POLITECNICO MILANO 1863

Dynamics and Control of Chemical Processes

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Lab #1

Exercise 1

A biological process is operated in a batch reactor characterized by the growth of biomass (B) at a loss of substrate (S). The material balances for the two species are:

$$\begin{cases} \dfrac{dB}{dt} = \dfrac{k_1 BS}{k_2 + S} \\ \dfrac{dS}{dt} = -k_3 \dfrac{k_1 BS}{k_2 + S} \end{cases}$$

Determine the dynamics of both the substrate and biomass over 15 h, knowing that:

$$k_1 = 0.5 \text{ h}^{-1}$$

$$k_2 = 10^{-7} \text{ kmol/m}^3$$

$$k_3 = 0.6$$

The initial conditions are:

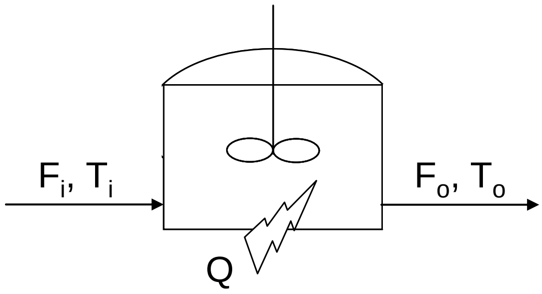
$$\begin{cases} B(0) = 0.03 \text{ kmol/m}^3 \\ S(0) = 4.5 \text{ kmol/m}^3 \end{cases}$$

Solve the problem in Matlab. Modify the parameters for the error control of the ordinary differential system by adopting a relative tolerance of 10^{-8} and an absolute one of 10^{-12} (respect to the default Matlab values). Compare the two dynamics.

Exercise 2

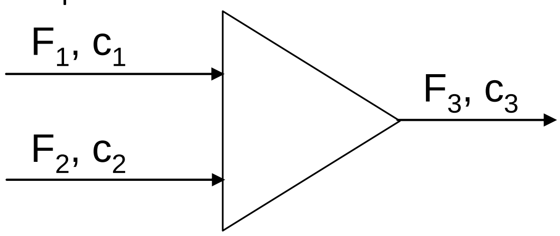
Consider an intermediate storage tank that is perfectly mixed (CST) and heated.
Evaluate the dynamics of the outlet temperature after a step disturbance of 30 °C on the inlet temperature, given the following data:

- Heat power supplied to the system: $Q = 1\text{MW}$
- Inlet flowrate: $F_i = 8\,\text{kmol/s}$
- Mass holdup of the CST: $m = 100\,\text{kmol}$
- Specific heat of the mixture: $cp = 2.5 \text{ kJ/kmol K}$
- Inlet temperature: $T_i = 300\,\text{K}$



Exercise 3

Let us consider the mixing of two streams featuring different concentrations of the same component.



Input data:

- Stream 1: $F_1 = 2\,\mathrm{m^3/h}$; $c_1 = 0.5\,\mathrm{kmol/m^3}$
- Stream 2: $F_2 = 10\,\mathrm{m^3/h}$; $c_2 = 6\,\mathrm{kmol/m^3}$
- Volume of the mixer: $V_{mixer} = 12\,\mathrm{m^3}$

Determine the outlet concentration dynamics from the mixer when the flowrate, F_1, varies linearly with the time as follows: $F_1 = 0.04 \times \mathrm{t}$, up to the maximum value of: $20\,\mathrm{m^3/h}$.

Exercise 4

A side reaction occurs in a storage tank. The variations of conversion (z) and temperature (θ) can are described by the following formula:

$$\begin{cases} \dfrac{dz}{d\tau} = \dfrac{\psi}{B}(1-z)^n \, h(\theta) \\ \dfrac{d\theta}{d\tau} = \psi (1-z)^n \, h(\theta) - \theta \end{cases}$$

In these reactions, B is the heat of reaction; n is the reaction order; ψ the ratio between the reaction heat and the heat removed by heat exchange; ε is the reaction activation energy; h is the exponential term of the reaction kinetics:

$$h(\theta) = \exp\left[\theta / (1 + \varepsilon\theta)\right]$$

All the variables are non-dimensional.

Evaluate the temperature dynamics when ψ varies between 0.35 and 0.65, with the following parameter values:

- $n = 1$
- $B = 20$
- $\varepsilon = 0.05$

The initial conditions are:

- $z(0) = 0$
- $\theta(0) = 1$.