Liquid—Solid Semi-fluidization of Homogeneous Mixtures-1

Prediction of the onset of semi-fluidization velocity

Dr. G. K. ROY, B.Sc. Chem. Engg., M. Tech., Ph.D., A.M.I.E. (India), A.M.I.I.Ch.E., Assistant Professor
J. DASH, B.SC. Chem. Engg., Junior Research Fellow, B.S. & I.R. Scheme,
Department of Chemical Engineering Regional Engineering College,
Rourkela-769 008. Orissa India

ABSTRACT

The necessity of a generalised correlation for the prediction of the onset of semi-fluidization velocity for homogeneous mixtures is stressed. Details of an experimental set-up used for the study have been outlined. Values of the onset of semi-fluidization velocity have been compared with those obtained from theoretical equation, developed earlier for single sized particles and the deviations have been critically commented.

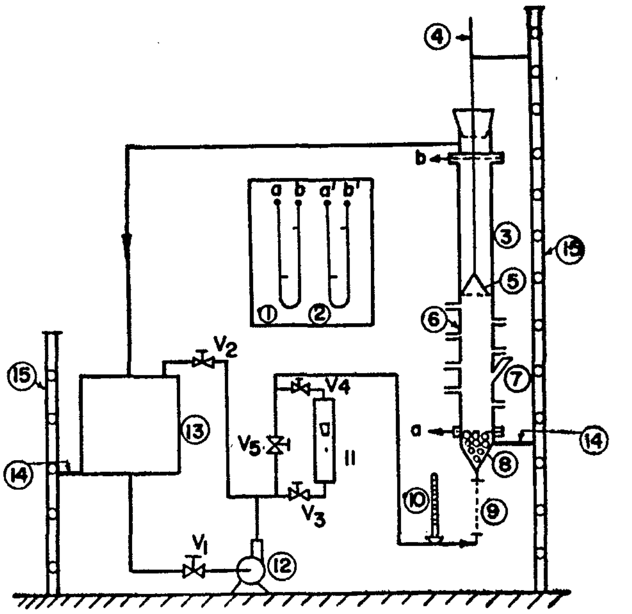
INTRODUCTION:

Semi-fluidization is a unique and novel type of fluid-solid contacting technique which has been reported in the early sixties. Like the packed and the fluidized bed techniques this is also a two-phase phenomenon. A semi-fluidized bed is a compromise between the packed and the fluidized bed conditions and can be achieved in a conventional fluidizer by incorporating certain modifications to the column constructions.

The various aspects of liquid-solid semi-fluidization which have been 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 and gas-solid systems, behaviour of mixed particle systems has not been touched with. An attempt has therefore been made here to develop a correlation for such systems which will relate the ratio of maximum semi-fluidization velocity to minimum semi-fluidization velocity with the system parameters. This information will be quite useful for the design of MT reactors.

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 21.0 cms. from



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 reservoir
14. Base plate support
15. Supporting structure

a, b, Column pressure tappings

v_1-v_5 Control valves

Fig. 1 — Schematic diagram of the liquid-solid semi-fluidization set-up

Reprinted from **Indian Chemical Journal** February, 1977

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 nearly the same as the inside diameter of the column. With the help of a 3 mm. diameter brass rod this restraint can be moved to any position within 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 screen and the other at the top of the column are provided to record the bed pressure drops. The inlet temperature of liquid is noted by a thermometer.

Results and Discussion:

Altogether 40 sets of runs were taken using various mixtures of a coarse (14/16 BSS) and a fine (44/52 BSS) size of dolomite particles to study the effects of various system of parameters on G_{osf} values. The mixtures can be called homogeneous with respect to density as only one type of material was used. Properties for fluids and the characteristics of solid mixtures used in the experiments are given in Table 1 and 2 respectively.

Production of the onset of semi-fluidization velocity (G_{osf}) for mixtures: Based on exhaustive experimentation the author has given the following correlations for the prediction of the maximum and the minimum semi-fluidization velocities for single-sized particles in liquid-solid systems (9).

For maximum semi-fluidization velocity;

$$G_{msf} = 1.85 \times 10^5 \frac{(d_p)^{0.65} \; [\rho_f (\rho_s - \rho_f)]^{0.55}}{\mu \, 0.10} \quad \text{...... (1)}$$

and, for minimum semi-fluidization velocity,

$$\frac{G_{osf}}{G_{msf}} = 0.473 \; (D_c/d_p)^{-0.20} \; (\rho_s/\rho_f)^{0.17} \; (R)^{0.38} \quad \text{... (2)}$$

The particle size 'd_p' in the above equations has been replaced by (d_p) avg and this has been calculated by (10).

$$\frac{1}{(d_p)avg} = \Sigma \frac{x}{d_p} \quad \text{......... (3)}$$

With (dp)avg the values of G_{msf} have been calculated by equation (1) and the same have been used in equation (2) to obtain G_{osf} values. .

The experimental values of G_{osf} have been obtained from the pressure drop vs. mass velocity plots and have been given in Table-3. It is observed that the the onset of semi-fluidization velocity is little affected by the initial static bed heights (Fig. 2) and hence average

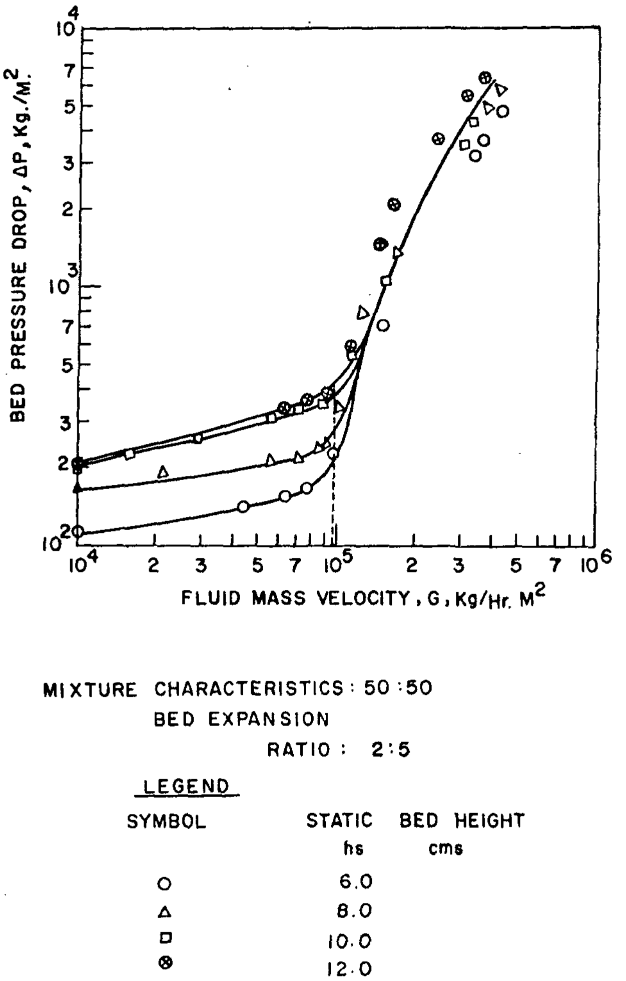


Fig. 2 — Effect of initial static bed height on the onset of semi-fluidization velocity

values can be used for such cases. Moreover bed expansion ratio and mixture characteristics have profound influence on the onset of semi-fluidization velocity. With the increase of bed expansion ratio, the onset velocities increase (Fig. 3) whereas with the increase of fine concentration in the mixture the values decrease (Fig. 4).

The experimental values of G_{osf} have been compared in Table 4 with those obtained for single sized particles by equation (1) & (2) modified with respect to particle size. In majority of the cases the deviations lie within

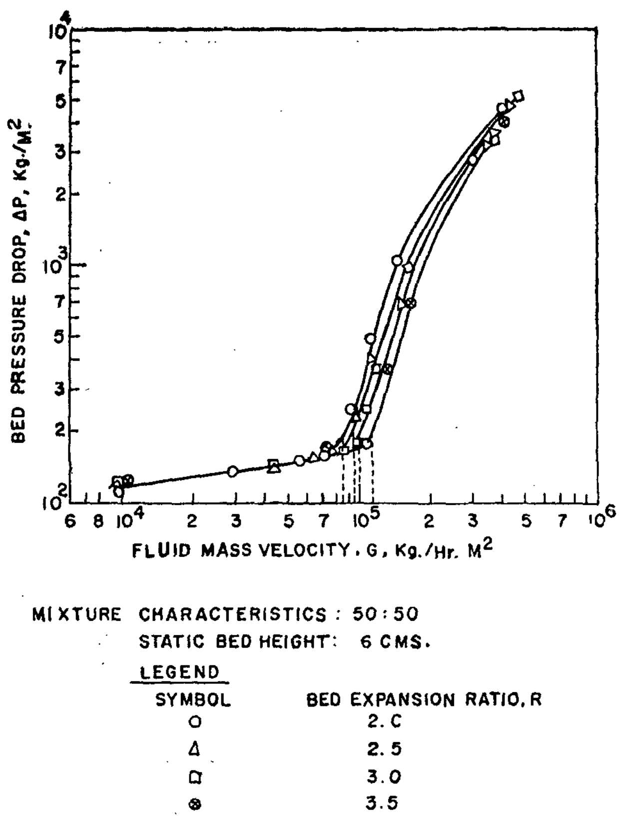


Fig. 3 — Effect of bed expansion ratio on the onset of semi-fluidization velocity

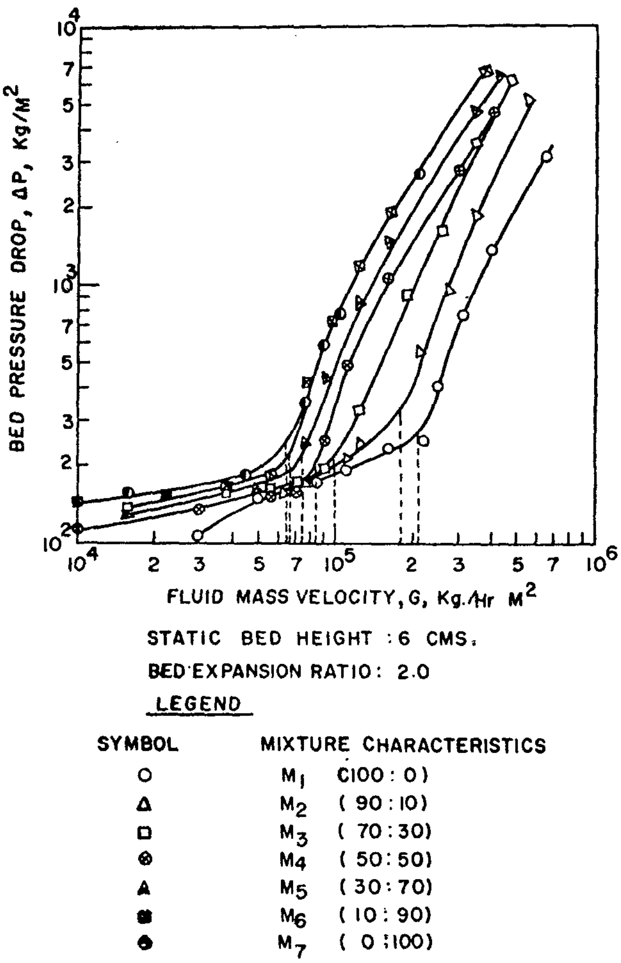


Fig. 4 — Effect of mixture characteristics on the onset of semi-fluidization velocity

+ 25% to —7.0%. It has also been found that the calculated values for mixtures M3, M4 and M5 deviate comparatively more from the experimental values. In all these cases, the experimental values are lower than the calculated ones. Average values of particle size have been used for calculation, whereas in an actual semi-fluidization experiment with mixtures, it is always possible that the fines will move at a faster rate than the coarser ones and reach the top restraint earlier, thus indicating a value of G_{osf}, which will be much less than the value calculated on the basis of average particle diameter of mixtures. This is more apprehended in the case of semi-fluidized bed containing appreciable fines, say in the range of 30-70%.

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_p = Particle diameter, L

(d_p) avg = Average particle diameter for mixture, L

G_{osf} = Minimum (onset of) semi-fluidization velocity, $ML^{-2}\Theta^{-1}$

G_{msf} = Maximum semi-fluidization velocity $ML^{-2}\ \Theta^{-1}$

h = Height of semi-fluidized bed, L

h_s = Height of initial static bed, L

$M_1, M_2 \ldots M_7$ = Nomenclature for mixtures

ΔP = Pressure drop across semi-fluidized bed, FL^{-2}

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.

REFERENCES :

1. Kurian, J. and Raja Rao, M., Indian Jl. of Technol., 8,275, (1970).
2. Poddar, S. K. and Dutt, D. K., Transaction of the Indian Institute of Chem. Engrs., 11,80, (1969).
3. Roy, G. K. and Sarma, K.J.R., The Chem. Engg. Jl., 4, 294, (1972).
4. Roy G. K. and Sarma K.J.R., Jl. of the Instu. of Engrs. (India) 54,34, (1974).
5. Fan L. T. and Wen C.Y.. A.I.Ch.E. Jl., 7, 606, (1961).
6. Fan, L.T., Wang S.C. and Wen C.Y:, A.I.Ch.E. Jl., 9,316, (1963).
7. Roy G. K. and Sarma, K.J.R. Chem. Proc. & Engg., 5, No. 6, 23, (1971).
8. Roy G. K. and Sarma K.J.R., Indian Chem. Engr., 14,4,90, (1974).
9. Roy G. K., Ph.D. Thesis, Sambalpur University, 1974.
10. Kuni, D. and Levenspiel, O., Fluidization Engineering, John, Wiley, New York, 1969.

TABLE — 1

PHYSICAL PROPERTIES OF FLUIDS USED

No.	Fluid	Ave. temp. °C	Density gm/cc	Viscosity CP	Use
1.	Water	26	1.00	0.874	Semi-fluidizing medium.
2.	Carbon tetrachloride	26	1.63	—	Manometer Liquid
3.	Mercury	26	13.60	—	Manometer Liquid

TABLE — 2

CHARACTERISTICS OF MIXTURES AND RANGES OF VARIABLES STUDIED

Material : dolomite **Density : 2.83 gm/cc.**

Sl. No.	Mixture characteristics				R	hs cms
	Coarse (14/16 BSS) %	Fine (444/52 BSS) %	Nomenclature	(dp) avg cm		
1.	100	0	M_1	0.1104		6.0
2.	90	10	M_2	0.0890		6.0
3.	70	30	M_3	0.0641	2.0	6.0
					2.5	
4.	50	50	M_4	0.0501	3.0	6.0, 8.0
					3.5	10.0, 12.0
5.	30	70	M_5	0.0411		6.0
6.	10	90	M_6	0.0348		6.0
7.	0	100	M_7	0.0324		6.0

TABLE — 3

EXPERIMENTAL MINIMUM SEMI-FLUIDIZATION VELOCITIES FOR MIXTURES

Sl. No.	Mixtures	hs cms	Maximum semi-fluidization velocities at various bed expansion ratios (R) R = 2.0	R = 2.5	R = 3.0	Kg/hr M^2 R = 3.5
1	M_1	6.0	210000	240000	260000	280000
2.	M_2	6.0	180000	195000	220000	240000
3.	M_3	6.0	100000	125000	135000	145000
4.	M_4	6.0	85000	95000	100000	115000
		8.0	85000	95000	100000	115000
		10.0	90000	100000	105000	120000
		12.0	90000	100000	105000	120000
		avg. value	87500	97500	102500	117500
5.	M_5	6.0	75000	85000	93000	105000
6.	M_6	6.0	67000	77000	90000	95000
7.	M_7	6.0	65000	73000	85000	95000

TABLE — 4

COMPARISION OF THE ONSET OF SEMI-FLUIDIZATION VELOCITIES

Sl. No.	Mixtures	G_{msf}, kg/hr. M^2	R	G_{osf}, kg/hr. M^2 From expt.	G_{osf}, kg/hr. M^2 From eqn.	Percentage deviation of calculated values from the experimental values
1.	M_1	551000	2.0	210000	216500	+ 3.10
			2.5	240000	235500	— 1.87
			3.0	260000	252500	— 2.88
			3.5	280000	267500	— 4.46
2.	M_2	481500	2.0	180000	182000	+ 1.11
			2.5	195000	197500	+ 1.28
			3.0	220000	211500	— 3.36
			3.5	240000	224600	— 6.41
3.	M_3	389500	2.0	100000	137600	+37.6
			2.5	125000	149700	+19.8
			3.0	135000	160000	+18.5
			3.5	145000	169500	+16.9
4.	M_4	332000	2.0	87500	111700	+27.6
			2.5	97500	121000	+24.1
			3.0	102500	130000	+26.8
			3.5	117500	138000	+17.45
5.	M_5	290000	2.0	75000	93500	+24.70
			2.5	85000	101800	+19.75
			3.0	93000	109000	+17.20
			3.5	105000	115700	+10.20
6.	M_6	262000	2.0	67000	81600	+21.80
			2.5	77000	88600	+15.05
			3.0	90000	95000	+ 5.55
			3.5	95000	100800	+ 6.10
7.	M_7	250400	2.0	65000	77000	+18.46
			2.5	780000	83700	+ 7.30
			3.0	85000	89700	+ 5.52
			3.5	95000	95200	+ 0.21