ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2018 SESSION

Open book examination
Calculators: only authorized models
Duration: 3 heures

16-CH-A6 Process dynamics and control

Question 1 : (25 points)

The mathematical model below has been written for an exothermal Continuous Stirred Tank Reactor (CSTR). We must control the process using the variables h, C_A and T which represent respectively the level, concentration and temperature in the reactor. Obtain the linearized form of the model.

$$\frac{dh}{dt} = \frac{F_i}{S} - \frac{C}{S}\sqrt{h} \quad , \quad \frac{dC_A}{dt} = \frac{F_i}{Sh}\left(C_{A0} - C_A\right) - Ae^{-E/RT} C_A \quad \text{, and}$$

$$\frac{dT}{dt} = \frac{F_i}{sh}\left(T_i - T\right) + \frac{\left(\Delta H_r\right) Ae^{-E/RT} C_A}{\rho\ C_p}$$

Question 2 (25 points):

A first order system is controlled by a PI controller, which of the following is (are) true :

a) The offset is eliminated.

b) The order of the closed-loop response becomes 2nd order.

c) An increase in the integral time constant τ_I decreases the response time and the oscillations.

A first order system is controlled by a PD controller, which of the following is (are) true :

d) The oscillations will decrease with an increase of the τ_D

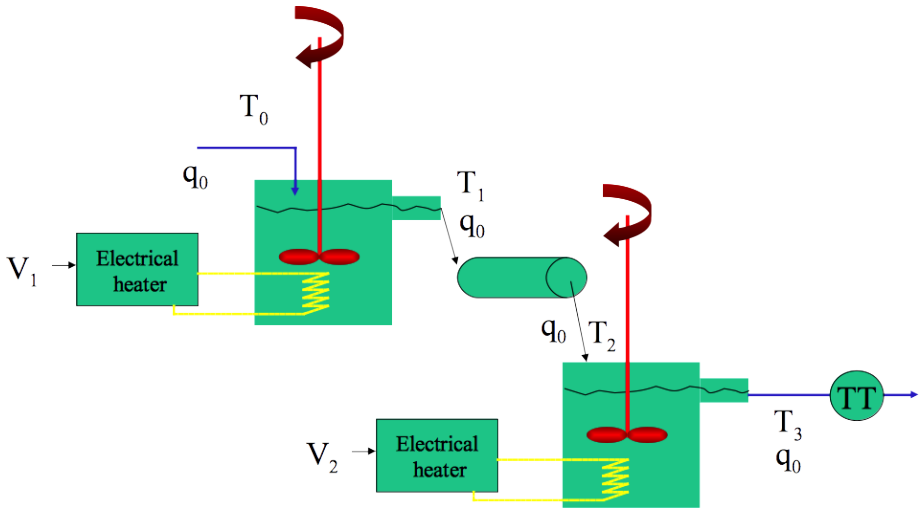
e) The order of the response will remain 1st order.

f) The offset of the response will be eliminated.

Question 3 (25 points):

Explain the gain and phase margin method based on the Bode diagram of a process of your choice. How do you choose the numerical values of the margins for the gain and phase?

Question 4 (25 points):



The following tests have been performed to obtain information on the response of the system:

1- Step of – 0.75 Standard Liters per Minute (SLPM) on q_0.
- T_1 increased by 3 degrees C, two thirds of this change has been observed in 12 minutes.
- T_3 increased by 5 degrees.

2- Step of +2 volts on V_1 (from 10 to 12 volts)
- T_1 increased by 2 degrees (from 76 to 78 degrees).
- T3 increases by 5 degrees (from 85 to 90 degrees).
- The apparent time constant for these two steps is 10 minutes.

3- Step of T_2
- The response of T_3 is almost complete in 50 minutes.

4- The calibration of the thermocouple measuring T_3 is $V_3=0.15T_3+5$

5- There is a delay of 30 seconds in the tube connection the two tanks.

Find all the process transfer functions.