Liquid-Solid Semi-Fluidization of Homogenous Mixtures — II: Prediction of Maximum Semi-Fluidization Velocity

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ABSTRACT

The necessity of a generalized correlation for predicting the maximum semi-fluilization velocity is stressed. The experimental set up used for the study has been described in detail. Values of the maximum semi-fluidization velocity, obtained from the experimental data have been compared with those from -theoretical equation, developed earlier for single sized particles and the deviations have been commented.

INTRODUCTION :

The various aspects of liquid-solid semi-lluidization studied and reported earlier by different authors include the prediction of minimum and maximum semi-fluidization velocities, (1, 2, 3, 4) packed bed formation (5, 6, 7) and pressure drop across a semi-fluidized bed (8). Although considerable information is available for semi-fluidization characteristics of close-cut particles in liquid-solid system, literature related to the behaviour of mixed particles system is very limited (9).

Here an attempt has been made to calculate the maximum semi-fluidization velocities by the equation developed for single-sized particles incorporating suitable modifications and compare the same with the experimental values.

Experimental set-up

The experimental set-up used in the present study is described in Fig. 1. The semi-fluidizer is a perspex column of 2.54 cms. inside diameter and 100 cms long inserted between two flanges and provided with an inclined feeder at a height of about 21 cms. from the base for intermediate addition and removal of materials to the column. A movable restraint made up of 100 mesh stainless steel screen is placed between two perspex rings, the outside diameter of which is very close to the inside diameter of the column. With the help of a 3 mm. diameter brass rod this restraint can slide to any position in the column. A rotameter is included in the liquid line and the fluid is recirculated by means of a pump. Two pressure taps, one just below the bottom

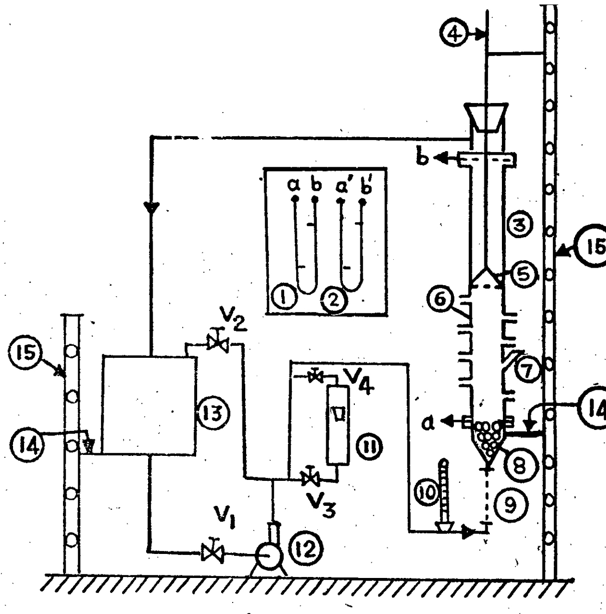

FIG. 1. SCHEMATIC DIAGRAM OF THE LIQUID-SOLID SEMI-FLUIDIZATION SET-UP

1 & 2. Manometers for bed pressure drop
3. Semi-Fluidizer
4. Movable Restraint Assembly
5. Top Restraint
. 6. Intermediate Pressure Tappings
7. Inclined Feeder
8. Distributor
9. Flexible Connection
10. Thermometer
11. Rotameter
12. Circulating Pump
13. Liquid Reservor
14. Base Plate Support
15. Supporting Structure
a. b. Column Pressure Tappings
V_1—V_5 Control Valves

screen and the other at the top of the column are provided to record the bed pressure drop. The inlet temperature of the liquid is noted by a thermometer.

RESULTS AND DISCUSSION :

Altogether 32 sets of runs were taken using

TABLE — 1

CHARACTERISTICS OF MIXTURES AND RANGES OF VARIABLES STUDIED

Material : Dolomite   Density : 2.83 gm/c.c.

Sl. No.	Mixture characteristics			$(d_p)_{av}$ From eqn. (2	R	cms. hs.
	Coarse (14/16 BSS	Fine (44/52 BSS)	Nomen-clature			
1.	90	10	M_1	0.1026		6.0
2.	70	30	M_2	0.0870		
					2.0	6.0
3.	50	50	M_3	0.0714	2.5	6.0,8.0
			M_4	0.0558	3.0	10.0,12.0
4.	30	70			3.5	6.0
5.	10	90	M_5	0.0402		6.0

various mixtures of a coarse (14/16 B.S.S.) and a fine (44/52 B.S.S.) size of dolomite particles to study the effects of various system parameters on Gmsf (maximum semi-fluidization velocity) values. The mixtures can be called homogenous with respect to density as only one type of material was used. The characteristics of solid mixtures and ranges of variables studied are given in Table 1.

Based on exhaustive experimentation one of the authors has given the following correlation for the prediction of maximum semi-fluidization velocities for singie sized particles in liquid solid system. (10).

$$G_{msf} = \frac{1.85 \times 10^4 (d_p)^{0.65} \rho_f (\rho_s - \rho_f)^{0.55}}{(\mu)^{0.1}} \quad (1)$$

The particle size 'd_p' in the above equation has been replaced by $(d_p)_{av}$ and this has been calculated by using the equation (11).

$$(d_p)_{av} = \Sigma x d \quad (2)$$

With $(d_p)_{av}$ the values of G_{msf} have been calculated by equation (1)

The experimental values of G_{msf} have been obtained from the packed bed formation Vs. mass velocity plots. It is observed that the maximum semi-fluidization velocity is little affected by both static bed height and the bed expansion ratio (Figs. 2 and 3 respectively). However, the mixture characteristics have profound influence on the maximum semi-fluidization velocity (Fig. 4).

The experimental values of G_{msf} have been compared in Table 2 with those obtained by equation (1) modified with respect to particle size by using $(d_p)_{av}$ found from eqn. (2). The deviations lie within 7.5 to — 19.0. It is observed that in all the cases (except one) the experimental values are higher than the calculated ones. Maximum semi-fluidization velocities have been calculated on the basis of the average values of particle size whereas in an actual semi-fluidization experiment with mixtures, it is always possible that the fluid velocities necessary to lift the coarser particles will be higher than those calculated from the average particle diameters of the mixtures. The deviations are comparatively more for mixtures containing coarser components in the range of 30 — 70%.

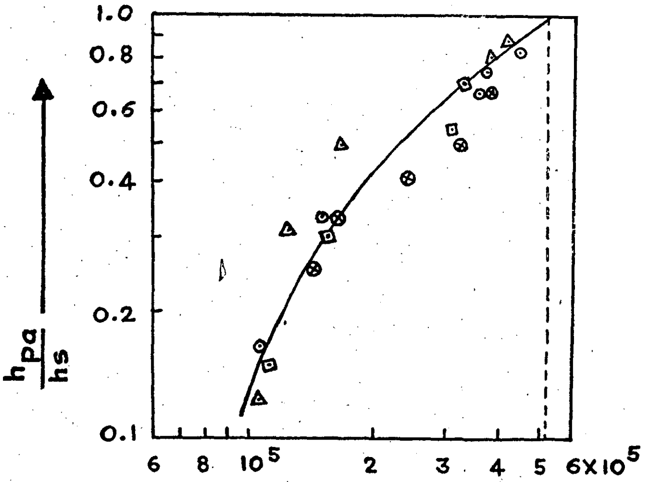

FIG. 2. EFFECT OF STATIC BED HEIGHT ON MAX SEMI-FLUIDIZATION VELOCITY

Fluid Mass Velocity, G, kg/Hr. M^2.
System Dolomite-Water
Mixture Characteristics : M_3 (50 : 50)
Bed Expansion Ratio : R 2.5

LEGEND

h_{s1} ------ ⊙
h_{s2} ------ △
h_{s3} ------ ⊡
h_{s4} ------ ⊗

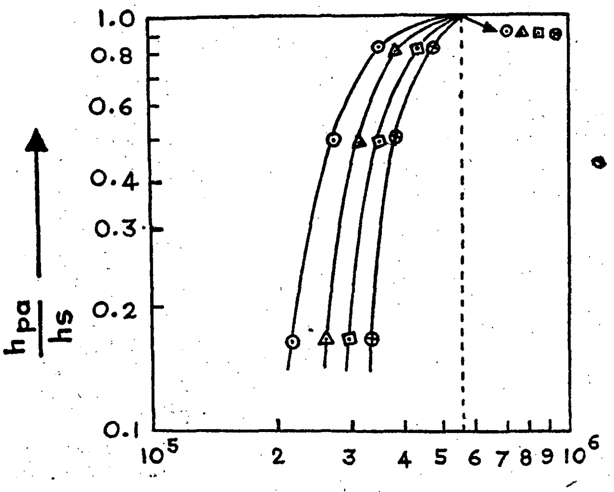

FIG. 3. EFFECT OF BED EXPANSION RATIO ON MAX m SEMI-FLUIDIZATION VELOCITY

Fluid Mass Velocity, G, kg/Hr. M^2.
System Dolomite-Water
Static Bed Height : 6 cm.
Mixture Characteristics M_1 (10 : 90)

LEGEND

R = 2 ------ ⊙
R = 2.5 --- △
R = 3 ----- ⊡
R = 3.5 --- ⊗

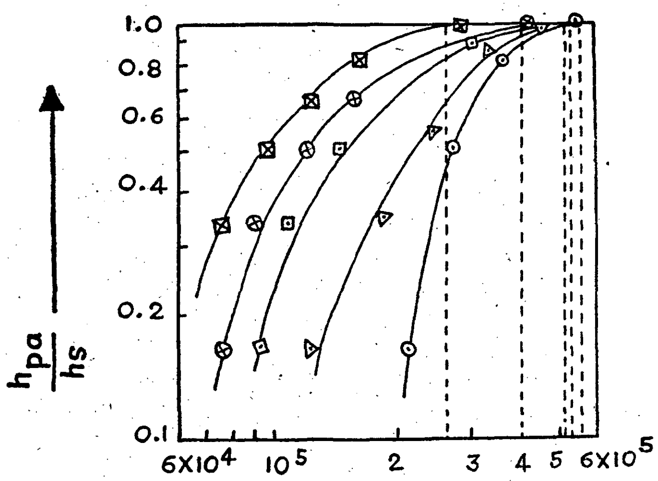

FIG. 4. EFFECT OF MIXTURE CHARACTERISTICS ON MAX m SEMI-FLUIDIZATION VELOCITY

Fluid Mass Velocity, G, kg/Hr. M^2.
System Dolomite-Water
Static Bed Height : hs—6
Bed Expansion Ratio : R—2
Mixture Characteristics .

LEGEND

M_1 -------- ⊙
M_2 -------- △
M_3 -------- ⊡
M_4 -------- ⊗
M_5 -------- ⊠

TABLE — 2

COMPARISON OF THE MAXIMUM SEMI- FLUIDIZATION VELOCITIES

Sl. No.	Mixture characteristics	G_{msf} From Expt.	Kg./hr (M^2) From Eqn.	Deviation of calculated values from the Experimental values
1.	M_1	550000	524000	— 4.72
2.	M_2	520000	474000	— 8.84
3.	M_3	510000	414000	—18.82
4.	M_4	400000	354000	—11.50
5.	M_5	265000	285000	+ 7.55

ACKNOWLEDGEMENTS :

The authors are thankful to B.S. & I.R., Orissa for providing the necessary finance to carry out this work.

Nomenclature :

B.S.S. = British Standard Sieve
D_c = Diameter of the semi-fluidizer, L
d_i = Particle diameter, L
$(d_p)_{avg}$ = Average particle diameter for mixture, L
G_{msf} = Maximum semi-fluidization velocity, $ML^{-2}\theta^{-2}$
h = Height of semi-fluidized bed, L
h_s = Height of initial static bed, L
$M_1, M_2 \ldots M_5$ = Nomenclature for mixtures
R = Bed expansion ratio in semi-fluidization dimensionless, h/hs
x = Mass fraction of components of the mixture

Greek Letters :

ρ_s = Density of solid, ML^{-3}

ρ_f = Density of fluid, ML^{-3}

μ = Viscosity of fluid, $ML^{-1}\Theta^{-1}$

Σ = Summation

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Reprinted from "INDIAN CHEMICAL JOURNAL", January, 1976