INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics & Control
Assignment #6

Due: Thursday, May 27, 2021

Exercises

1. A process has the transfer function,

$$G(s) = \frac{K}{(10s+1)(5s+1)}$$

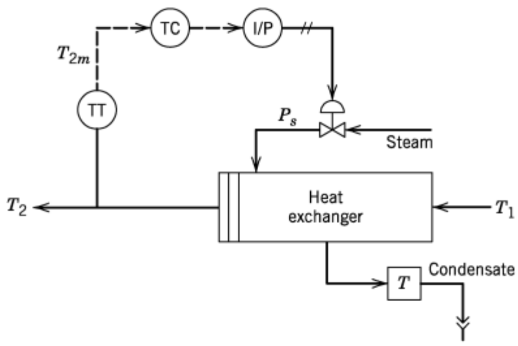
where K has a nominal value of $K = 1$. PID controller settings are to be calculated using the Direct Synthesis approach with $\tau_c = 5$ min. Suppose that these controller constants are employed and that K changes unexpectedly from 1 to $1+\eta$.

   (a) For what values of α will the closed-loop system be stable?

   (b) Suppose that the PID controller constants are calculated using the nominal value of $K = 1$ but it is desired that the resulting closed-loop system be stable for $|\eta| \leq 0.2$. What is the smallest value of τ_c that can be used?

   (c) Design a FF controller $G_{ff}(s)$ for rejecting a measured disturbance that affects the output through $G_d(s) = 1/(5s+1)$ using the nominal plant. Tune the filter constant such that the combined FF + PID control yields a settling time of 15 min. for a unit step change in disturbance with $\eta = 0.15$. Report the FF controller.

2. A process stream is heated using a shell and tube heat exchanger. The exit temperature is controlled by adjusting the steam control valve shown in figure below. During an open-loop



experimental test, the steam pressure P_s was suddenly changed from 18 to 20 psig and the temperature data shown below were obtained. At the nominal conditions, the control valve

t (min)	0	1	2	3	4	5	6	7	8	9	10	11	12
T_{2m} (mA)	12.0	12.5	13.1	14.0	14.8	15.4	16.1	16.4	16.8	16.9	17.0	16.9	

and current-to-pressure transducers have gains of $K_v = 0.9$ psi/psi and $K_{IP} = 0.75$ psi/mA, respectively. Determine appropriate PID controller settings using the following approaches:

   (a) Internal Model Control (select a reasonable value of τ_c)

(b) ITAE (set point)

(c) ITAE (disturbance)

3. The relation between the steam valve position and reactor temperature (exhibiting inverse response) is modelled as follows:

$$G(s) = \frac{-0.5(-10s+1)e^{-10s}}{(5s+1)(3s+1)}$$

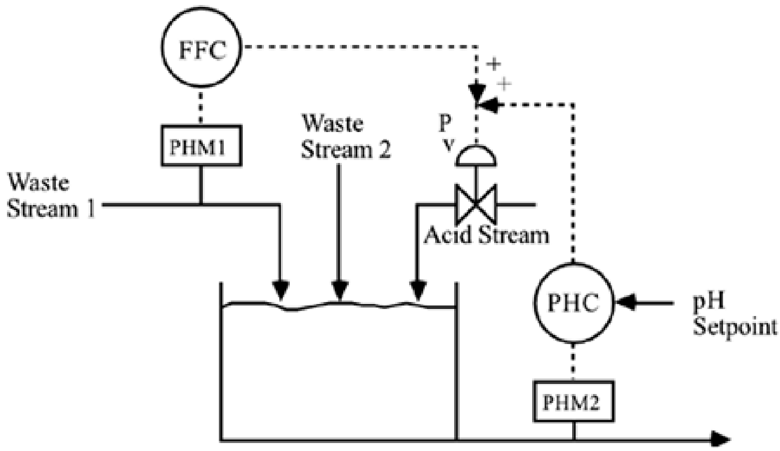
(a) What are the units of process gain?

(b) Design an IMC for this process. Use the all-pass factorization for RHP zero, and assume that $Q(s)$ is bi-proper.

(c) Assume a perfect model, plot **qualitatively** the temperature response to a step-type setpoint change of 1°C.

(d) It is desirable to make certain that the control valve position, immediately after a 10°C, does not move more than 25%. What is the smallest value of λ that you can use? Show your work.

4. A mixing vessel is used to maintain a desired pH level in a stream flowing to a waste treatment plant. The pressure to the valve on an acid stream is used as the manipulated variable. Most of the variability in pH is due to waste stream 1, which is a caustic stream. It is desirable to implement a feed-forward controller to reject the pH disturbances due to this stream. The



following data are relevant to this problem. Without control, a change in the inlet pH of 0.5 leads to a change of 0.25 pH in the outlet stream. The time delay is 10 minutes and the time constant is 30 minutes. A change in the acid stream valve-top pressure of 1 psig leads to a change in pH in the outlet stream of 0.4 pH. The time constant is 25 minutes and the time delay is 7.5 minutes.

(a) Design a feed-forward controller for this process and simulate the resulting control system in MATLAB / SIMULINK.

(b) Implement the feedforward controller together with a (tuned) PI feedback controller and quantify the improvement in performance using the IAE criterion.

(c) Describe (do not necessarily implement) how you would set up an MPC for this process. Essentially identify a suitable sampling interval, prediction and control horizons, and any constraints that you would deem appropriate.