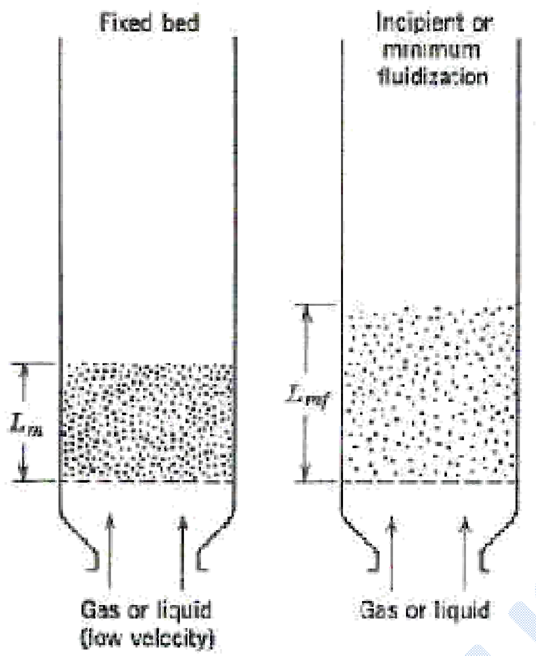
Fluidization

Fluidization is a method of contacting granular solids with fluid (where the fluid passes upwards through the bed) .



The application of fluidization falls into one of two general classes :

1- Chemical reactions catalysis .
2- Physical and mechanical processes .

The fluidized bed has similar properties to those of fluid , therefore , it is considered to be " rendered fluid " .Hence the operation achieving this termed " fluidization " .

- At a certain rate of fluid flow , a packed bed of granular solid will expand to such a point that the granules may move within the bed . This condition is known as the onset (incipient) of fluidization , or the min. fluidization point .
  Fig.

- At a velocities higher than min. press. Gradient in bed as a function of fluid velocity fluidizing velocity (U_{mf}) , there is a fairly sharp distinction between the be haviour in the two cases :
  1- Particulate fluidization – with a liq. (or with a gas at relatively low velocities) , the bed continues to expand as the velocity is increased and it maintains its uniform character with the amount of agitation of the press. drop over fixed and fluidized bed particles increasing progressively .
  2- Aggregative fluidization – occurs at high gas velocities ,two separate phaves are formed , the continuous phase which is often referred to as the dense or emulsion , and the dis continues phase known as the lean or babble phase .
- The Froude number $Fr = \frac{U_{mf}^2}{g_d}$ gives a criterion from which the type of fluidization can be predicted .

  Here U_{mf} is the min. superficial velocity of flow (min. fluidizing velocity)

  d: is the dia. of particles.

  g : is accerelation due to gravity .

  Fr < 1 ; particulate fluidization .

  Fr > 1 ; aggregative fluidization .

Minimum fluidizing velocity (U_{mf})

If a fluid in laminar flow is passed upwards through a static packed bed of solid particles , the press. gradient is given by kozeny eq.

$$U = \left(\frac{\Delta P}{L}\right)\left(\frac{1}{K"\mu}\right)\left(\frac{e^3}{(1-e)^2 S^2}\right) \text{ -------- (1)} \quad \text{kozeny's eq.}$$

As the fluid velocity is increased appoint reached when the viscous frictional and drag forces on the particles in the fluid stream . This is the start fluidization and a force balance gives :

$$\Delta P = (1-e)(\rho_s - \rho)L.g \qquad \text{--------------------(2)}$$

Where :

ρ_s , ρ : are the densities of the solid and fluid respectively . combine eq.s (1) and (2) to give

$$U = \left[\frac{(\rho_s-\rho)g}{\mu K"}\right]\left[\frac{e^3}{(1-e)S^2}\right] \qquad \text{------------------(3)}$$

Where :

K" is usually about (5)

For spherical particles

S = 6/d

and eq.(3) can be written

$$U = \left[\frac{(\rho_s-\rho)g}{\mu}\right]\left[\frac{e^3 d^2}{180(1-e)}\right] \qquad \text{-------------------(4)}$$

At the point of incipient fluidization , the min. fluidizing velocity (U_{mf}) is obtained by substituting the appropriate value of voidage (e_{mf}) in eq.(4)

$$U_{mf} = \left[\frac{(\rho_s-\rho)g}{\mu}\right]\left[\frac{e_{mf}^3 d^2}{180(1-e_{mf})}\right] \qquad \text{--------------(5)}$$

Values of e_{mf} will vary considerably from powder to powder , but a typical value for a bed of isometric particles is (0.4) substituting this value :

$$(U_{mf})_{e_{mf}=0.4} = \left[\frac{(\rho_s-\rho)gd^2}{1687.5\ \mu}\right] \qquad \text{------------(6)laminar}$$

For larger particles , where the point of incipient fluidisation is no longer streamline , it is necessary to use one of the more general equations for the pressure gradient in the bed, such as the Ergun equation :

$$\frac{\Delta P}{L} = 150\frac{(1-e_{mf})^2}{e_{mf}^3}.\frac{\mu U_{mf}}{d^2} + 1.75\frac{1-e_{mf}}{e_{mf}^3}.\frac{\rho U_{mf}^2}{d} \qquad \text{----(7) Ergun eq.}$$

Substituting for $(\Delta P/L)$ from eq. (2) and multiplying both side by :

$$(1-e_{mf})(\rho_s-\rho).g = 150\frac{(1-e_{mf})^2}{e_{mf}^3}.\frac{\mu U_{mf}}{d^2} + 1.75\frac{1-e_{mf}}{e_{mf}^3}.\frac{\rho U_{mf}^2}{d}$$

Multiplying both side by $\frac{\rho d^3}{\mu^2(1-e_{mf})}$ gives :

$$\frac{\rho(\rho_s-\rho)gd^3}{\mu^2} = 150(\frac{1-e_{mf}}{e_{mf}^3}).(\frac{\rho U_{mf}d}{\mu}) + \frac{1.75}{e_{mf}^3}(\frac{\rho U_{mf}d}{\mu})^2 \qquad \text{-------(8)}$$

Eq.(8) can be solved to give U_{mf} explicitly , noting that

$\frac{\rho(\rho_s-\rho)gd^3}{\mu^2}$ = Ga (Galileo number)

$\frac{\rho U_{mf}d}{\mu}$ = Re'_{mf} (Reynolds number at the minimum fluidizing velocity)

Eq.(8) then becomes :

$$Ga = 150(\frac{1-e_{mf}}{e_{mf}^3}).Re'_{mf} + \frac{1.75}{e_{mf}^3}Re_{mf}'^2$$

For a typical value of (e_{mf} = 0.4) :

$$Re'^2_{mf} + 51.4\ Re'_{mf} - 0.0366Ga = 0$$

Thus

$$(Re'^2_{mf})_{e_{mf}=0.4} = 25.7\left[\sqrt{(1 + 5.53 * 10^{-5}Ga)} - 1\right]$$

Note :

$\frac{L_1}{L_2} = \frac{(1-e_2)}{(1-e_1)}$ for a bed uniform cross sectional area

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