Exercise 16

It is planned to carry out a second order reaction in a circular microchannel at a Reynolds number of 200 in order to benefit from accelerated mixing by stretching and engulfment. The two reactants are fed separately and contacted in a T-mixer.

Physical properties and geometric factors

Kinematic viscosity: $\nu = 10^{-6}\, m^2 \cdot s^{-1}$

Density: $\rho = 1000\, kg \cdot m^{-3}$

Characteristic reaction time: $t_r = 1s$

$A_1 + A_2 \rightarrow P \quad r = k \cdot c_1 \cdot c_2$

Equal inlet molar flowrates of the two reactants

Questions

1. Calculate the diameter and length of a single channel circular micro-reactor to carry out this reaction at $Re = 200$ with 96% conversion in the absence of segregation. Assume plug flow behavior of the micro-channel.
2. What flowrate can be processed in this reactor?
3. What is the pressure drop?

Solution

For negligible effect of segregation: $t_{mx} = 0.1 \cdot t_r = 0.1s$

$$t_{mx} = 0.215 \cdot \varepsilon^{-0.5} \quad \rightarrow \quad \varepsilon = \left(\frac{0.215}{t_{mx}}\right)^2 = 4.62\, W \cdot kg^{-1}$$

Equal molar flowrates: $c_1 = c_2 = c \quad ; \quad r = kc^2$

PFR with 2nd order kinetics: $DaI = \frac{\tau}{t_r} = \frac{X}{1-X} = 24$

$\tau = DaI \cdot t_r = 24s$

$$Re = \frac{u \cdot d_t}{\nu} \; ; \quad \varepsilon = \frac{32 \cdot \nu \cdot u^2}{d_t^2} \quad \rightarrow \quad u = \left(\frac{\varepsilon \cdot \nu \cdot Re^2}{32}\right)^{1/4} = 0.276\, m \cdot s^{-1}$$

$$\boldsymbol{d_t} = \frac{\nu \cdot Re}{u} = \mathbf{7.3 \cdot 10^{-4}\, m}$$

$$\boldsymbol{L} = \tau \cdot u = \mathbf{6.6\, m}$$

$$\boldsymbol{Q} = u \cdot \pi \frac{d_t^2}{4} = 1.14 \cdot 10^{-7} m^3 \cdot s^{-1} = \mathbf{0.41\, l \cdot h^{-1}}$$

$$\Delta \boldsymbol{p} = \frac{\varepsilon \cdot L \cdot \rho}{u} = 1.11 \cdot 10^5 Pa = \mathbf{1.1\, bar}$$