Ex/ChE/T/322/2019

Bachelor of Chemical Engineering Examination 2019 – 3rd Year, 2nd Semester

PROCESS DYNAMICS AND CONTROL

Time: Three hours; Full Marks = 100

Answer any FOUR questions. All questions carry equal marks

1. In a liquid mixing tank (A= 7 sq. m.) liquid level at steady state [h_S] is 7 m, inflow and outflow rates are q_i=q=100 m^3h^{-1}.Predict the final level for a step change of -10 m^3h^{-1} in inflow rate for two cases:
(a) a linear head-flow relationship, and (b) a nonlinear relation $q = C_V h^{0.5}$.

2. Derive, and compare the transfer function models of isothermal CSTR with liquid phase reaction for the cases of 1st order and 2nd order kinetics respectively.

3. (a). The liquid level in a two-tanks-in-series system is to be controlled using a simple proportional controller. Both tanks have unity gain with time constants 1 min. and ½ min. respectively. The liquid level measuring device that provides feedback to the controller is also unity gain with time-constant 1/3 min. Draw a block diagram of the control system. Using the Routh test, find the range of values of controller gain K_c, for which the control system is stable.
(b). A temperature sensor with heat transfer area = 1×10^{-5} m^2, mass = 1×10^{-4} kg. and sp. heat capacity = 504 J/kg K; is used to measure the temperature of a gas stream flowing through a conduit. After having remained unchanged at 200°C for a long time, the gas stream temperature suddenly jumps to 210°C due to some disturbance in the source of flow. 4.8 minutes after this instant, the sensor shows a reading of 209.8°C. Estimate the film coefficient of heat transfer (W/m^2K). State necessary assumptions.

4. A stirred-tank blending process with constant liquid holdup of 2 m^3 is used to blend two streams whose densities are both approximately 900 kg/m^3. The density does not change during mixing.
(a) Assume that the system has been operating for a long period of time with steady flow rates of $w_{1,ss}$=500 kg/min and $w_{2,ss}$=200 kg/min. The mass fraction of component A in the first feed stream is x_1=0.4 and the mass fraction of component A in the second feed stream is x_2=0.75. What is the value of $x_{ss,}$ the steady-state composition of the effluent stream?
(b) Derive a linear model which describes the dynamic response ofx(t) to variation in the feed stream flow rates $w_1(t)$ and $w_2(t)$, and thereby obtain the appropriate transfer functions.

5. The outflow from a storage tank (A=4 m^2, maximum liq. height = 5 m) is forcibly constrained at 0.02 m^3/s. At a certain "steady state", tank fluid level was 2 m. The inflow rate is suddenly decreased by 10%.
(a) How is the tank fluid level affected? Does it reach a final 'steady' value?
(b) Redo the above problem when there is no constraint on the tank outflow.

6. Compare Ziegler-Nichols controller settings (based on the Bode stability criterion and Frequency Response) and Cohen-Coon settings (based on the Process Reaction Curve approximated by a FOPDT model $G_{PRC} = Ke^{-\lambda s}/(1+\tau s)$ for a P-only controller used in a control system where $G_p=1/[1+5s][1+2s]$; $G_m=1/[1+10s]$ and a very fast FCE.
[N.B. For a P-only controller, Z-N settings give $K_C=0.5K_{C,max}$ whereas C-C settings give $K_C = (1/K)(\tau/\lambda)(1+[\lambda/3\tau])$.]
State all necessary assumptions.