Zaid

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Spring Semester 2022-23 (closed book)

Course No.: CH21208 **Max. Time**: 2 hrs

Course Title: Instrumentation and Process Control **Total Marks**: 30

Answer all questions

Q1. Consider an isothermal stirred-tank blending system shown in Figure 1. Here, V denotes the liquid volume. The mass fraction of component A in the two inlet streams are x_1 and x_2, and that in the exit stream is x. The respective mass flow rates are F_1, F_2 and F.

(a) Stating suitable assumptions, develop the dynamic model.

(b) Supposing constant V, F_1, F_2 and F, develop the transfer function model in terms of gain K_p and time constant τ_p:

(i) When x_1 varies and x_2 remains constant,

(ii) When both x_1 and x_2 vary. **[2+(2+2)+(3+2)=11]**

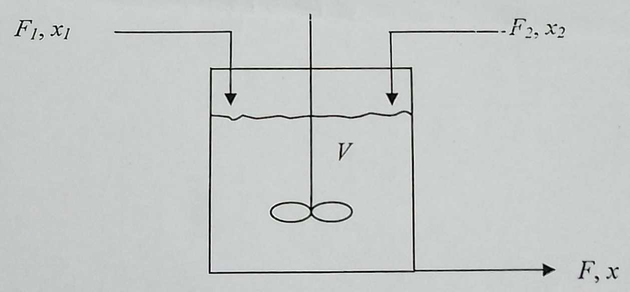

Fig. 1: A stirred-tank blending system.

(c) Consider a constant liquid holdup of 2 m^3 maintained to blend the said two streams whose densities are both approximately 900 kg/m^3. The density does not change during mixing.

(i) Assume that the process has been operating for a long period of time with flow rates of $F_1 = 500$ kg/min and $F_2 = 200$ kg/min, and the feed compositions (mass fractions) of $x_1 = 0.4$ and $x_2 = 0.75$. What is the steady state value of x?

(ii) Suppose that F_1 changes suddenly from 500 to 400 kg/min and remains at the new value. Determine an expression for $x(t)$.

Q2. (a) Why do we need to develop the mathematical model of a process we want to control?

(b) Derive the standard expression of decay ratio for an underdamped response.

(c) With an example of first-order system, show how the time constant is correlated with storage capacitance and resistance to heat flow. **[2+3+3+3+8=19]**

(d) How the system responds when the real part of its complex poles is zero? Mathematically prove it.

(e) Two noninteracting liquid tanks having the following transfer functions are connected in series (see Figure 2):

$$G_1(s) = \frac{K_1}{\tau_1 s + 1} \text{ (for Tank 1)} \qquad G_2(s) = \frac{K_2}{\tau_2 s + 1} \text{ (for Tank 2)}$$

Consider $K_1 = K_2 = 1$ and $\tau_1 = \tau_2 = 1$.

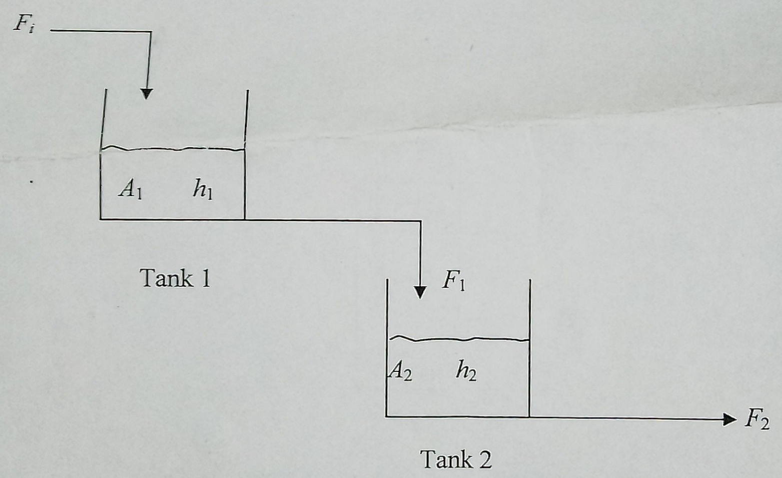

Fig. 2: Two noninteracting tanks in series.

Obtain an expression for the response of $h_2'(t)$ (the level in the second tank as a deviation from its initial steady state value) to a unit step change in the inlet flow rate to Tank 1.

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