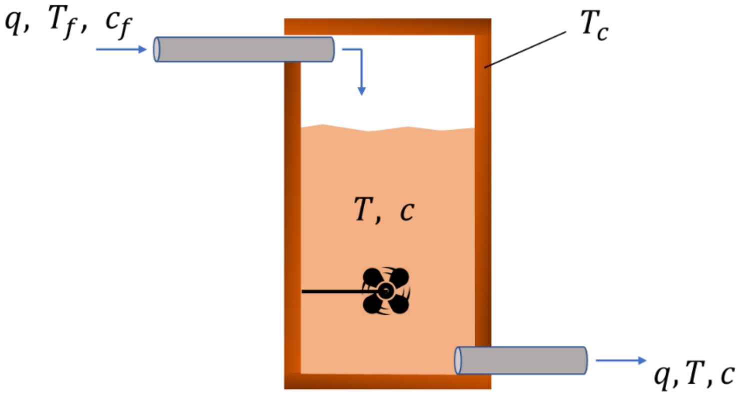
CONTROL OF A CONTINUOUS STIRRED TANK REACTOR (CSTR)



Problem

Chemical reactors are very common in the industrial world since they provide the adequate environment to make chemical reactions happen under precise system conditions (temperature, liquid concentration, etc.). Because of this, they need to be controlled to maintain the internal variables at the proper references despite the external disturbances.

Precisely, the working behaviour of the considered system can be summarized as follows:

- The reactor receives an input liquid with a concentration $\boldsymbol{c_f}$, a temperature $\boldsymbol{T_f}$ and a flow $\boldsymbol{q}$. The last two variables are not controlled and so they are considered as external constant disturbances, while the concentration $\boldsymbol{c_f}$ can be manipulated as a control input to the system.
- The reactor walls are regulated to a temperature $\boldsymbol{T_c}$ which can be manipulated as a control input to the system.
- The internal reaction produces a fluid with a temperature $\boldsymbol{T}$ and the concentration $\boldsymbol{c}$ and which flows away with a flow $\boldsymbol{q}$.

The control goal is therefore to design and test different control structures aiming to maintain the variables $\boldsymbol{T}$ and $\boldsymbol{c}$ at the requested references rejecting the external disturbances.

The system dynamics are nonlinear and they can be described through two state-space equations:

$$\frac{dc(t)}{dt} = \frac{q}{V}\left(c_f(t) - c(t)\right) - c(t)\ k\, e^{-\frac{E}{RT(t)}}$$

$$\frac{dT(t)}{dt} = \frac{UA}{V\,\rho\, c_P}\left(T_c(t) - T(t)\right) + \frac{q}{V}\left(T_f(t) - T(t)\right) - \frac{\Delta H}{\rho\, c_P}\ k\, c(t)\, e^{-\frac{E}{RT(t)}}$$

where the corresponding parameters are defined in the Matlab script "*datacstr.m*".

Tasks

1. Find the inputs the gives the desired equilibrium $\bar{T} = 350\ K,\ \bar{c} = 0.5\ mol/l$. Then, draw the state plane of the open loop system (using *pplane.m*) to analyze the system trajectories around the equilibrium.

2. Linearize the system around the obtained equilibrium. To do that run the Simulink file *openloop_response.* Thanks to the *"Time-Based Linearization"* block you will find in the workspace the matlab structure *openloop_response_Timed_Based_Linearization* with the matrices of the linearized system.

3. Project 1:
    a. Design a closed-loop action to stabilize the equilibrium using the pole placement approach.
    b. Then, analyze the singular values both in the open-loop and in the closed-loop case.
    c. Design two decentralized PI controllers acting on the closed-loop stabilized system to track the system references.

4. Project 2:
    a. Augment the initial system structure with two integral actions to track the references.
    b. Design a closed-loop control action using the pole-placement approach considering the augmented system structure.
    c. Analyze the singular values of the closed-loop system.