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Semifluidization Characteristics of Some Gas-Solid Heterogeneous Binary Mixtures of Particles

B MONDAL, P. THOMAS, J. S. N. MURTHY AND G. K. ROY
Department of Chemical Engineering, R. E. College, Rourkela 769 008

IN VIEW of the distinct advantages of a heterogeneous semifluidized bed, it is a prerequisite for clearly understanding the dynamics of the system and the interrelations between the relevant process parameters. Although various aspects of gas-solid semifluidization for close-cut particles have been reported in the literature,[1] very little information[2] is available for mixtures of a heterogeneous nature.

In this communication correlations relating to gas-solid semifluidization characteristics (viz. the minimum and maximum semifluidization velocities and semifluidized bed pressure drop) of the heterogeneous binaries of spherical particles have been reported.

Experimental

Semifluidization characteristics of five different binaries (mustard seed, sago, glass bead and urea) in the proportion of 50:50 with varying static bed heights and bed expansion ratios have been studied. Three different particle sizes for a 50:50 mixture of mustard seed and sago and five different mixture proportions of mustard seed and glass bead have also been investigated. The ranges of variables studied appear in *Table 1.*

Development of Correlations

Based on the experimental data and from a dimensional analysis approach, the following correla-

TABLE I

RANGES OF VARIABLES STUDIED

Sl. No.	Mixture components	Mixture proportions	ρ_{sav} (Kg/m³)	d_p (m)	h_s (m)	R
1.	Mustard seed-glass bead	50:50	1588	0.00100076	0.104	2.0, 2.5, 3.0, 3.5
2.	-do-	20:80	2070	-do-	0.045	-do-
3.	-do-	40:60	1720	-do-	0.073	-do-
4.	-do-	60:40	1470	-do-	0.137	-do-
5.	-do-	77:23	1312	-do-	0.177	-do-
6.	Mustard seed-sago	50:50	1218	-do-	0.130	-do-
7.	Glass bead-sago	50:50	1737	-do-	0.127	-do-
8.	Sago-urea	50:50	1464	-do-	0.115	2.5
9.	Mustard seed-urea	50:50	1357	-do-	0.125	2.5
10.	Mustard seed-sago	50:50	1218	0.0011705	0.05, 0.07, 0.103, 0.130	2.0
11.	Mustard seed-sago	50:50	1218	0.0014100	0.03, 0.06, 0.085	2.0

Particle density of pure components in Kg/m³ are : mustard seed—1143.0, sago—1304.0, urea—1670.0 and glass bead—2600.0 tions have been developed to predict the semifluidization dynamics for heterogeneous binaries of spherical particles,

Minimum semifluidization velocity

$$Re_{osf} = 1.83 \left(\frac{Dc}{d_p}\right)^{-1.07} \left(\frac{\rho_{sav}}{\rho_f}\right)^{1.32} (R)^{0.50} \quad (1.A)$$

$$\text{or, } G_{osf} = ^{1.88} \frac{(\mu)}{d_p} \left(\frac{Dc}{d_p}\right)^{1.0} \left(\frac{\rho_{sav}}{\rho_f}\right)^{1.32} (R)^{0.50} \quad (1.B)$$

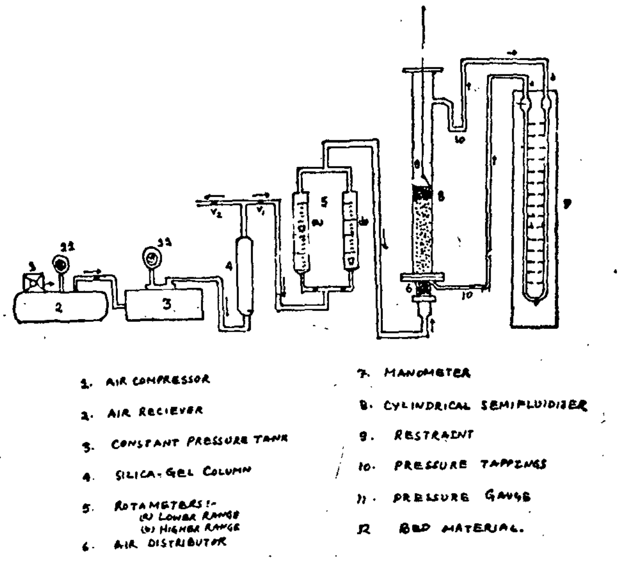

Fig. 1 Schematic diagram of the experimental set-up

Maximum semifluidization velocity

$$Re_{msf} = ^{5.3} \left(\frac{Dc}{d_p}\right)^{-2.08} \left(\frac{\rho_{sav}}{\rho_f}\right)^{2.04} \quad (2.A)$$

$$\text{or, } G_{msf} = ^{5.3} \frac{(\mu)}{d_p} \left(\frac{Dc}{d_p}\right)^{-2.08} \left(\frac{\rho_{sav}}{\rho_f}\right)^{2.04} \quad (2.B)$$

Pressure drop for semifluidized bed

$$\frac{\Delta P_{sf}}{\Delta P_{mf}} = 2.5 \times 10^{3} \left(\frac{\rho_{sav}}{\rho_f}\right)^{0.80} \left(\frac{Dc}{d_p}\right)^{-0.62} (R)^{0.54} \left(\frac{h_{pa}}{h_s}\right)^{0.18} \quad (3)$$

$$\text{where, } \Delta P_{mf} = h_s (\rho_{sav} - \rho_f)(1 - \epsilon_{mf}) \quad (4)$$

Average particle density (ρ_{sav}) in the above equations has been calculated as

$$\rho_{sav} = \sum \frac{W}{W/\rho} \quad (5)$$

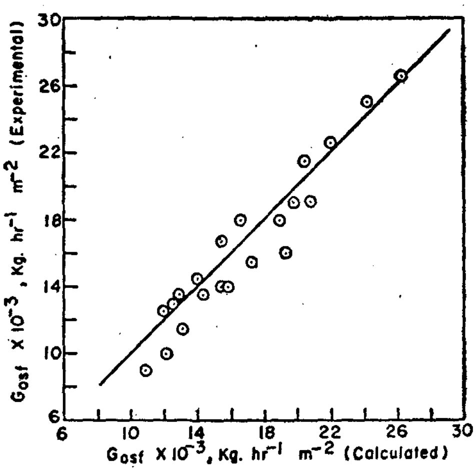

Fig. 2 Comparison of G_{osf} *values*

A theoretical equation has also been developed for the prediction of the minimum semifluidization velocity from the bed expansion data (incorporating the influence of particle interaction), from a hindered settling approach (3) through Steinour's concentration correction term, ψp. The equation is

$$G_{osf} = 0.62 \left(\frac{R-1}{R}\right)^{1.1} (G_t - G_{mf}) + G_{mf} \quad (6)$$

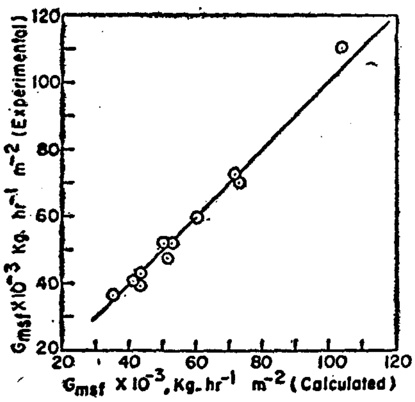

Fig. 3 Comparison of $\overline{G}_{msf}$ *values*

Results and Conclusion

The values for minimum semifluidization velocity have been found from the bed pressure drop versus mass velocity plots obtained from diverse experimental conditions, viz. binary types, mixture proportions, particle size, static bed height and bed expansion ratio. These values have been compared with the corresponding ones obtained with the help of equations (1.B) and (6). Experimental values for maximum semifluidization velocity were obtained from the extrapolation of the fractional packed bed formation (h_{ps}/h_s) versus mass velocity plots and then compared with those calculated from equation-(2.B.). Values of the semifluidized bed pressure drop for sixty-two cases obtained in different experimental runs have been compared with the corresponding calculated ones obtained with the help of equations (3) and (4).

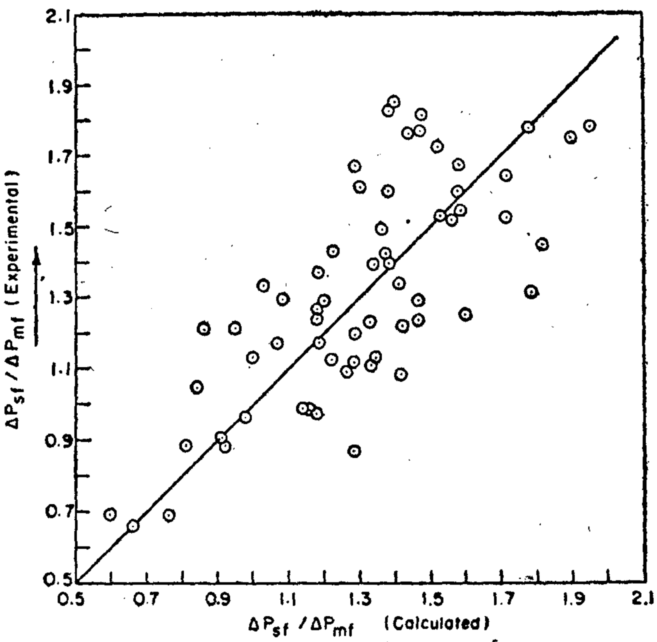

Fig. 4 Comparison of $\Delta P_{sf}/\Delta P_{mf}$ values

The mean and standard deviations for the calculated values are given as under :

TABLE II

Sl. No.	Characteristics	Deviations, % mean	standard
1.	G_{osf} (Calculated from eqn. 6)	15.30	18.04
	G_{osf} (Calculated from eqn. 1.B)	8.80	10.17
2.	G_{msf}	3.83	4.88
3.	$\frac{\Delta Psf}{\Delta Pmf}$	16.00	18.47

The correlations developed will be useful for the prediction of gas-solid semifluidization characteristics of heterogeneous binary mixtures of spherical particles.

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NOMENCLATURE

d_p	particle diameter, L
D_c	column diameter, L
G_{mf}	mass velocity for minimum fluidization condition, $ML^{-2}\ \theta^{-1}$
G_{msf}	mass velocity for maximum semifluidization condition, $ML^{-2}\ \theta^{-1}$
G_{osf}	mass velocity for the onset of semifluidization, $ML^{-2}\ \theta^{-1}$
G_t	mass velocity for hindered setting condition, $ML^{-2}\ \theta^{-1}$
h_{ps}	height of packed section in semifluidization, L
h_s	height of initial static bed, L
ΔP_{sf}	pressure drop across semifluidized bed, FL^{-2}
ΔP_{mf}	pressure drop across bed corresponding to minimum fluidization, FL^{-2}
R	bed expansion ratio in semifluidization, dimensionless
W	weight of solids in the bed, M

Greek letters

ϵ_{mf}	bed porosity corresponding to minimum fluidization, dimensionless
ρ_f	density of fluid, ML^{-3}
ρ_s	density of solid, ML^{-3}
ρ_{sav}	average density of heterogeneously-mixed particles, ML^{-3}
μ	viscosity of fluid, $ML^{-1}\ \theta^{-1}$
ψP	Steinour's concentration correction factor for hindered settling, dimensionless

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