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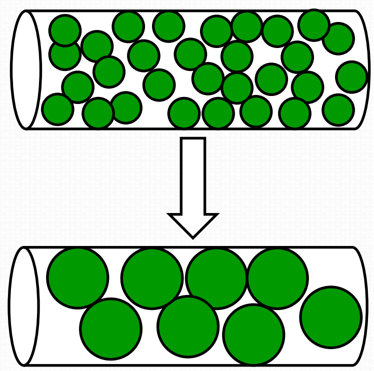
Pressure Drop in PBRs

What if we increase the catalyst size by a factor of 2?



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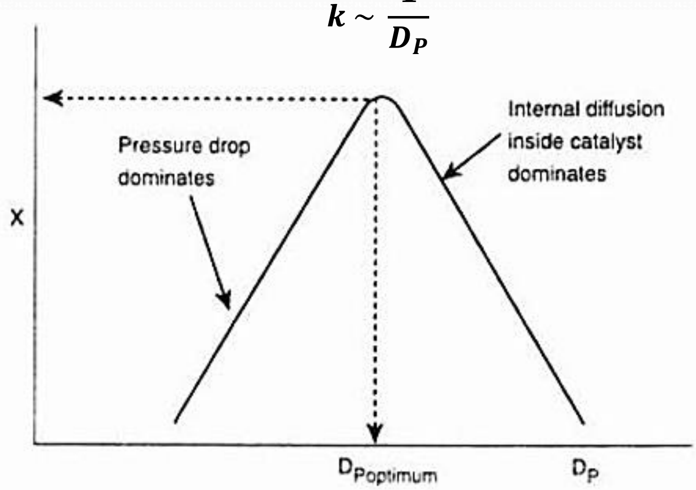
Finding the Optimum Particle Diameter

$$k \sim \frac{1}{D_P}$$



Pressure Drop – Engineering Analysis – Entering Pressure

$$\alpha = \frac{2}{A_C(1-\phi)\rho_C P_0}\beta_0 = \frac{2}{A_C(1-\phi)\rho_C P_0}\left[\frac{G(1-\phi)}{\rho_0 g_C D_P \phi^3}\left[\overbrace{\frac{150(1-\phi)\mu}{D_P}}^{\text{Laminar}} + \overbrace{1.75G}^{\text{Turbulent}}\right]\right]$$

$$\rho_0 = MW * C_{T0} = \frac{MW * P_0}{RT_0}$$

$$\alpha = \frac{2RT_0}{A_C \rho_C g_C P_0^2 D_P \phi^3 MW} G\left[\frac{150(1-\phi)\mu}{D_P} + 1.75G\right]$$

$$\alpha \approx \left(\frac{1}{P_0}\right)^2$$

As P_0 increases, α decreases, and thus pressure drop decreases

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Pressure Drop – Engineering Analysis

$$\alpha = \frac{2RT_0}{A_C \rho_C g_C P_0^2 D_P \phi^3 MW} G\left[\frac{150(1-\phi)\mu}{D_P} + 1.75G\right]$$

*A. **Laminar Flow Dominant (Term 1 >> Term 2)***

$$\alpha \sim \frac{GT_0}{A_C D_P^2 P_0^2}$$

Case 1 / Case 2

$$\alpha_2 = \alpha_1 \left(\frac{G_2}{G_1}\right)\left(\frac{A_{C1}}{A_{C2}}\right)\left(\frac{D_{P1}}{D_{P2}}\right)^2\left(\frac{P_{01}}{P_{02}}\right)^2\left(\frac{T_{02}}{T_{01}}\right)$$

Pressure Drop – Engineering Analysis

$$\alpha = \frac{2RT_0}{A_C \rho_C g_C P_0^2 D_P \phi^3 MW} G \left[\frac{150(1-\phi)\mu}{D_P} + 1.75G \right]$$

B. Turbulent Flow Dominant (Term 2 >> Term 1)

$$\alpha \sim \frac{G^2 T_0}{A_C D_P P_0^2}$$

Case 1 / Case 2

$$\alpha_2 = \alpha_1 \left(\frac{G_2}{G_1}\right)^2 \left(\frac{A_{C1}}{A_{C2}}\right) \left(\frac{P_{01}}{P_{02}}\right)^2 \left(\frac{D_{P1}}{D_{P2}}\right) \left(\frac{T_{02}}{T_{01}}\right)$$

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Pressure Drop – Engineering Analysis

Example 5–6 (5th edition)

How will the pressure drop parameter (e.g., α) and conversion change if you decrease the particle diameter by a factor of 4 and increase entering pressure by a factor of 3, keeping everything else the same?

$$D_{P2} = \frac{1}{4} D_{P1} \text{ and } P_{02} = 3P_{01}$$

(a) Laminar Flow

$$\alpha_2 = \alpha_1 \left(\frac{G_2}{G_1}\right) \left(\frac{A_{C1}}{A_{C2}}\right) \left(\frac{D_{P1}}{D_{P2}}\right)^2 \left(\frac{P_{01}}{P_{02}}\right)^2 \left(\frac{T_{02}}{T_{01}}\right)$$

$$\alpha_2 = \alpha_1 \left(\frac{D_{P1}}{\frac{1}{4} D_{P1}}\right)^2 \left(\frac{P_{01}}{3P_{01}}\right)^2 = \frac{16}{9}\alpha_1$$

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Pressure Drop – Engineering Analysis

Example 5–6 (5th edition)

How will the pressure drop parameter (e.g., α) and conversion change if you decrease the particle diameter by a factor of 4 and increase entering pressure by a factor of 3, keeping everything else the same?

$$D_{P2} = \frac{1}{4} D_{P1} \text{ and } P_{02} = 3P_{01}$$

(b) Turbulent Flow

$$\alpha_2 = \alpha_1 \left(\frac{G_2}{G_1}\right)^2 \left(\frac{A_{C1}}{A_{C2}}\right) \left(\frac{P_{01}}{P_{02}}\right)^2 \left(\frac{D_{P1}}{D_{P2}}\right) \left(\frac{T_{02}}{T_{01}}\right)$$

$$\alpha_2 = \alpha_1 \left(\frac{D_{P1}}{\frac{1}{4} D_{P1}}\right) \left(\frac{P_{01}}{3P_{01}}\right)^2 = \frac{4}{9} \alpha_1$$