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PREDICTION OF ONSET SEMI-FLUIDIZATION VELOCITY OF THREE-PHASE SEMI- FLUIDIZED BEDS

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ABSTRACT

A semi-fluidized bed is characterized by a combination of packed bed or fixed bed at the top and fluidized bed at the bottom within a single contacting vessel. Such a bed has advantages of both packed and fluidized beds. Various authors have studied the hydrodynamics, mass transfer, reaction kinetics of semi-fluidized beds of two phases and few studies in three phases. In the present study hydrodynamic characteristics viz. onset (minimum) semi-fluidization velocity of a co-current gas-liquid-solid semi-fluidized bed have been studied using liquid as continuous phase and gas as discrete phase. Experiments have been conducted in a 100 mm ID, 1.8 m height vertical Perspex column using air, water and glass beads in order to develop a good understanding of each flow regime in gas-liquid-solid semi-fluidization. It is found that minimum liquid semi-fluidization velocity increases with bed expansion ratio and decreases with superficial gas velocity.

Key words: Three-phase semi-fluidization, Pressure drop, Bed expansion ratio, Minimum semi-fluidization velocity.

INTRODUCTION

Semi-fluidization is a novel fluid solid contacting technique which was first reported in sixties[1]. The increasing popularity of semi-fluidized beds is because of its unique operation in overcoming some inherent disadvantages of both fluidized and fixed beds[2-4]. A semi-fluidized bed, which is characterized by a fluidized bed and a fixed bed in series within a single contacting vessel is formed when a mass of fluidized particles is compressed a porous retaining grid at the top. The internal structure of a semi-fluidized bed can easily altered to create an optimal operating configuration. This unique feature of semi-fluidized bed allows it to be utilized for a wide range of physical, chemical and biochemical applications[5]. Studies of semi-fluidization have been mainly limited to the gas-solid or

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liquid-solid systems[2,6,7]. A little information however is available on semi-fluidization in the gas-liquid-solid systems[5,8-10].

For successful design and operation of such reactors the knowledge of pressure drop, minimum semi-fluidization velocity, top packed bed formation etc. are required[11]. The study of semi-fluidized bed has been broadly classified as prediction of minimum and maximum semi-fluidization velocities, prediction of top packed bed height, and prediction of pressure drop across the semi-fluidized bed.

In the present study, experiments have been conducted for prediction of the hydrodynamic behavior such as onset semi-fluidization velocity in which co-current flow of air and water takes place in a bed of glass beads particles of various sizes.

EXPERIMENTAL

A schematic representation of the experimental setup is shown in Figure 1. The vertical Perspex fluidizer column is of 100 mm ID with a maximum height of 1.8 m. The column consists of three sections, viz., the gas-liquid distributor, test section, and gas-liquid disengagement section. The gas-liquid distributor is located at the bottom of the test section and is designed in such a manner that uniform distribution of the liquid and gas can be maintained in the column. The distributor section is a conical frustum of 14 cm in height, with diameter of 5.1 cm and 8 cm at the two ends and having liquid inlets. A perforated plate of 23 cm ID 1 mm thick, 11.5 cm diameter, of about 300 numbers of 2, 2.5 and 3 mm perforations is placed at the top of this section. There is an air sparger consisting of 48 numbers of 1 mm perforations in triangular pitch. In this section the gas and liquid streams get mixed and passed through the perforated grid. Bed pressure drop has been measured using U-tube mercury manometers.

Glass beads, water and compressed air (oil free) have been used as solid, liquid and gas phases, respectively. The ranges of variables for experimental studies are shown in Table 1. The flow of air and water is co-current and upward. Accurately weighed amount of materials was charged into the column and adjusted for some initial static bed height. The liquid flow rate is varied for constant gas flow rate using the control valves and bypass adjustment. The bed pressure drop is measured by manometer reading. To predict the minimum semi-fluidization velocity, bed pressure drop is measured from manometer reading.

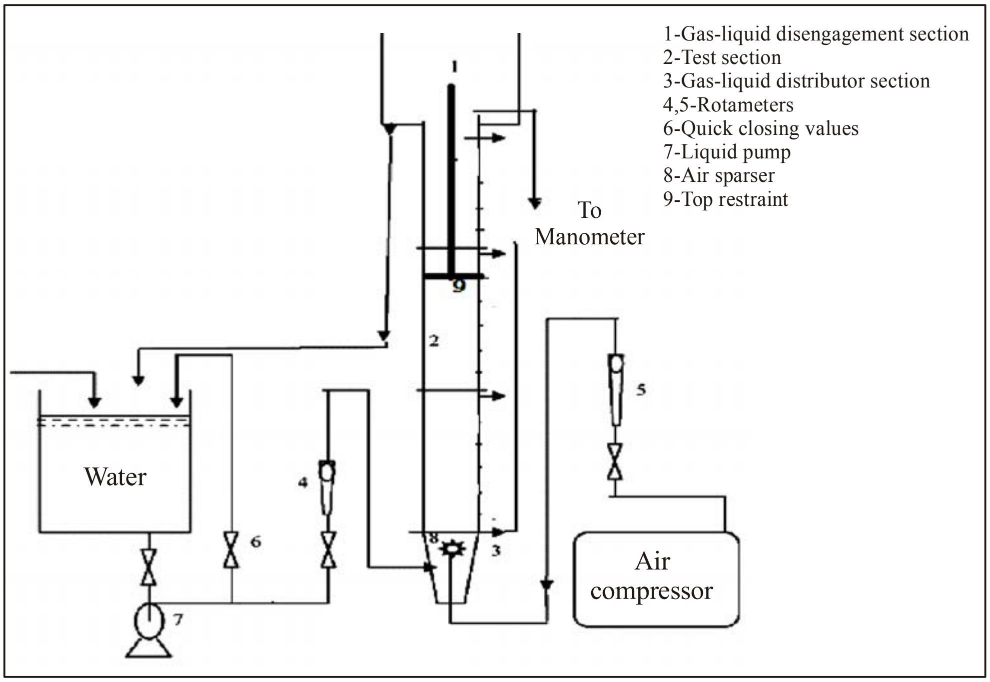

Fig. 1: Experimental set-up

Table 1: Range of operating variables

Particle size (mm)	Particle density (Kg/m^3)	Static bed height (cm)	Expansion ratio	Fluidizing media	
				Liquid	Gas
1.67	2712	17	2	Water of density 999 Kg/m^3 and viscosity 0.099Pa	Air of density 1.16 Kg/m^3 and viscosity 0.0019Pa
2.18	2712	21	2.5		
3.07	2712	25	3		
4.05	2712	31	3.5		

Table 2: Ulmsf at different Ug for hs = 17 cm, dp = 3.07 mm and R = 2

Ug, m/s	0	0.02	0.042	0.064	0.084
Ulmsf*, m/s	0.092	0.072	0.057	0.048	0.035
Ulmsf**, m/s	0.106	0.079	0.061	0.044	0.034

*Experimental value
**Calculated value

Table 3: Ulmsf at different Ug R for hs = 25 cm, dp = 3.07 mm and Ug = 0.064 m/s

R	2	2.5	3	3.5
Ulmsf*, m/s	0.06	0.069	0.081	0.098
Ulmsf**, m/s	0.057	0.071	0.086	0.1

*Experimental value; **Calculated value

RESULTS AND DISCUSSION

Onset semi-fluidization velocity

The minimum semi-fluidization velocity or onset velocity of semi-fluidization is defined as the fluid velocity at which first particle of the fluidized bed just touches the top restraint. The minimum liquid semi-fluidization velocity (Ulmsf) in this study has been obtained from the relationship between pressure drop and superficial liquid velocity (the velocity of a liquid is equal to the volumetric flow rate divided by the cross-sectional area. Figure 2 shows the variation of pressure drop with superficial liquid velocity for gas-liquid-solid system at various superficial gas velocities. From this, it is observed that the minimum liquid semi-fluidization velocity decreases with increase in gas velocity. The variation of minimum liquid semi-fluidization velocity with superficial gas velocity is shown in Figure 3. It shows steady decrease in minimum liquid semi-fluidization velocity with gas velocity.

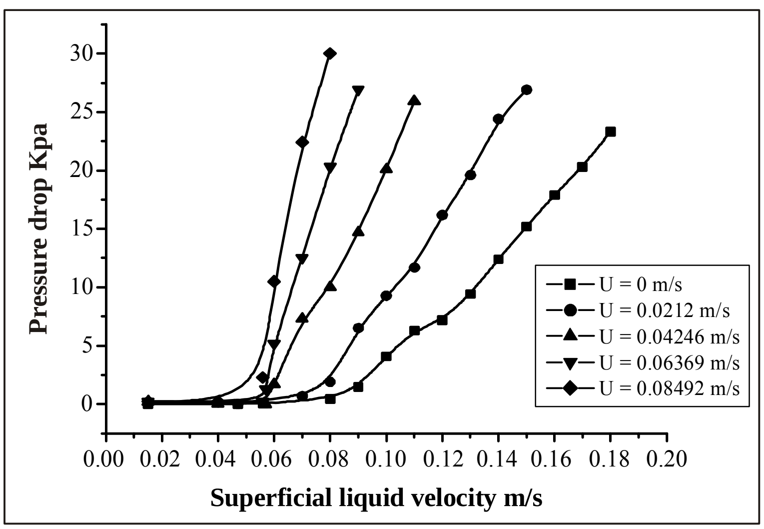

Fig. 2: Variation of bed pressure drop with superficial liquid velocity at different superficial gas velocities for 0.003 m glass beads at R = 2 and hs = 0.17 m

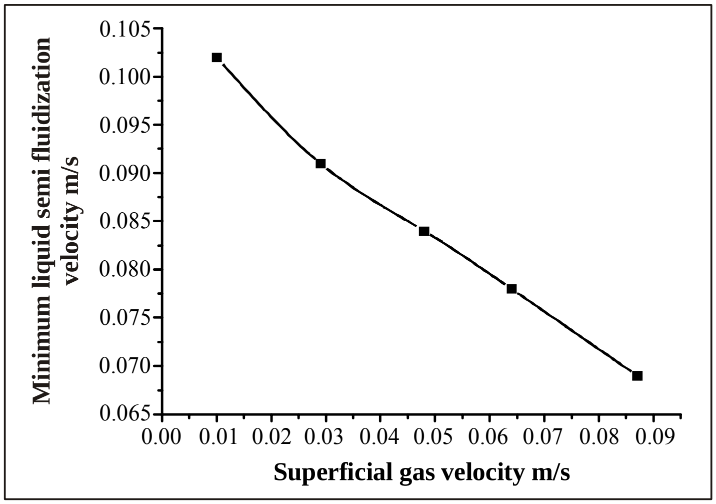

Fig. 3: Variation of minimum liquid semi-fluidization velocity with superficial gas velocity for 0.003 m glass beads at R = 2 and hs = 0.17 m

The expansion ratio in the semi-fluidized bed is defined as the ratio of the height of top grid to the initial static bed height of the solid particles. Figure 4 shows the variation of pressure drop with superficial liquid velocity at various expansion ratios. The variation of minimum liquid semi-fluidization velocity with expansion ratio is shown in Figure 5. The minimum liquid semi-fluidization velocity increases with expansion ratio for a definite particle size and constant gas velocity.

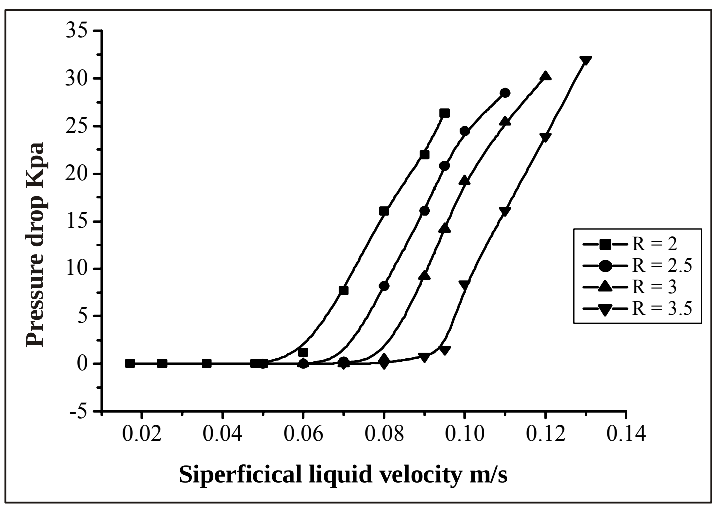

Fig. 4: Variation of bed pressure drop with superficial liquid velocity at different bed expansion ratios for 0.003 m glass beads at hs = 0.25 m and Ug = 0.064 m/sec.

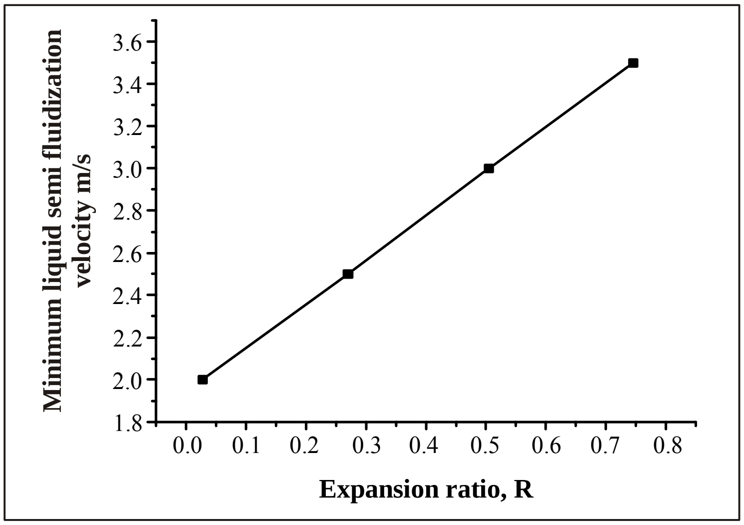

Fig. 5: Variation of minimum liquid semi-fluidization velocity with bed expansion ratio for 0.003 m glass beads at hs = 0.25 m and Ug = 0.064 m/sec.

CONCLUSION

The hydrodynamic study of the three-phase semi-fluidized bed with spherical particles reveals that the minimum liquid semi-fluidization velocity (Ulmsf) is a strong function of gas superficial velocity and bed expansion ratio. The study will help in successful design and operation of a three-phase semi-fluidized bed reactor. Minimum liquid semi-fluidization velocity is increases with bed expansion ratio and decreases with superficial gas velocity.

Nomenclature

dp	Particle diameter, mm
hs	static bed height, m
ΔP	Pressure drop, Pa
Ul	Superficial liquid velocity, m/s
Ulmsf	Minimum liquid semi-fluidization velocity
Ug	Superficial gas velocity, m/s
ρ	Phase density, Kg/m^3
R	Expansion ratio

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