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Short Communication

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Dynamics of Liquid-Solid Semi-Fluidization (IV)

The necessity of a generalised correlation for the prediction of the pressure drop across a semi-fluidized bed is emphasized. Methods available for calculating the same have been briefly summarized. A correction factor in terms of system variables has been suggested to be applied to the calculated values of the pressure drop. For a few cases the values calculated, using the correction factor, have been compared with the experimental values.

SEMI-FLUIDIZATION is a recent development in the field of fluid-solid contact operations. Like the packed and the fluidized bed operations, this is also a two-phase phenomenon. A semi-fluidized bed is a compromise between the packed and the fluidized bed conditions. Special features of such a bed have already been reported in the literature.[1] Investigations dealing with various aspects of liquid-solid semi-fluidization, as reported earlier, have been reviewed by the authors.[2,3] A review of the literature reveals that, although a few correlations have been developed for the prediction of the minimum and the maximum semi-fluidization velocity, scanty information is available on the prediction of pressure drop in a liquid-solid semi-fluidized bed. The available correlations for the prediction of semi-fluidized pressure drops show wide deviations between the calculated and the experimental values. Therefore, an attempt has been made hereon similar lines to the work done earlier for the gas-solid systems[4]—suggesting a correction factor to the calculated values of pressure drop across a semi-fluidized bed in terms of various system parameters so that the exact values can be estimated.

Observations

Altogether 91 sets of runs have been taken using four non-spherical materials: coal, stone chips, dolomite and iron ore. Two different sizes of 6/8 and 14/16 BSS have been used. The lowest and the highest specific gravities of materials studied are 1.58 and 5.05 respectively. The properties of the fluid and the solid particles used in the experiments are given in an earlier paper.[5]

Prediction of Pressure Drop in a Semi-fluidized Bed

The pressure drop of a semi-fluidized bed is the algebraic sum of the pressure drops across the fluidized section and the packed section, as both are aligned in series in the direction of flow.

Hence, $$\triangle P_t = \left(\frac{\triangle P}{L}\right)_f (h - h_{pa}) + \left(\frac{\triangle p}{L}\right)_{pa} h_{pa} \qquad (1)$$

For the fluidized section

$$\left(\frac{\triangle P}{L}\right)_f = (1-\epsilon_f)\ (\rho_s - \rho_f) \qquad (2)$$

For the packed section, using Ergun's equation

$$\left(\frac{\triangle P}{L}\right)_{pa} = \frac{1}{gc}\left[150\,\frac{(1-\epsilon_{pa})^2}{\epsilon_{pa}^3}\cdot\frac{\mu\, u}{dp^2} + 1{\cdot}75\,\frac{(1-\epsilon_{pa})}{\epsilon_{pa}^3}\cdot\frac{G\, u}{dp}\right] \qquad (3)$$

From the material balance it can be shown that

$$h_{pa} = (h_f - h)\,\frac{(1-\epsilon_f)}{\epsilon_f - \epsilon_{pa}} \qquad (4)$$

$$\text{So, } \triangle P_t = \left(\frac{\triangle P}{L}\right)_{pa.} h_{pa} + \left(\frac{\triangle P}{L}\right)_f (h - h_{pa})$$
$$= \left[150\,\frac{(1-\epsilon_{pa})^2}{\epsilon_{pa}^3}\cdot\frac{\mu\, u}{dp^2} + 1{\cdot}75\,\frac{(1-\epsilon_{pa})}{\epsilon_{pa}^3}\cdot\frac{Gu}{dp}\right]\left[(h_f - h)\,\frac{(1-\epsilon_f)}{\epsilon_f - \epsilon_{pa}}\right]\frac{1}{gc}$$
$$+\left[h_f - \frac{(h_f - h)\,(1-\epsilon_{pa})}{\epsilon_f - \epsilon_{pa}}\right](1-\epsilon_f)\ (\rho_s - \rho_f) \qquad (5)$$

Fan and co-workers[7,8] measured the pressure drop in fixed and fluidized beds separately, and the total pressure drop was obtained using equation (1). They have compared the values with the observed bed pressure drop and also with that calculated using equation (5). It was observed by them that experimental values are nearer to those calculated by using equation (1), whereas equation (5) gave lower values. As equation (1) involved the accurate measurement of pressure drops across packed and fluidized sections separately necessitating elaborate experimentation, equation (5) has been used in the present calculations and a suitable correction factor has been incorporated to reduce deviations from the experimental values.

Correlations

The pressure drop expression can now be written as

$$\frac{(\triangle P_t)_{act}}{(\triangle P_t)_{cald}} = C \qquad (6)$$

where, $(\triangle P_t)_{act}$ = experimental or actual value of total pressure drop

$(\triangle P_t)_{cald}$ = calculated value of total pressure drop by using equation (5)

C = correction factor

It is imperative that the correction factor should be related to the system parameters. The parameters of importance in this case are $h_s/D_c, \rho_s/\rho_f$ h_{pa}/h_s, D_c/d_p and R.

The relation can be written in the following manner

$$C = A\left[(D_c/D_p)^{a_1}(\rho_s/\rho_f)^{a_2}(h_s/D_c)^{a_3}(h_{pa}/h_s)^{a_4}(R)^{a_5}\right] \quad (7)$$

$$C = A\left[(D_c/d_p)^{-0.79}(\rho_s/\rho_f)^{-0.90}(h_s/D_c)^{-0.58}(h_{pa}/h_s)^{0.113}(R)^{0.114}\right] \quad (8)$$

$$C = \frac{(\triangle P_t)_{act}}{(\triangle P_t)_{cald}} = 16.7\left[(D_c/d_p)^{-0.59}(\rho_s/\rho_f)^{0.67}(h_s/D_c)^{-0.43}(h_{pa}/h_s)^{0.08}(R)^{0.08}\right] \quad (9)$$

The values of the pressure drop for a few representative cases have been calculated by using the above correction factors and have been compared with the corresponding experimental values in *Table I.* The percentage deviations have also been shown.

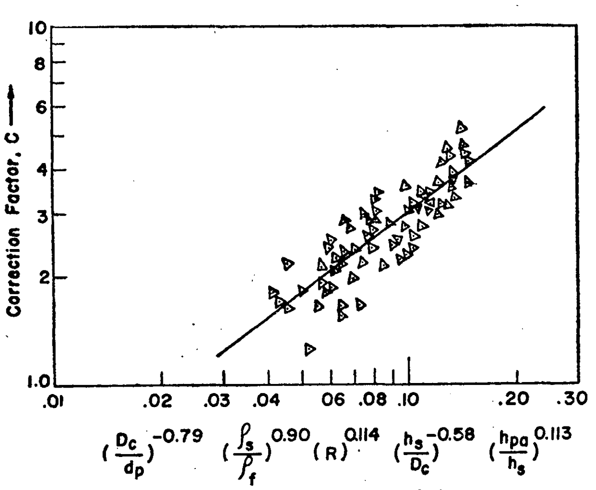

Fig. 1 Relation of C with system variables

TABLE I

COMPARISON OF PRESSURE DROP VALUES FOR SOME TYPICAL CASES

sl. n.	$\triangle P_t$, lb/ft^2 experimental	$\triangle P_t$ lb/ft^2 calculated (using correction factor)	% deviation of calculated values
1.	86·0	65·1	−24·3
2.	100·4	83·3	−17·0
3.	200·0	282·0	+41·0
4.	228·5	189·2	−17·2
5.	234·0	184·6	−21·1
6.	240·0	328·0	+36·7
7.	260·0	236·5	− 9·0
8.	260·0	252·0	− 3·1
9.	275·0	264·0	− 4·0
10.	320·0	320·0	0·0
11.	366·0	356·0	− 2·7
12.	375·0	385·0	+ 2·7
13.	408·0	338·0	−17·2
14.	485·0	504·0	+ 3·9
15.	787·0	652·0	−17·2

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NOMENCLATURE

D_c diameter or column (semi-fluidizer), L

d_p particle diameter, L

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

G mass velocity of fluid, $ML^{-2}\ \theta^{-1}$

h overall height of column or semi-fluidized bed, L

h_s height of initial static bed, L

h_{pa} height of packed section in semi-fluidized bed, L

h_f height of fully fluidized bed, L

$(\triangle P/L)_f$ pressure gradient across fluidized bed, FL^{-3}

$(\triangle P/L)_{pa}$ pressure gradient across packed bed, FL^{-3}

$\triangle P_t$ overall pressure drop through the semi-fluidized bed, FL^{-2}

R bed expansion ratio in semi-fluidization

$\triangle$ finite change of variable

ρ density, ML^{-3}

ϵ bed porosity, dimensionless

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

Subscripts

c column (semi-fluidizer)

f fluid or fluidized bed

s solid or initial static bed

pa packed bed

REFERENCES

1. Fan, L. T., Yang, Y. C, and Wen, C. Y., *A.I.Ch.E.Jr.5*,407 (1959)
2. Roy, G. K. and Sarma, K. J. R., *Ind. Chem. Manfr.*, 12, No. 12, 14 (1970)
3. Roy, G. K. and Sarma, K. J. R., *Chem. Processing & Engg.*, 5, No. 3, (1971)
4. Roy, G. K. and Sen Gupta, P., *The Chem. Engg. Jr.*, 5, 191-196, (1973)
5. Roy, G. K. and Sarma, K. J. R., *Chem. Processing & Engg.*, 5, No. 6 (1971)
6. Leva, M., *Fluidization*, Mc-Graw-Hill Book Co. Inc. (1959)
7. Fan, L. T. and Wen, G. Y., *A.I.Ch.E., Jr., 7*, 606, (1961)
8. Fan, L. T., Wang, S. C. and Wen, G. Y., *A.I.Ch.E., Jr.*, 9, 316, (1963)