DEPARTMENT OF CHEMICAL ENGINEERING
CHL710 MAJOR TEST

1-12-06
Duration: 2 hrs 30 min.

1. A flow control loop consisting of an orifice in series with the control valve, a differential pressure transmitter, and a controller, is to be designed for a nominal process flow of 150,000 scfh of air. Valve inlet conditions are 100 psig and 60^0F, and the outlet pressure is 80 psig. The valve has linear characteristics, and a square root extractor is built into the transmitter so that its output signal is linear with flow. The valve time constant is 0.06 min. and the transmitter time constant is negligible. A proportional integral controller controls the flow.

a) Obtain the valve capacity factor, C_v, and the gain of the valve. Size it for 100% overcapacity, and assume $C_f = 0.9$ (Masoneilan)
b) Calculate the gain of the transmitter if it is calibrated for a range of 0 to 250,000scfh.
c) Draw the instrumentation diagram and the block diagram of the flow control loop, showing the specific transfer functions of the controller, the control valve and the flow transmitter.

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2. From an open-loop identification experiment, the transfer function model for the level in a thermo-siphon re-boiler in response to steam rate changes has been obtained as

$$y(s) = \frac{0.9\,(0.3s - 1)}{s\,(2.5s + 1)}\,u(s)$$

The time constants are in minutes. This model is to be used for the design of a digital controller with a sample rate of $\Delta t = 0.1$ min; obtain the required pulse transfer function model for the sampled process incorporating a ZOH element.

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3. An approximate model for a reactor temperature response to changes in jacket cooling water flowrate is given as

$$g(s) = \frac{-0.55\ ({}^{o}F/gpm)}{(5s - 1)(2s + 1)}$$

The time constants are in minutes. First show that the closed loop system is stabilized under proportional feedback control in continuous time with $K_c = -4.0$. Next,investigate the closed-loop stability of the digital control system employing the same controller(incorporating a ZOH element) with $\Delta t = 0.5$ min.

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4. Given the first-order-plus-time-delay system:

$$g(s) = \frac{K e^{-\alpha s}}{\tau s+1}$$

and an appropriate reference trajectory, the continuous direct synthesis controller is given as

$$g_c = \frac{(\tau s+1)}{K}\left[\frac{1}{\tau_r s+1-e^{-\alpha s}}\right]$$

Discretize the above controller and obtain an expression for $g_c(z)$.

From the transfer function given by eq. (1), first obtain g(z), the corresponding pulse transfer function incorporating ZOH, and use this to obtain the Dahlin controller employing the q(z) given as

$$q(z) = \frac{(1-e^{-\Delta t/\tau_r})}{(1-e^{-\Delta t/\tau_r}z^{-1})} z^{-M-1}$$

Compare the Dahlin controller with the discretized version of the continuous direct synthesis controller.

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5. a) Why does standard process control pay more attention to control strategy and not sumch to the analysis of process variability ?.

b) What is the common cause variation and how is it different from special cause variation.

c) When does a signal occur in a Shewart chart ?

d) What is the motivation behind augmenting the Shewart Chart with the Western Electric rules ?

e) What process variable is plotted on a CUSUM chart ? 10

6. Write the ladder logic for the following steps"

1. Open SV1 and start pump1 after a 5 sec. Delay
2. Run the pump for 80 sec.
3. After pumping for 80 sec. start a heater
4. Run the heater for 50 sec. and stop it. 10

Use non-retentive TON for steps 1 and 2 and non-retentive TOF for step 4.