Identification and Control of A First Order Process / Temperature Control System

Objective: The aim of this experiment is to characterize a typical process in terms of its time lags and gain and study the performance of various types of controllers that are typically used to control such a process.

Instructions to the TAs /Students:

1. This experiment needs to be performed in **MATLAB Simulink.**
2. Simulink Model of the Process and the Controllers (**Temp_control.slx)** will be provided to the students.

1. Introduction:

A schematic diagram of the system with plant and the controllers is shown in Fig. 1.

Process: Air drawn from the atmosphere by a centrifugal blower is driven past a heater grid through a length of tubing to the atmosphere again. The process consists of heating the air flowing in the tube to the desired temperature level.

Controller: The purpose of the control equipment is to measure the air temperature, compare it with a value set by the user and generate a control signal which determines the electrical voltage applied to the heater. Controller options are relay control with variable hysteresis settings and combination of proportional, derivative and integral blocks having variable coefficient settings.

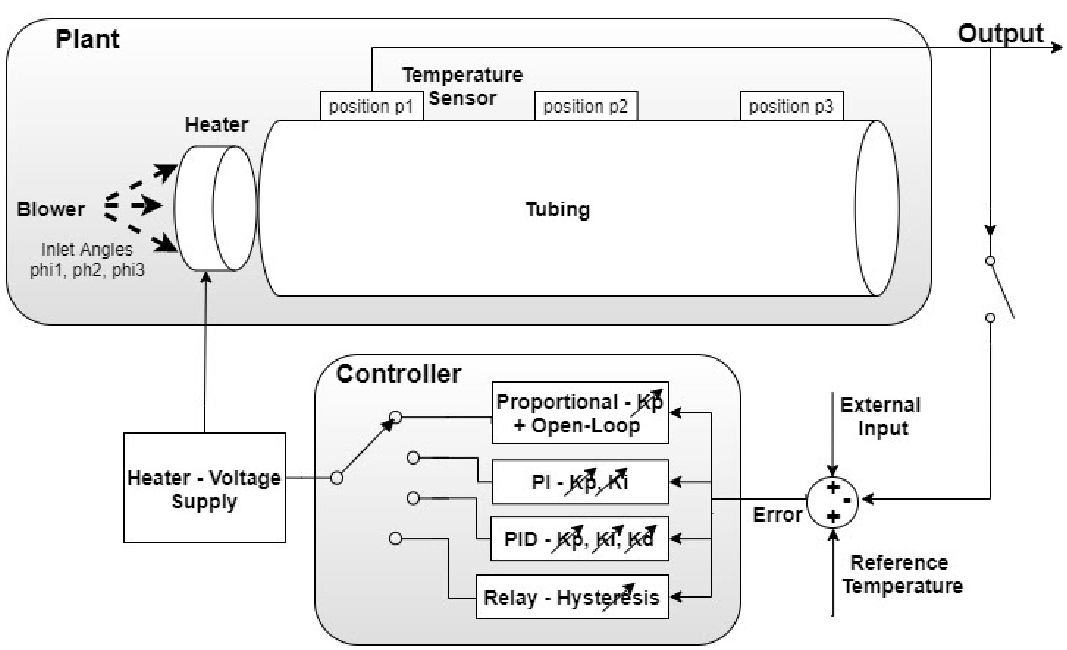

Fig 1. Schematic Diagram of the Experimental set-up

Mathematical Model: A typical model used to describe the dynamics of the above process is a first order with a time delay model. The parameters of the model that are to be identified are the time constant (transfer lag), gain and the time delay (transport lag/dead time).

The Temperature Sensor sensitivity is assumed to be 0.1V/degC and the reference temperature and the output feedback temperature are scaled accordingly.

2. Experiments:

2.1 Measurement of Transport lag (T1): This experiment is to be carried out in an open loop. T1 is the time lag between a change in the input signal and a change in the output response of the system. In a real system, it is usually measured by providing an external input as shown in Fig 2. In order to measure T1 using external input -

a. Configure the system in Open Loop by disconnecting the feedback path, and setting Open Loop Enable to 1 and proportional gain Kp = 1.
b. Set the Reference Temperature to 0.
c. Set Blower Input Angle as phi1 and Temperature Sensor Position as 1.
d. Connect one of the external inputs to the system and simulate. Measure T1. Submit your Plant input and output response plots.

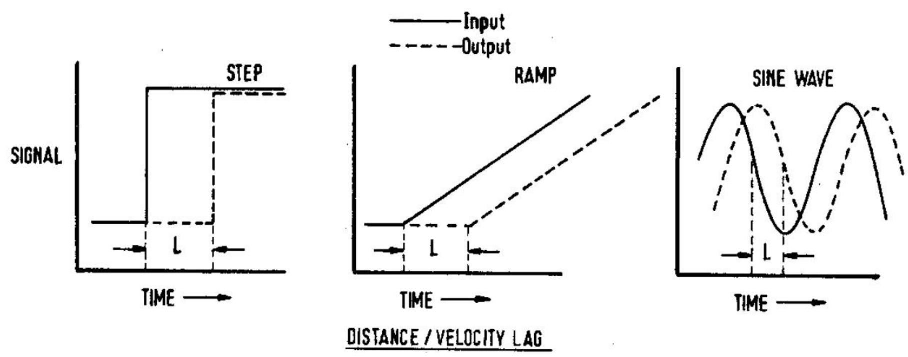

Fig 2. Transport lag of the process

2.2 Measurement of Transfer lag (T2): The transfer lag is introduced by the thermal time constant of the system. A typical open loop response of a first order system is shown in Fig.3. The time constant (T2) is the time taken by the system to reach 63.2% of the final settling value Vf.

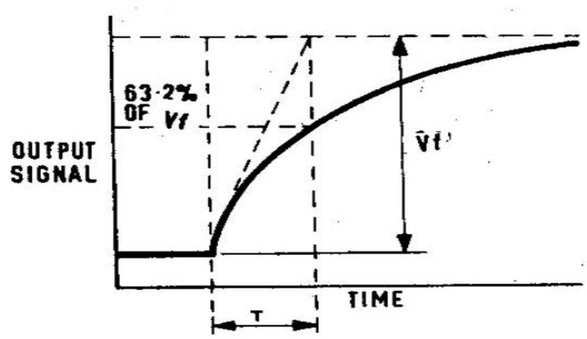

Fig 3. Transfer lag of a process.

In order to generate the open loop response of the system and measure T2 -

a. Configure the system in Open Loop by disconnecting the feedback path, and setting Open Loop Enable to 1 and proportional gain Kp = 1.
b. Set the Reference Temperature to 60.
c. Set Blower Input Angle as phi1 and Temperature Sensor Position as 1 and simulate. Measure T2. Submit your Plant input and output response plots.

2.3 Measurement of Gain (K):

Use the open loop response curve obtained in Step 2.2 to compute Gain K. Ambient Temperature is the starting temperature at time t=0. Plant Input Voltage / Controller Output Voltage can be measured while generating the Open Loop response.

$$K = \frac{Final\ Temperature - Ambient\ Temperature}{Plant\ Input\ Voltage}$$

2.4 Obtain the Transfer Function of the Plant for Temperature Sensor Position 1 and Blower Inlet Angle Phi1

$$G(s) = \frac{K * e^{(-T1*s)}}{T2*s + 1}$$

Use the values of T1, T2 and K obtained in the previous steps to find the transfer function G(s).

2.5 Study the effect of Blower Inlet Angle on the plant parameters (T1, T2 and K)

Repeat Step 2.1, 2.2 and 2.3 with Blower Input Angle set to Phi1, Phi2 and Phi3. Don't vary the Temperature Sensor Position and let it remain as 1.

2.6 Study the effect of Temperature Sensor Position on the plant parameters (T1, T2 and K)

Repeat Step 2.1, 2.2 and 2.3 with Temperature Sensor Position set to 1, 2 and 3. Don't vary the Blower Inlet Angle and let it remain as phi1.

2.7 Obtain the Transfer Function for different Temperature sensor positions and

Blower Angle settings.

Use the values of T1, T2 and K obtained in steps 2.6 and 2.7 to find the transfer function G(s) for all the various settings and fill up Table 1.

Table 1: Transfer Functions

	Sensor Position 1	Sensor Position 2	Sensor Position 3
Inlet Angle Phi1			
Inlet Angle Phi2			
Inlet Angle Phi3			

2.8 Use the Relay / ON-OFF Controller to study the effect of varying the hysteresis band on the closed loop system

ON-OFF or Relay type controller is also referred to as two position controller and is a relatively simple and inexpensive way to control the system. As per Fig. 4, the controller turns ON or goes to position M1 when the error between the desired temperature and the measured temperature is greater than or equal to Relay ON Level and turns OFF or goes to position M2 when the error is less than or equal to Relay OFF Level. As shown in Fig. 4, H is the Hysteresis band. Hysteresis is necessary as it enables the controller output to remain at its present value till the error has increased a little beyond zero. It helps in avoiding too frequent switching of the controller although a large value results in greater errors.

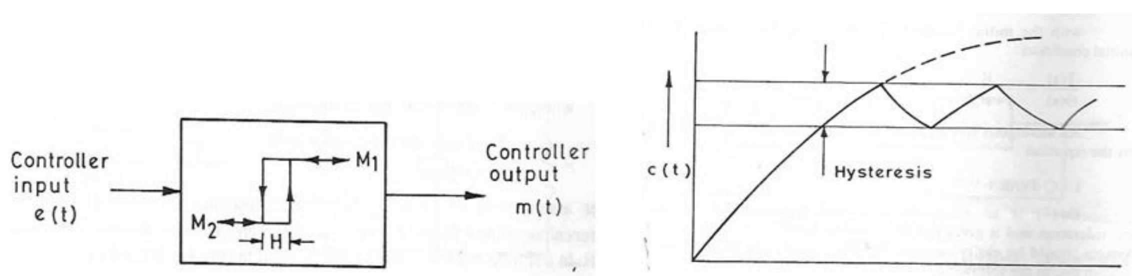

Fig 4. Relay Controller.

Use the system obtained in step 2.4 for this study.

a. Configure the system in Closed Loop by connecting the feedback path, and setting Open Loop Enable to 0.
b. Set Relay Control Enable to 1.
c. Set the Reference Temperature to 60.

d. Simulate various hysteresis bands by varying the Relay OFF Level and Relay ON Level settings. Submit your Plant input and output response plots.
    i. ON level = OFF level = 0 (zero hysteresis)
    ii. ON level = 0.2, OFF Level = -0.2 (low hysteresis)
    iii. ON Level = 0.5, OFF Level = -0.5 (high hysteresis)

2.9 Design the P, PI and PID Controllers for the System

Controller Transfer Function C(s) for each controller is given by the equations shown below.

Proportional (P) Controller: C(s) = Kp

Proportional-Integral (PI) Controller: C(s) = Kp + Ki / s

Proportional-Integral-Derivative (PID) Controller: C(s) = Kp + Ki / s + Kd*s

Ziegler Nichols Method is one of the techniques to compute the values of the coefficients Kp for P controller (P), Kp, Ki for PI controller and Kp, Ki and Kd for PID controlled. The equations for computing these parameters are given below.

P Controller: Kp = (1/K) * (T2/T1)

PI Controller: Kp = (0.9/K) * (T2/T1), Ki = 1/(3.3*T1)

PID Controller: Kp = (1.2/K) * (T2/T1), Ki = 1/(2*T1), Kd = 0.5*T1

Compute the coefficients for all the three controllers using the Ziegler Nichols method and fill up Table 2. Use the transfer function obtained in step 2.4 for this purpose.

Table 2: Controller Coefficients

Controllers	Kp	Ki	Kd
P		0	0
PI			0
PID			

2.10 Compare the Performance of the P, PI and PID controllers

Use the system obtained in step 2.4 for this comparison. The coefficients computed in Step 2.9 is a good starting point but may need to be modified for improving performance.

a. Configure the system in Closed Loop by connecting the feedback path, and setting Open Loop Enable to 0.

b. Set Relay Control Enable to 0.
c. Set the Reference Temperature to 60.
d. Set the values of Kp, Ki and Kd and simulate.

Calculate the various parameters for all the controllers and fill up Table 3. Attach the plant input and output response plots for each case.

Table 3: Performance Comparison

Controllers	Settling Time (sec)	Rise Time (sec)	Overshoot (%)	Damping State
P				
PI				
PID				

2.11 Repeat steps 2.9 and 2.10 for Temperature Sensor Position 3 and Blower Inlet Angle Phi3