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Liquid–solid semi-fluidization of heterogeneous mixtures

II: Prediction of the minimum semi-fluidization velocity

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Data on liquid–solid semi-fluidization characteristics for heterogeneous mixtures are reported. Values of the minimum semi-fluidization velocity obtained from experimental investigations are compared with those calculated from a modification of a theoretical equation developed earlier for single-sized particles.

Although considerable information is available on the dynamics of liquid–solid semi-fluidization of close-cut particles[1–8], literature relating to the behaviour of mixed particle systems is very limited[9]. In a recent communication[10], a correlation was suggested for the prediction of the maximum semi-fluidization velocity for heterogeneous mixtures. In this paper a correlation is developed which relates the ratio of minimum and maximum semi-fluidization velocities to the system parameters. The apparatus used in the present study is described in detail in an earlier paper[9]. Altogether 32 sets of observations were made using five different combinations of dolomite, chromite, baryte and iron ore particles, all of size 36/44 BSS (British Standard Sieve).

Prediction of minimum semi-fluidization velocity

Based on his experimental investigations, Roy[11] presented the following correlation for prediction of the minimum semi-fluidization velocity of pure components in liquid–solid systems:

$$\frac{G_{0sf}}{G_{msf}} = 0.473 \left(\frac{D_c}{d_p}\right)^{-0.20} \left(\frac{\rho_s}{\rho_f}\right)^{0.17} R^{0.38} \qquad (1)$$

G_{msf} can be calculated using[11]

$$G_{msf} = 1.85 \times 10^4 \frac{d_p^{0.65}\{\rho_f(\rho_s - \rho_f)\}^{0.55}}{\mu_f^{0.10}} \qquad (2)$$

The particle density in eqns. (1) and (2) is replaced by $(\rho_s)_{av}$ for mixtures, where

$$(\rho_s)_{av} = \Sigma W \Big/ \Sigma \frac{W}{\rho_s} \qquad (3)$$

The experimental values of G_{0sf} were obtained from plots of the bed pressure drop *versus* fluid mass velocity and are presented in Table 1. It has been observed that the minimum semi-fluidization velocity is little influenced by the initial static bed height (Fig. 1) and hence an average value of the velocity can be used for different bed heights. However, with an increase in bed expansion ratio, the values of G_{0sf} also increase (Fig. 2). Similarly the characteristics of the mixture have a marked influence on the minimum semi-fluidization velocity. Increase in the density of the mixture increases the above values (Fig. 3).

The experimental values of G_{0sf} have been compared (Table 1) with those obtained using eqns. (1) and (2), modified to account for the mixture density. The deviations lie within 0 to −10%. It is observed that in all these cases the experimental values are lower than the calculated ones. Average values of the particle density have been used for calculation, whereas in an actual semi-fluidization experiment with mixtures it is always possible that the lighter components will move at a faster rate than the heavier ones and will reach the top restraint earlier. This will give a value of G_{0sf} that is smaller than the value calculated on the basis of the average density. Nevertheless, the equation developed for pure components can be used for solid binaries without great error, as shown above.

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NOMENCLATURE

d_p	particle diameter, L
D_c	diameter of the semi-fluidizer, L
G	mass velocity of the fluid, $ML^{-2}T^{-1}$
h	height of the semi-fluidized bed, L
h_s	height of the initial static bed, L

TABLE 1

Comparison of minimum semi-fluidization velocity for heterogeneous mixtures

Mixture	*Mixture density* (kg m^{-3})	G_{msf} *(from eqn. (2))* (kg h^{-1} m^{-2})	*R*	G_{osf} (kg h^{-1} m^{-2})		*% deviation from expt.*
				calc.	*expt.*	
Dolomite–chromite	3 210	309 000	2.0	100 000	94 750	−5.54
			2.5	109 000	105 250	−3.57
			3.0	117 000	113 750	−2.85
			3.5	124 000	120 000	−3.33
Dolomite–baryte	3 450	327 000	2.0	108 000	100 000	−8.00
			2.5	117 500	114 000	−3.07
			3.0	126 000	124 000	−1.61
			3.5	134 000	130 000	−3.08
Dolomite–iron ore	3 670	339 000	2.0	112 500	110 000	−2.27
			2.5	122 000	115 000	−6.08
			3.0	131 500	120 000	−9.55
			3.5	139 500	128 000	−9.00
Iron ore–chromite	4 340	384 000	2.0	132 000	120 000	−10.00
			2.5	143 500	137 000	−4.75
			3.0	154 000	145 000	−6.22
			3.5	163 500	155 000	−5.47
Iron ore–baryte	4 800	411 000	2.0	143 000	132 000	−8.31
			2.5	155 000	150 000	−3.34
			3.0	166 000	160 000	−3.75
			3.5	176 500	165 000	−6.96

Mixture characteristics: 36/44 BSS size; 50:50 binary.

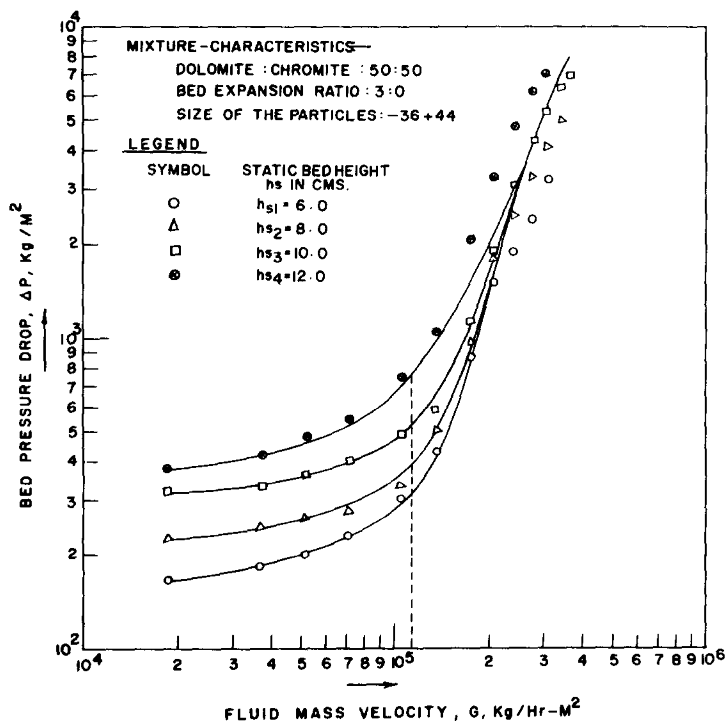

Fig. 1. Effect of the initial static bed height on the onset of semi-fluidization velocity.

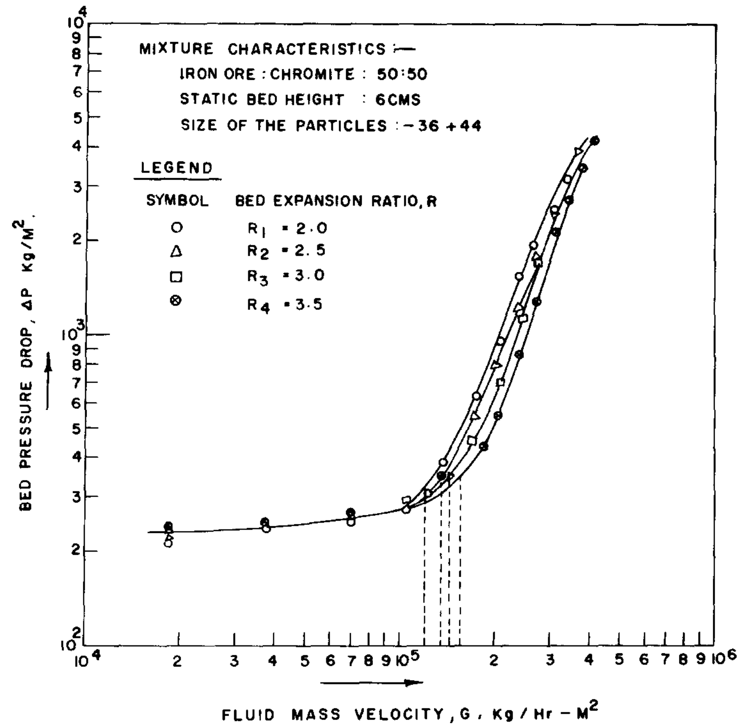

Fig. 2. Effect of the bed expansion ratio on the onset of semi-fluidization velocity.

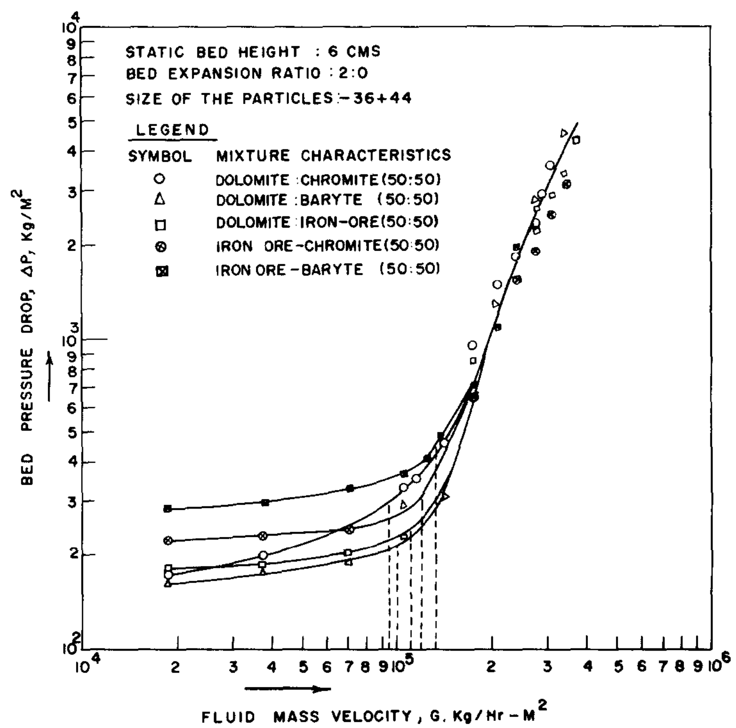

Fig. 3. Effect of the mixture characteristics on the onset of semi-fluidization velocity.

ΔP	pressure drop across the semi-fluidized bed, FL^{-2}
R	h/h_s, bed expansion ratio in semi-fluidization, dimensionless
W_1, W_2...	weights of the components of the mixture
x	mass fraction of the components of the mixture

Greek symbols

ρ	density, ML^{-3}
μ	viscosity, $ML^{-1}T^{-1}$

Subscripts

av	average
f	fluid
msf	maximum semi-fluidization condition
Osf	minimum semi-fluidization condition
s	solid

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