CEN 212 FLUID MECHANICS

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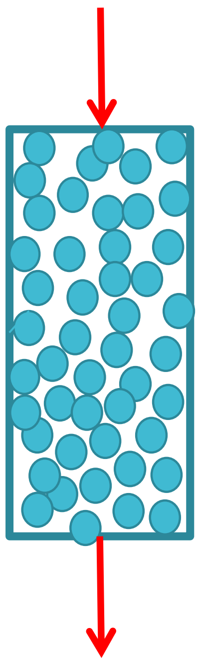
FLOW IN PACKED BEDS

The packed bed (or packed column) is found in a number of chemical processes including fixed bed catalytic reactor, filter bed, absorption and adsorption.



FLOW IN PACKED BEDS

Definitions:

The void fraction, ε: ε<1.0
(porosity)
ε= volume of voids in bed / total volume of bed (voids + solids)

Superficial velocity (vo):
(empty column velocity)
the velocity based on the cross section of the empty column

Interstitial velocity (v):
(avarage velocity in the channels)

PRESSURE DROP IN PACKED BEDS

For laminar flow :

Hagen-Poiseullie eq. $\Delta P = \dfrac{32\mu\bar{v}L}{D^2}$

$$\Delta P = \frac{32\mu\bar{v}L}{D^2} = \frac{32\mu(\bar{v}_o/\varepsilon)L}{(4r_H)^2} = \frac{72\mu\bar{v}_o L(1-\varepsilon)^2}{\varepsilon^3 D_p{}^2}$$

$$\boxed{\Delta P = \frac{150\mu\bar{v}_o L}{D_p{}^2}\frac{(1-\varepsilon)^2}{\varepsilon^3}}$$

Blake-Kozeny equation

for laminar flow,
void fraction less than 0.5,
effective particle diameter Dp,
and Re,p < 10

PRESSURE DROP IN PACKED BEDS

For turbulent flow :

$$\Delta P = \frac{1.75\rho\bar{v}_o{}^2 L}{D_p}\frac{(1-\varepsilon)}{\varepsilon^3}$$

Burke-Plummer equation

for turbulent flow,
Re,p > 1000

PRESSURE DROP IN PACKED BEDS

Ergun equation:

An equation covering the entire range of the flow rates

$$\Delta P = \frac{150\mu\bar{v}_o L}{D_p^{\ 2}}\frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{1.75\rho\bar{v}_o^{\ 2} L}{D_p}\frac{1-\varepsilon}{\varepsilon^3}$$

PRESSURE DROP IN PACKED BEDS

Shape factor (sphericity) ϕ_s :

Many particles in packed beds are often irregular in shape.

Sphericity of a particle is the ratio of the surface area of sphere having the same volume as the particle to the actual surface of the particle

For a sphere, the surface area: $S_p = \Pi D_p^{\ 2}$ For sphere ϕ_s=1.0

For any particle: $\Phi_s = \dfrac{\Pi D_p^{\ 2}}{S_p}$

where Sp is the actual surface area of the particle and Dp is the diameter of the sphere having the same volume as the particle

Then, for particle: $$a_v = \frac{S_p}{V_p} = \frac{\Pi D_p^{\ 2}/\Phi_s}{\Pi D_p^{\ 3}/6} = \frac{6}{\Phi_s D_p}$$

For bed: $$a = a_v(1-\varepsilon) = \frac{6}{\Phi_s D_p}(1-\varepsilon)$$

PRESSURE DROP IN PACKED BEDS

Therefore, Ergun Equation becomes:

$$\Delta P = \frac{150\mu\bar{v}_o L}{\Phi_s^{\,2} D_p^{\,2}} \frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{1.75\rho\bar{v}_o^{\,2} L}{\Phi_s D_p} \frac{(1-\varepsilon)}{\varepsilon^3}$$