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Short Communication

Prediction of Minimum Liquid-Solid Semifluidization Velocity from Bed-Expansion Data

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A correlation has been proposed for the prediction of the minimum semifluidization velocity from bed-expansion data for liquid-solid systems. The influence of particle interaction on hindered settling has been incorporated through Steinour's concentration-correction term, ψ_p. Values calculated by the correlation have been compared with the experimental ones obtained over a wide range of operating parameters, viz. particle size, shape and density for both pure-component and binaries (mixed particle and mixed-density systems).

EXTENSIVE investigations have been carried out in the field of semifluidization during the last three decades with a view to establish this phenomenon in the chemical process industries because of its obvious advantages over conventional packed and fluidized beds.[1-3] A recent review by Murthy and Roy[4] summarizes the available literature on semifluidization relating to momentum, heat and mass transfer, and to its application to the design of reactors and to miscellaneous industrial applications.

In order to apply the concept of semifluidization more extensively to industrial processes it is imperative that the various fundamental aspects are critically analysed and understood. Minimum semifluidization velocity in the fluid velocity which initiates the formation of a packed bed below the top restraint of a semifluidizer. Several correlations[5-7] are available for the prediction of this quantity in a liquid-solid semifluidized bed. These correlations being empirical in nature have a limited range of applicability. It has, therefore, been attempted in this communication to relate the bed expansion ratio with the velocity ratio, taking into account the influence of particle interaction on the hindered-settling phenomenon, and to propose a correlation for the prediction of minimum semifluidization velocity.

Development of Correlation

Velocity and bed expansion ratios have been correlated along the lines of Beranek and Sokol[8] which is of the form,

$$\frac{1}{R} = f(G_R) \qquad (1)$$

where

$$G_R = \frac{G_f - G_{mf}}{G_t - G_{mf}}$$

The use of a free-settling mass velocity for Gt in the above expression has incorporated an appreciable amount of error when applied to liquid fluidized beds; particularly of fine particles where particle interaction is considerable. Therefore, in the present calculation the value of Gt has been modified through Steinour's concentration correction term, Y_p, which is

$$\psi_P = e^{-4.19(1-\epsilon_e)} \qquad (2)$$

The above equation was developed for the settling of spheres in the Stokes' law. range. However, in the absence of a general relationship between the concentration correction factor and the expanded bed voidage for the entire range of Reynolds number, equation (2) has been used for

the complete flow regime and for spherical as well as non-spherical particles of close size ranges.

Incorporating ψ_p, the criterion K, for the fixation of the flow regime in the case of hindered settling, becomes,

$$K = d_p \left[\frac{g_c \rho_m (\rho_p - \rho_m) \psi_p^2}{\mu^2} \right]^{\frac{1}{3}} \tag{3}$$

With the help of appropriate equations[9] the values of Ut (hereafter *Gt)* can be calculated. G_{mf} is calculated from-

$$\frac{d_p G_{mf}}{\mu} = (33.67^2 + 0.0408\ K^3)^{\frac{1}{2}} \tag{4}$$

Ninety-one bed expansion data, using varying particle sizes of spherical (glass beads) and non-spherical (iron ore, chromite, baryte, dolomite and coal particles) materrials, have been correlated *(Figure 1)** in the form of

$$\left(1 - \frac{1}{R}\right) = G_R^{0.588} \tag{5}$$

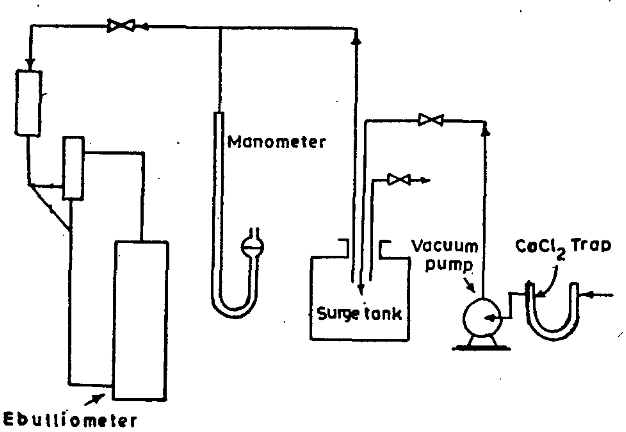


Fig. 1 : ***Schematic diagram of experimental set up.***
1. Ebulliometer 2. Mercury manometer 3. Surge tank 4. Vacuum pump 5. $CaCl_2$ trap

This equation can be used to predict minimum semifluidization velocity by modifying it in the form

$$G_{osf} = \left(1 - \frac{hs}{h}\right)^{1.79} (G_t - G_{mf}) + G_{mf} \tag{6}$$

Checking of **the** Correlation

The correlation has been tested for different liquid-solid systems of close-cut spherical and non-spherical particles as well as for homogeneous and heterogeneous mixtures as detailed in *Table I.* Fairly good agreement exists between the calculated and the experimental values of the minimum semifluidization velocicity *(Figure 2).**

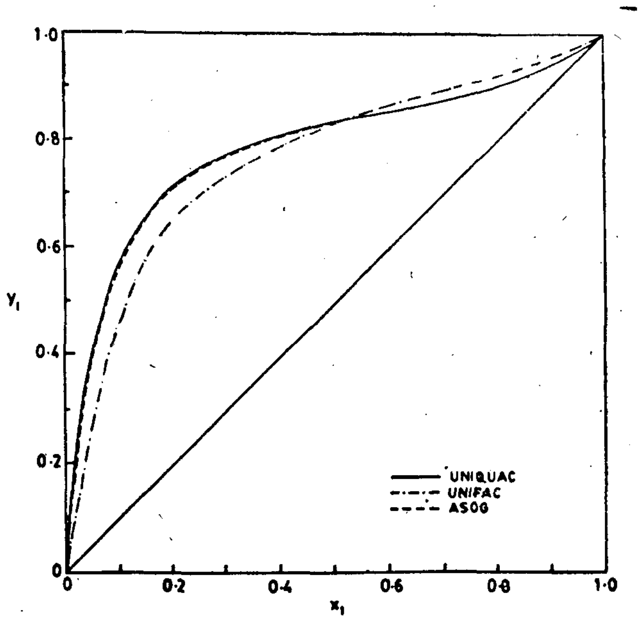
TABLE I

RANGES OF VARIABLES STUDIED

Sl. No.	Fluidized material	d_p (d_{pavg})* m	ρ (ρ_{avg})+ Kg/m³	R
Close cut particles				
1.	Glass beads	0.005000	2443	—2.0,2.5,3.0,3.
2.	Dolomite	0.002443	2830	-do-
3.	-do-	0.001104	-do-	-do-
4.	-do-	0.000550	-do-	-do-
5.	-do-	0.000388	-do-	-do-
6.	-do-	0.000273	-do-	-do-
7.	Coal	0.001104	1579	2.0,2.5,3.0
8.	-do-	0.000388	-do-	-do-
9.	Chromite	0.001104	3720	-do-
10.	-do-	0.000388	-do-	-do-
11.	Baryte	0.001104	4450	-do-
12.	-do-	0.000388	-do-	-do-
13.	Iron ore	0.001104	5250	-do-
14.	-do-	0.000388	-do-	-do-
Mixtures (homogeneous)				
15.	Dolomite	0.000890	2830	2.0,2.5,3.0.3.5
16.	-do-	0.000501	-do-	-do-
17.	-do-	0.000348	-do-	-do-
Mixtures (heterogeneous)				
18.	Dolomite-chromite	0.000388	3210	-do-
19.	Dolomite-baryte	-do-	3450	-do-
20.	Dolomite-iron ore	-do-	3670	-do-
21.	Iron ore-chromite	-do-	4340	-do-
22.	Iron ore-baryte	-do-	4800	-do-

* d_{pavg} *: average particle size for the homogeneous misture.*

+ ρ_{avg} *: average particle density for the heterogeneous mixture.*



**** Figures 1 and 2 contain some overlapping points***

Fig. 2 Equilibrium diagram : System ; Acetouitrile (1)—1—Butanol (2) Temperature : 348.15 K
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Conclusion

In a former observation[7] the values of minimum semifluidization velocity obtained from the bed expansion data were found to be varying widely from the experimental ones (obtained from ΔP ^{rs}G plots). This can be attributed *to* the fact that the particle interaction factor was not taken into account. The present correlation which has incorporated the effect by suitable modification of the settling-velocity term is, no doubt, a better approach for the prediction of minimum semifluidization velocity. As evident in *Figure 2,* the deviations for a few calculated values pertaining to large-diameter irregular particles are more comparatively. This may be attributed to the effect of particle roughness and the shape factor. However, in the present study the deviations of the calculated values for eighty different casses lie with $\pm$22 er cent for most of the cases with their mean and standard i values being 13.43 per cent and 16.19 per cent, respectively. The present correlation will be useful for the prediction of minimum liquid-solid semi-fluidization velocity for pure components and binaries and can be improved by incorporating the sphericity effect.

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NOMENCLATURE

d_p particle diameter, L

G_R mass velocity ratio, dimensionless

G_f mass velocity for fluidization condition, $ML^{-2}\theta^{-1}$

G_{mf} mass velocity for minimum fluidization condition, $ML^{-2}\theta^{-1}$

G_{osf} minimum mass velocity for elutriation (when h is column height), or for minimum mass velocity for semifluidization (when h is the height of the top restraint) $ML^{-2}\theta^{-1}$

G_t mass velocity for hindred settling condition, $ML^{-2}\theta^{-1}$

g_c gravitational constant, $L\theta^{-2}$

h column height (in the case of elutriation) or height of top restraint (in the case of semifluidization) L

h_s Initial static bed, L

Δp pressure drop across bed, FL^{-2}

R bed expansion ratio, $\frac{h}{h_s}$, dimensionless

U_t linear velocity for hindered settling condition $L\theta^{-1}$

Greek letters

ϵ_e expanded bed porosity, dimensionless

ψ_p steinour's concentration correction factor for hindered settling, dimensionless

ρ_m density of slurry, ML^{-3}

ρ_p density of particle, ML^{-3}

μ viscosity of the liquid, $ML^{-1}\theta^{-1}$

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