INDIAN INSTITUTE OF TECHNOLOGY MADRAS

Department of Chemical Engineering

CH3050 Process Dynamics & Control

Assignment #2

Due: Monday, February 17, 2020

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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) Using the information below, develop a first-principles model. State all assumptions that you make.

   (b) Determine the steady-state exit temperature using `trim` in MATLAB.

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

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

   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. (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) state-transition diagram 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.

3. 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 $Y(s)/R(s)$.

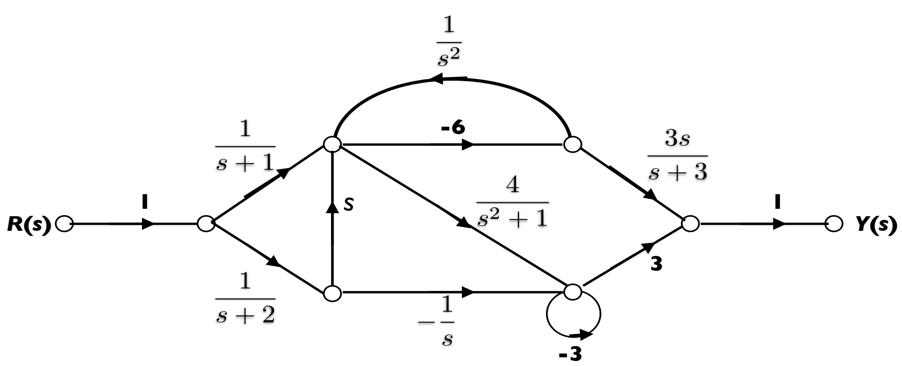

Figure 1: Signal flow graph for Q.3