A First Course on Kinetics and Reaction Engineering

Unit 30.Thermal Back-Mixing in a PFR

Definitions

back-mixing - situation where some or all of the product of a reaction is added to the feed

hot (or cold) approach - difference in temperature between the two streams flowing through a heat exchanger at the point where they are both at their highest (or lowest) temperature

Nomenclature

ΔT_{AM} arithmetic mean temperature difference

ΔT_{cold} cold approach

ΔT_{LM} logarithmic mean temperature difference

A heat transfer area

$\hat{C}_{p,i}$ molar heat capacity of species i

T temperature, a subscript k denotes the temperature of stream k

U_{AM} overall heat transfer coefficient for use with an arithmetic mean temperature difference

U_{LM} overall heat transfer coefficient for use with an logarithmic mean temperature difference

$\dot{n}_{i,k}$ molar flow rate of species i in stream k

Equations

$$\sum_{\substack{i=all\\species}} \dot{n}_{i,c} \int_{T_c}^{T_d} \hat{C}_{p,i}\, dT + \sum_{\substack{i=all\\species}} \dot{n}_{i,a} \int_{T_a}^{T_b} \hat{C}_{p,i}\, dT = 0 \qquad (30.1)$$

$$\sum_{\substack{i=all\\species}} \dot{n}_{i,c} \int_{T_c}^{T_d} \hat{C}_{p,i}\, dT + U_{LM} A \Delta T_{LM} = 0 \qquad (30.2)$$

$$\sum_{\substack{i=all\\species}} \dot{n}_{i,c} \int_{T_c}^{T_d} \hat{C}_{p,i}\, dT + U_{AM} A \Delta T_{AM} = 0 \qquad (30.3)$$

$$\Delta T_{LM} = \left(\frac{\left(T_d - T_a\right) - \left(T_c - T_b\right)}{\ln\left\{ \frac{\left(T_d - T_a\right)}{\left(T_c - T_d\right)} \right\}} \right) \qquad (30.4)$$

$$\Delta T_{AM} = \frac{T_c + T_d}{2} - \frac{T_a + T_b}{2} \qquad (30.5)$$

$$\dot{n}_{i,a} = \dot{n}_{i,b} \qquad \text{(for each species, } i\text{)} \tag{30.6}$$

$$\dot{n}_{i,c} = \dot{n}_{i,d} \qquad \text{(for each species, } i\text{)} \tag{30.7}$$

$$\Delta T_{cold} = T_d - T_a \tag{30.8}$$