0.06	0.034	0.048	0.05
0.08	0.062	0.063	0.066
0.10	0.077	0.078	0.082



1- Compressor
2- Needle valve
3- Rotameter
4,5- Valves
6- Gas distributor
7- Column
8- liquid ethanol + cobalt catalyst

Fig (1) Experimental – set up

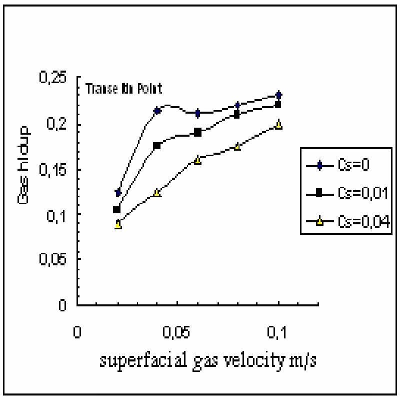


Figure (2) Gas holdup as a function of superficial gas velocity for different catalyst concentration.

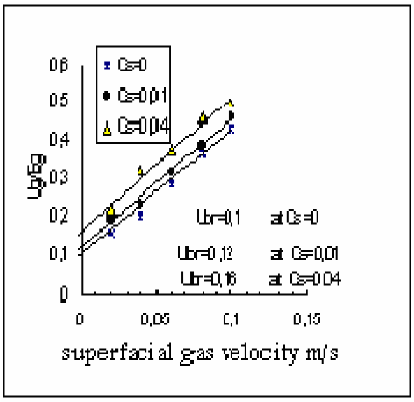


Figure (3) Ug/Eg vs. Superficial gas velocity for different catalyst concentration.

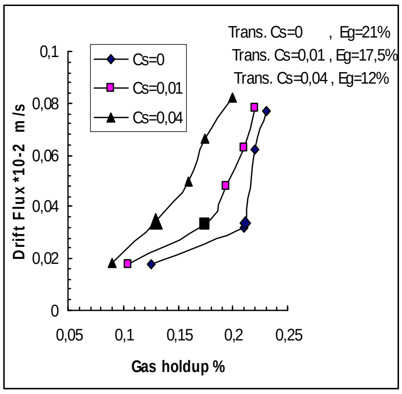


Figure (4) Drift flux vs. gas holdup for different catalyst concentration.