CHBE 470 – Process Dynamics and Control – Fall 2007

Homework Set 5

Assigned: Wednesday, October 17  
Due: Wednesday, October 24

Note: Please staple your papers and include your name in the first page

Problem 1: Consider the general closed-loop block diagram with $G_c(s) = 1.6$, $G_p(s) = \frac{5}{(s+1)(2s+1)}$, $G_f(s) = G_m(s) = 1$. Suppose that the system is subject to a set point change in the input of magnitude 0.1. Determine:
   a) The maximum value of the response
   b) The offset
   c) The period of the oscillation

Problem 2: Consult chapter 11 of the book for details on interacting 2nd order systems. Consider the liquid-level system of two noninteracting tanks with a proportional control and linear resistances. It was found that when the steady-state inlet flow rate $q$ (ft$^3$/min) is plotted against the steady-state liquid level in both tanks (h in ft), the slope of the line is 2 ft$^2$/min. Both tanks have the same cross sectional areas of 2 ft$^2$. The control valve was tested separately and it was found that a change of 1 psi in pressure to the valve produced a change in flow of 0.1 ft$^3$/min. There is no dynamic lag in the valve or the measuring device.
   a) Draw a block diagram of this control system and in each block give the transfer function with numerical values of the parameters
   b) Determine the controller gain $K_c$ for a critically damped response
   c) If the tanks were connected so that they were interacting, what is the value of $K_c$ needed for critical damping?
   d) Using 1.5 times the value of $K_c$ determined in part (c), determine the response of the level in tank 2 to a step change of 1 inch in the set point.

Problem 3: A mixing process consists of a single stirred tank instrumented as shown in figure 3. The concentration of the specie A in the feed stream varies as a result of upstream processes. The controller attempts to compensate for this change by varying the flow rate of pure A through the control valve. The transmission line dynamics are negligible (i.e. $\tau_L = 0$).
   a) Draw a block diagram for the controlled process.
   b) Derive a transfer function for each block in your block diagram.
Process
1. The volume is constant (5 m$^3$)
2. The feed flow rate is constant ($q_F = 7$ m$^3$/min)
3. The flow rate of the A stream varies but is small compared to $q_F$ ($q_A = 0.5$ m$^3$/min)
4. $c_F = 50$ kg/m$^3$ and $c_A = 800$ kg/m$^3$
5. All densities are constant and equal

Transfer Line
1. The transfer line is 20 m long and has 0.5 m inside diameter
2. Pump volume can be neglected

Composition Transmitter Data
<table>
<thead>
<tr>
<th>$c$ (kg/m$^3$)</th>
<th>$c_m$ (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>200</td>
<td>20</td>
</tr>
</tbody>
</table>

Controller
1. Ideal PID controller
2. Current (mA) input and output signals

I/P Transducer
<table>
<thead>
<tr>
<th>$p$ (mA)</th>
<th>$p_v$ (psig)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>15</td>
</tr>
</tbody>
</table>

Control Valve

An equal percentage valve is used which has the following relation:

$$q_A = 0.17 + 0.03(20)^{p_v-3}_{12}$$

For a step change in input pressure, the valve requires approximately 1 min to move in its new position.