Semi-fluidisation —a new method of solid$_9$ fluid contacting technique

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In most of the Chemical Engineering unit operations and processes we come across situations where a solid phase has to be kept in contact with a fluid phase. These may be mass transfer operations like adsorption, absorption, drying, extraction, reaction kinetics like solid reactions, heat transfer in pebble beds etc. The mutual contact between the two phases plays a very) important role and one must be on the look out for finding out ways and means of improving the contacting techniques.

Compared with conventional fixed bed techniques fluidization was considered to be a novice. The fluidization technique had its beginning with the petroleum! industry and at present it is being widely used in almost all chemical industries. Though considered to be advantageous in many respects,, fluidization has its own disadvantages.

Semifluidisation as a method of bringing solid and fluids in mutual contact was first visualized by Fan, Yang and Wen in 1959. Semifluidisation can be defined as the simultaneous formation of a packed bed and fludized bed by the prevention of free expansion of a fluidized bed with the introduction of an adjustable screen which allows only the fluid to pass through. The bottom portion of the bed will be in a fluidized condition and the top portion of the bed will be in packed bed state. This type of technique will overcome the disadvantages of fluidized beds viz. back mixing, attrition of solids and erosion and will also over come certain drawbacks of the packed beds namely seggregation, non-uniform temperatures and channel ling of liquid flow.

• The various aspects under which the subject has been studied so far are:

(i) prediction of onset of semifluidization or minimum semifluidization velocities.

(ii) prediction of maximum semifluidization velocities.

(iii) prediction of the height of packed bed formation.

(iv) prediction of total pressure drop in semifluidized beds.

(v) and studies of mass and heat transfer.

The variables which govern semifluidization phenomena are:

(i) properties of particles—size, shape and density,

(ii) properties of fluid — density, viscosity and velocity.

(iii) initial static bed height, height of the restraint position and

' (iv) dimensions of the column and its configuration.

Perdiction of Minimum semifluidization velocities:

The onset velocity of semifluidization or the minimum semifluidiation velocity depends upon the characteristics of the particles and the fluidizing medium and also on the quantity of particles in relation of column size h/hs or the bed expansion ratio (R). The various methods of estimation of semifluidization velocity are:

(i) Interpolation from experimental data on fluidization

In this method the experimental data on bed expansiori in a fluidised bed is plotted as a ratio hf/hs vs. the fluid velocity. The velocity of fluid corresponding to a value $\frac{hf}{hs}$ = R indicates the semifluidization velocity for the system and the value of bed expansion ratio R. Values of minimum semifluidization velocities can be read from the graph for known value of R.

(ii) Calculation by equations proposed by several authors:

(1) Fan at al's equation for evaluating the height of packed bed formation can be used for predicting the minimum and maximum semifluidization velocities. The relationship is as follows:

$$\left(\frac{h - h_s}{h - h_{pa}}\right) = a\left(\frac{G - G_{mf}}{G_t - G_{mf}}\right)^b \quad \ldots (1)$$

where a and (b) are constants. The values of G_t and G_{mf} are to be evaluated by the various mehods-available for the same.

(2) The minimum semifluidization velocity can also be estimated by the use of equation developed by Baburao and Doraiswamy.

$$\frac{G_s}{G_t} = \frac{17.3}{D\text{-}0.37?} \ (Ar)^{-0.15} \ (Sf)^{-0.186} \quad \ldots (2)$$

Since there are number of methods of evaluating G_t are available the equation has to be used cautiously.

(3) Poddar & Dutt have presented equation of the following type for evaluation of onset of semi-fluidization velocities from the physical properties of the system and the flow characteristics. Their equations are based on the relationship derived by Wen & Yu for the voidage function in an expanded bed.

$$18Re_{osf} + 2.7Re_{osf}^{1.687} = 0.966 \ \phi_S^{0.88}$$

$$Ga \left[\mp - \frac{h_S}{h} \ (1 - h_S) \right]^{4.7} \quad \ldots (3)$$

This equation involves a spehericity function. The; solution for this equation involves a trial and error procedure if the onset of semifluidization has to be evaluated.

(4) The authors have proposed the following equation which involves the evaluation of G_{msf} before hand.

$$\frac{G_{osf}}{G_{msf}} = 0.105 \ (R) + \frac{\text{long Ar.} + 2.465}{52} \quad \ldots (4)$$

The maximum semifluidization velocity can be evaluated from the following equation.

$$G_{msf} = 0.3 \,(Ar)^{0.58} \left(\frac{\mu}{D_p}\right) \quad \ldots (5)$$

Prediction of Maximum Semifluidization velocities:

Maximum semifluidization velocity can be defined as the velocity at which the packed bed formation, at the top is complete and is equal to the initial static bed height assuming that the porosities are the same.

The various methods available for evaluating the Maximum semifluidization velocity G_{msf} are

(i) by linear extrapolation of Ef vs. G line to Ef = 1 value.

(ii) Extrapolation of hp_a/h vs G curves to $hpa/^h = 1.0$

(iii) Method of Fan et al.

(iv) Method suggested by Poddar and Dutt.

(v) Method suggested by the authors.

The first method is based on the fact that when the expanded bed voidage increases to 1 all the particles would have been carried out if there had been no restraint. The velocity at which the bed voidage Ef = 1 this can be equalled to the maximum semifluidization velocity. The expanded bed voidage has to be determined experimentally.

Th second method is also based on the experi mental determination of height of the packed bed formed at the top a various veolcities of fluid. If the data is plotted as hpa/hs vs G and the value of G read out corresponding tc $hp_a/h_s = 1$ will indicate the maximum semifluidization velocity.

The other methods below do not require the experimental determination. The equations are either based on theoretical considerations or of empirical nature. They are mainly due to

(i) Fan et al, as already discussed under prediction of G_{osf} (1)

(ii) Podar and Dutt's equation for predicting G_{msf} is as follows.

$$18Re_{msf} + 2.7 \ Re_{msf}^{1.687} = G_a \quad \ldots (6)$$

(iii) The author's correlation given by equation (5).

Packed bed height in semifluidization Beds:

While equations are available to predict the beginning of formation of packed bed and the completion, of the same it is essential to know the variation of the height of packed bed formed with the fluid velocity. This forms a very important aspect in the design of, any set up which involves the semifluidization technique.

The four methods available for predicting the packed bed height are:

(i) method done to Fan et al as given by equation (1)

(ii) method done to Baburao and Doraiswamy as given by equation (2).

(jii) By using equation given by Poddar and Dutt which involves the substitute of f values.

$$h_{pa} \frac{h_s \ (1 - E_{pa})}{E_f \quad - E_{pa}} - \frac{h_f \ (1 - E_f)}{E_f \quad - E_{pa}} \quad \ldots (7)$$

when f can be evaluated to

$$\left[\frac{18Re + 2.7\ Re^{1.687}}{Ga} \right]^{0.2125}$$

(iv) the equations proposed by the authors which involve the use of G_{msf} and G_{osf} values.

$$\frac{h - h_s}{h - h_{pa}} = \left(\frac{G_f \ - G_{osf}}{G_{msf} - G_{osf}} \right)^{0.2} \quad \ldots (8)$$

Total Pressure drop in Semifluidization:

The importance of total pressure drop occurring in semi-fluidization need not be emphasized. The power requirement for the motivation of the fluid through the semi-fluidised bed of particles directly related to the total pressure that has to be overcome. This is a major as pect to be given weightage in the design of industrial reactors or equipment utilizing the semiuidized bed technique.

Studies towards this aspect were made only by Fan et al. Attempts have been made to express the total pressure drop, occurring in semifluidization as a combination of pressure drops occurring in a packed bed and fluidized bed. The values calculated this way are much; lower when compared with the experimental values directly measured.

Studies oriented towards the application of this technique to reaction kinetics has already been initiated by Baburao and Doriaswamy.

Conclusions:

Semifluidization is a new method of solid and fluid contacting technique which has been developed recent-, ly. Sufficient work has already been reported on the dynamics of semifluized beds except that of total pressure drop. Further studies have to be made in this aspect. The problem of scaling up of bench scale re suits to industrial units has yet to be solved. There; exists a wider scope in extending the studies towards application of this technique to heat and mass transfer studies and reaction kinetics.

Notations:

A_r = Archimedes number, dimensionless group

d_p = Particle diameter, L

D = Dia of reactor, L

G_{mf} = Onset velocity of fluidiation, $M.\theta^{-1}L^{-2}$

G_{osf} = Onset velocity of semifluidization, $M.\theta^{-1}L^{-2}$

G_{msf} = Maximum semifluidization velocity, $M.\theta^{-1}L^{-2}$

G_s = Semifluidized velocity, $M.\theta^{-1}L^{-2}$

G_t = Free fall terminal velocity (maximum semifluidization velocity) calculated,, $M.\theta^{-1}L^{-2}$

h = Overall height of column (or semifluidized bed) L

h_f = Height of fully fluidized bed,, L

h_s = Height of initial static bed, at lease dense conditions , L.

R = Bed expansion Ratio dimensionless

Re_{Osf} = Reynolds number at minimum semifluidization, dimensionless

Re_{msf} = Reynolds number at maximum semifluidization, dimensionless.

S_f = Semifluidization group, dimensionless.

Greek Letters:

E_{pa} = Porosib of Packed Bed.

E_f = Porosity of fluidized section or porosity of fully fluidized bed.

M = Viscocity of fluid, ML $ML^{-1}\theta^{-1}$

P_f = Density of fluid, ML^{-3} ML^{-3}

P_s = Density of solid particle, ML^{-3}