Plug Flow Reactor

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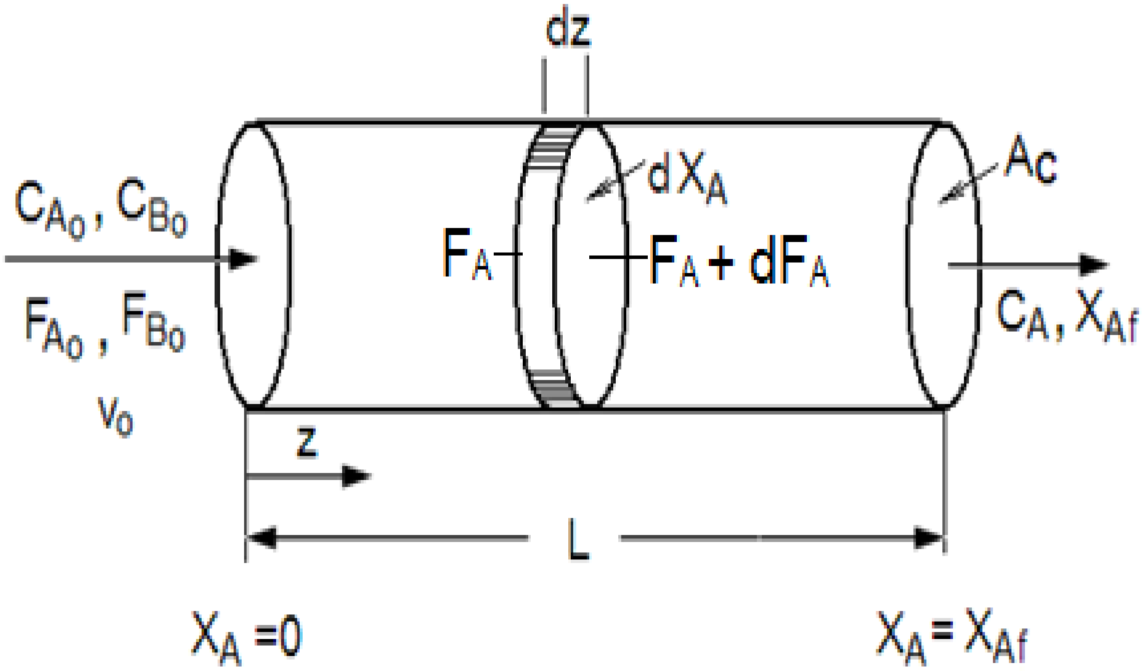


$$\boldsymbol{Mole\ Balance}: \quad \boldsymbol{F_A = (F_A + dF_A) + (-r_A)dV}$$

$$\boldsymbol{-dF_A = (-r_A)dV}$$

or,

$$\boldsymbol{-\frac{dF_A}{dV} = -r_A}$$

Design of Plug Flow Reactor(PFR)

Volume basis(Homogeneous reaction):

$$\boldsymbol{As,} \qquad F_A = F_{A0}(1 - X_A) \qquad \qquad then \quad F_{A0}\frac{dX_A}{dV} = -r_A$$

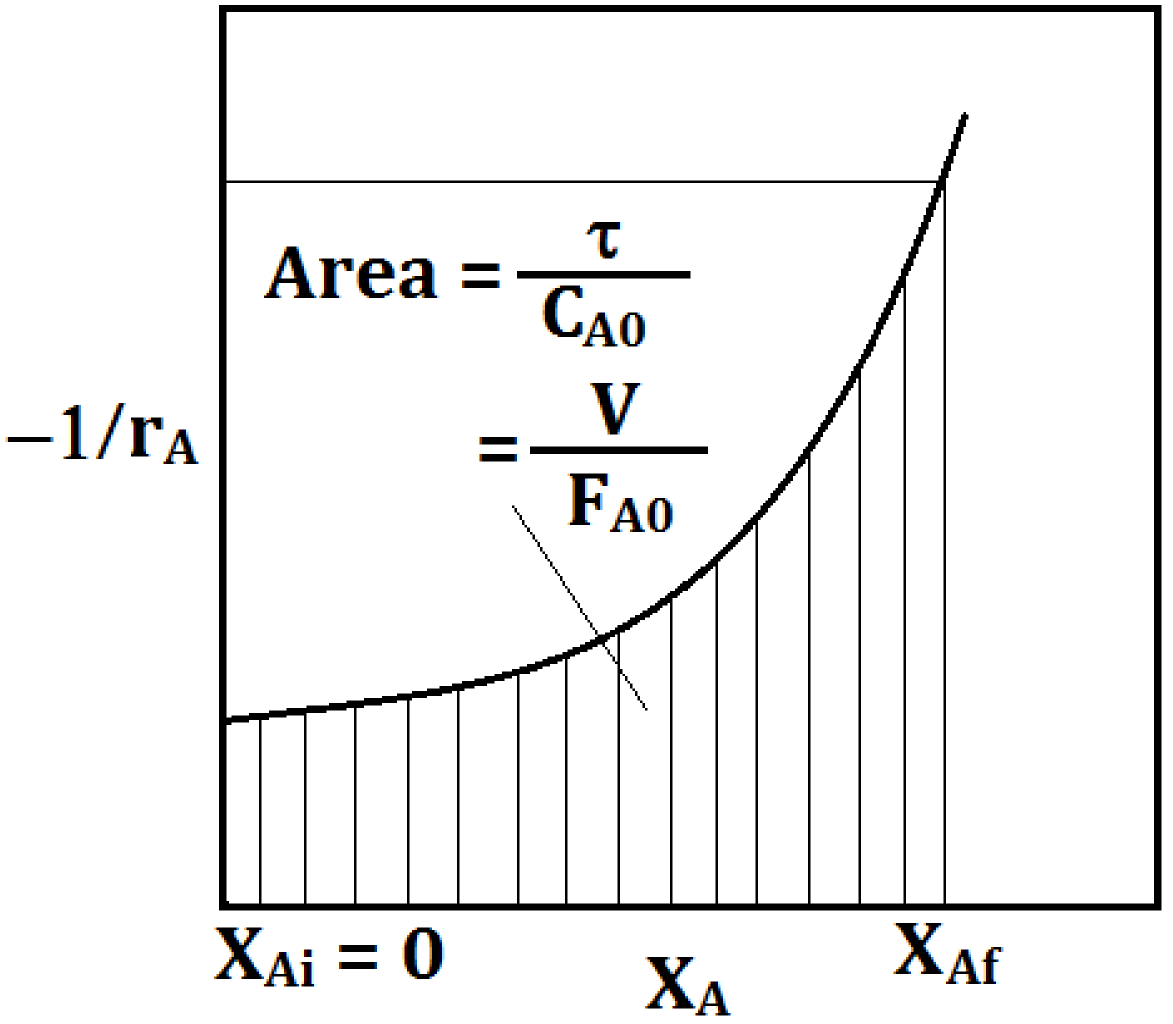
$$\frac{V}{F_{A0}} = \int_0^{X_{Af}} \frac{dX_A}{-r_A} \; or, \qquad \frac{\tau}{C_{A0}} = \int_0^{X_{Af}} \frac{dX_A}{-r_A}$$

C$\boldsymbol{atalyst\ weight\ basis}$($\boldsymbol{Heteroneous\ reaction}$):

$$-\frac{dF_A}{dW} = -r'_A$$

$$\frac{W}{F_{A0}} = \int_0^{X_{Af}} \frac{dX_A}{-r'_A}$$

Graphical Analysis for PFR design



Plug Flow Reactor for Variable Density with First-Order Kinetics

$$\boldsymbol{Rate\ equation: \ -r_A = kC_A}$$

$$\tau = C_{A0}\int_{X_{Ai}}^{X_{Af}} \frac{(1+\varepsilon_A X_A)dX_A}{kC_{A0}(1-X_A)}$$

$$k\tau = \int_0^{X_A} \frac{dX_A}{1-X_A} + \varepsilon_A \int_0^{X_A} \frac{X_A dX_A}{1-X_A}$$

$$\boldsymbol{k\tau = -(1+\varepsilon_A)\ln(1-X_A) - \varepsilon_A X_A = f(X_A)}$$

For constant volume

$$\boldsymbol{\varepsilon_A = 0:} \qquad \boldsymbol{k\tau = -\ln(1-X_A) = f(X_A)}$$

Plug Flow Reactor for Variable Density with Second-Order Kinetics

$$Rate\ equation:\ -r_A = kC_A^2$$

$$Mole\ Balance:\qquad \tau = C_{A0}\int_0^{X_{Af}} \frac{dX_A}{-r_A}$$

$$\tau = C_{A0}\int_0^{X_{Af}} \frac{X_A(1+\varepsilon_A X_A)^2 dX_A}{kC_{A0}^2(1-X_A)^2}$$

$$\boldsymbol{C_{A0}k\tau = 2\varepsilon_A(1+\varepsilon_A)\,ln\,(1-X_A)\,\varepsilon_A^2 X_A + (1+\varepsilon_A)^2\frac{X_A}{1-X_A}}$$

$$\boldsymbol{\tau = \frac{A_C L}{v_0}},\qquad where\ A_C is\ the\ cross\ sectional\ area$$

$\boldsymbol{C_{A0}k\tau}$ is called as Damköhler number(Flow reactor)

$C_{A0}^{n-1}k\tau$ is the Damköhler number for nth order reaction(Flow Reactor)

$X_A = kC_{A0}^{n-1}\tau(1-X_A)^n$ is the mole balance in CSTR

Damköhler number for batch reactor

- For batch reactor $'\boldsymbol{\tau}'$ will be replaced by 't'
- For batch reactor first-order reaction $\mathrm{k}\boldsymbol{\tau}$ = kt
- For batch reactor n-th order reaction $C_{A0}^{n-1}kt$
- All are dimensionless groups