INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics and Control

Assignment 2

Due: Wednesday, March 10, 2021 12:00 PM

Exercise

1. An exothermic reaction $A \longrightarrow 2B$, takes place adiabatically in a stirred-tank reactor. This liquid reaction occurs at constant volume in a 1200-gallon reactor. The reaction is first order, irreversible with the rate constant given by $k = 2.4 \times 10^{15} e^{-20000/T}$(min^{-1}) where T is in $^\circ R$.

    (a) Develop a first-principles model for dynamics of c_A and reactor (exit) temperature T. State all assumptions that you make.

    (b) Set up the SIMULINK model using DEE. Determine the steady-state exit temperature using `findop` in MATLAB.

    (c) Derive a transfer function relating T and c_A to the inlet concentration c_{Ai} using MATLAB (`linearise, ss, ss2tf`). Verify your result with hand calculation.

    (d) Compare the step response (to a 10% step in c_{Ai}) of the non-linear and linearized systems. What is the extent of error in steady-state values?

    (e) Which of the output variables is affected more to a unit step change in c_{Ai}?

    Steady-state conditions
    $c_{Ai,ss} = 0.8$ mol/ft^3 and $F_{ss} = 20$ gallons/min
    Physical property data for the mixture
    $T_i = 90$°F, $C = 0.8$ Btu/(lb °F), $\rho = 52$ lb / ft^3 and $\triangle H_R = -500$ kJ/mol

2. This is a MATLAB Grader problem. Visit the URL at Matlab Grader.

3. (a) For a system described by the TF $G(s) = (s+1)/(s^3 + 10s + 31s + 30)$, write an equivalent SS description using two different methods (i) partial fraction expansion method (call this SS1) and (ii) nested integral method (call this SS2). Compare SS1 and SS2 descriptions. Can you find a transformation matrix that takes SS2 to SS1? Explain.

    (b) Suppose, for a single-input two-output (SITO) system, $y_1(t) = G_{11}u_1(t)$ and $y_2(t) = G_{21}u_1(t)$, where $G_{11}(s) = \dfrac{4s+1}{(s+1)(s+3)}$ and $G_{21}(s) = \dfrac{10s}{(s+2)(s+3)}$. Arrive at a *minimal* order SS realization for the SITO system.

4. For the signal flow graph in Figure 1, (i) draw the block diagram relating $R(s)$ to $Y(s)$ and (ii) find the transfer function $Y(s)/R(s)$.

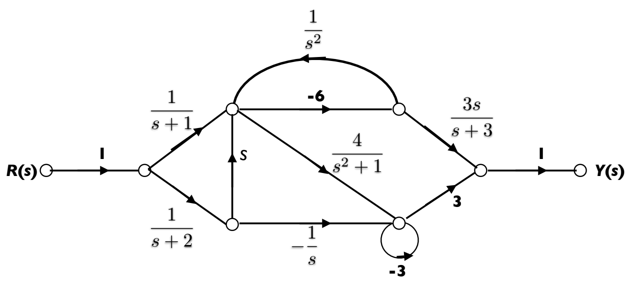

Figure 1: Signal flow graph for Q.4