MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE407
PROCESS CONTROL LABORATORY

EXPERIMENT 5
Heat Flow Characteristics and Temperature Control

Date of the Experiment:	03/12/2018
Lab Group:	Monday Afternoon 1
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I. Results and Discussion

1. (Bump test)

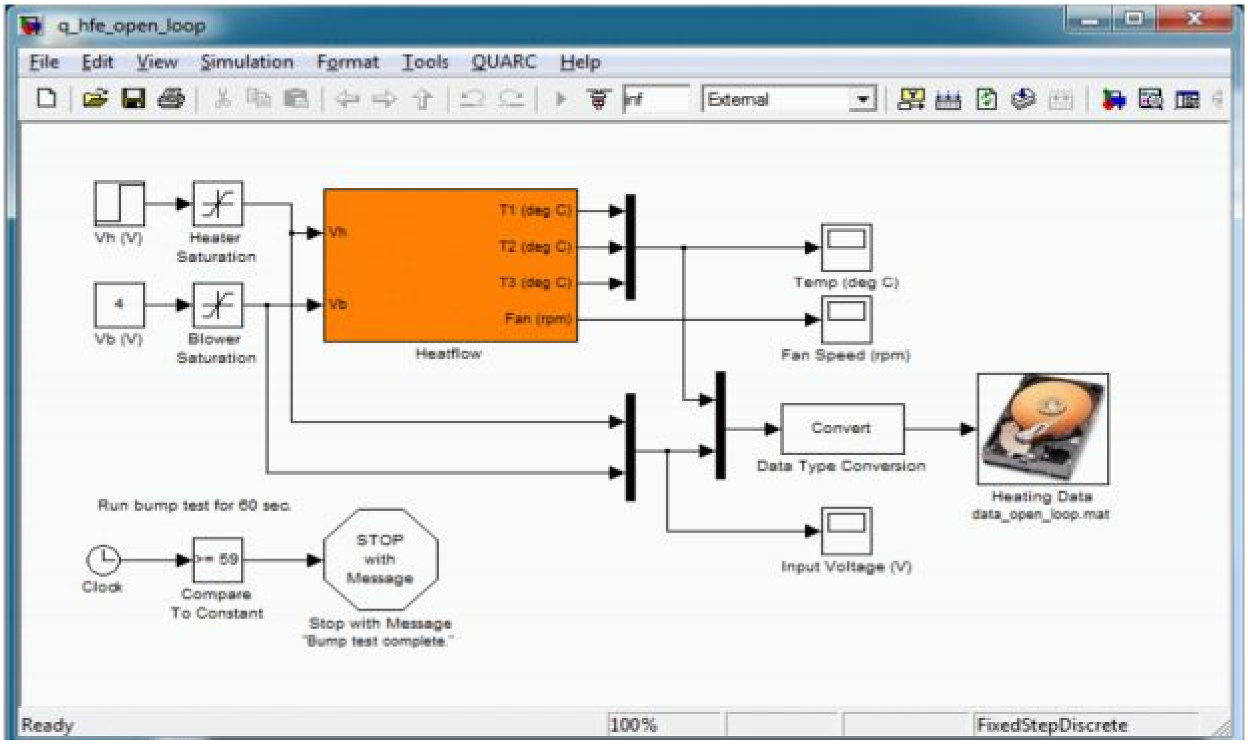

Figure 1: The simulink model of q_hfe_open_loop

The temperature responses of T1, T2 and T3 when the simulink model of q_hfe_open_loop runs can be seen from the Figure 2. The applied heater voltage can be seen from the Figure 3.

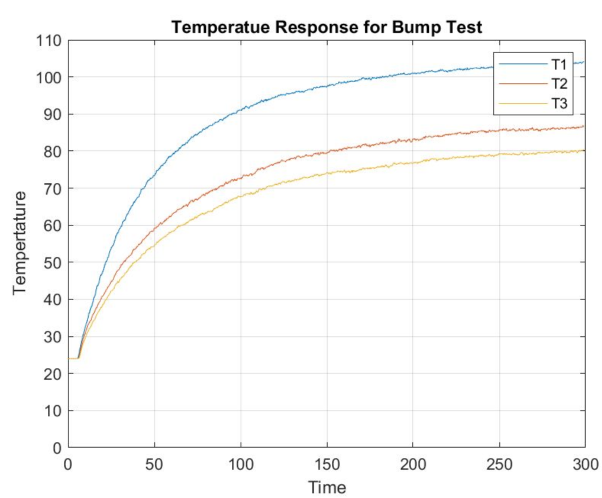

Figure 2: The temperature bump test response of the simulink model in Figure 1

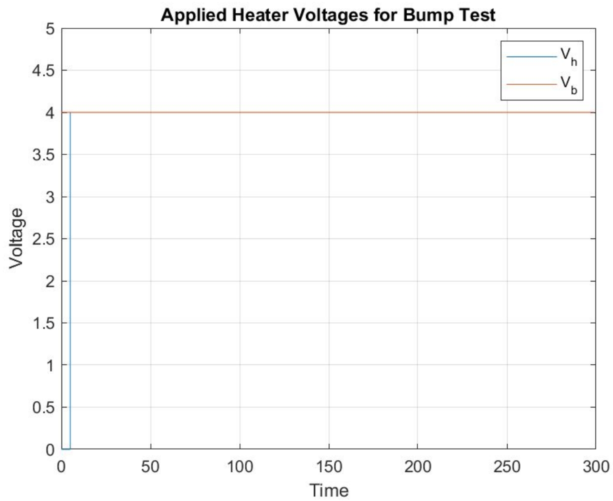

Figure 3: The applied heater voltage of the simulink model in Figure 1

2. No, the temperature in different locations along the duct go up at the different rate as can be seen from the Figure 1. The reason behind this the sensor of T1,T2 and T3 are located at different places.

3.

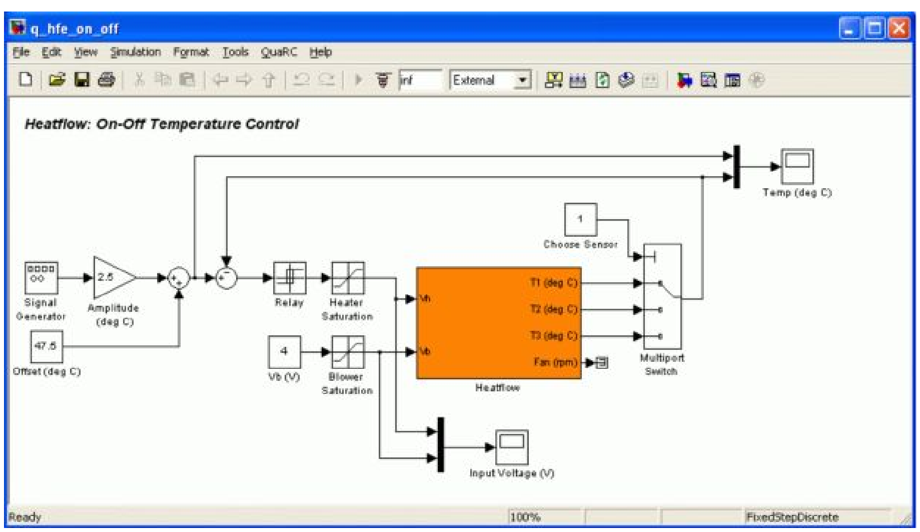

Figure 4: The simulink model of q_hfe_on_off

The temperature responses of T1 when the simulink model of q_hfe_on_off runs with Hysteresis Width = 1 can be seen from the Figure 5. Secondly, the temperature responses of T1 when the simulink model of q_hfe_on_off runs with Hysteresis Width = 0.2 can be seen from the Figure 6.

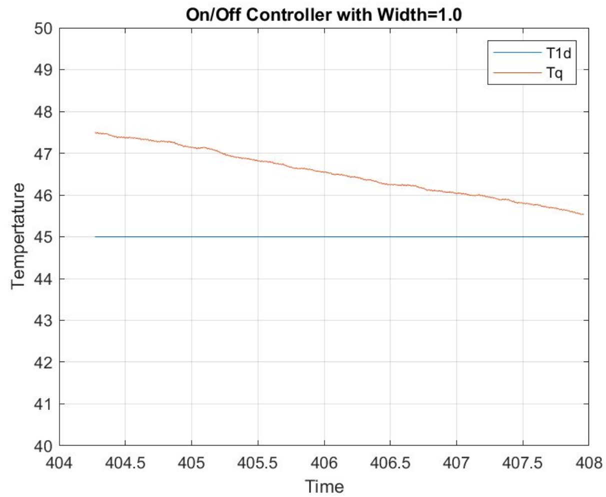

Figure 6: The temperature responses of T1 of the simulink model in Figure 5 when the hysteresis width = 1

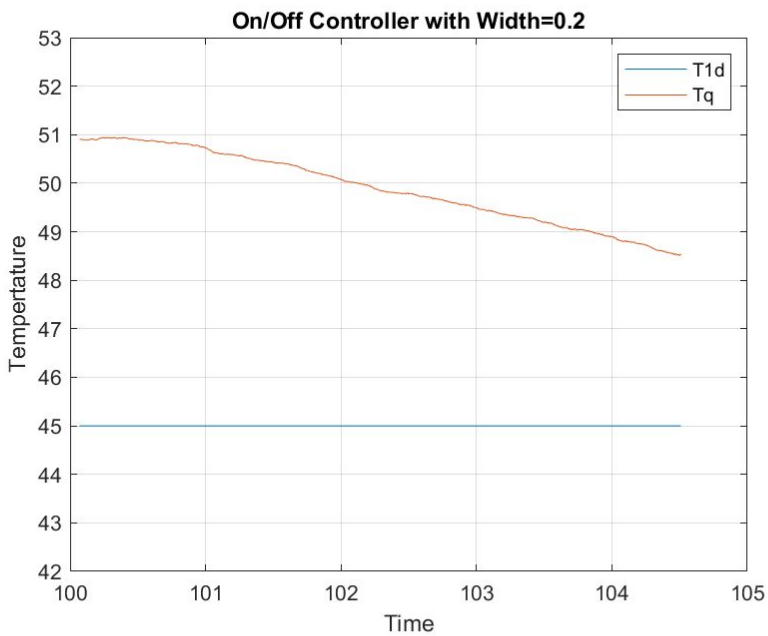

Figure 7: The temperature responses of T1 of the simulink model in Figure 5 when the hysteresis width = 0.2

Decreasing the hysteresis width of the relay is not a preferred choice since this way the ON OFF actions will occur more frequently, consequently wearing out the actuator and system in long run. The potential drawbacks can be burn the system.

4. Possible advantages of ON-OFF controller is achieving a more stable control by defining a dead band which is an operation range around the set point, avoiding the actuator from wearing off. Also ON- OFF control is sometimes used for the sake of simplicity. Note that it is advantages to use it when the output response delay is small. Another disadvantage of it may be namely the constant overshoot of the set point and hence the cyclic behavior. It should be known that this type of controller can not be used for critical systems.

5.

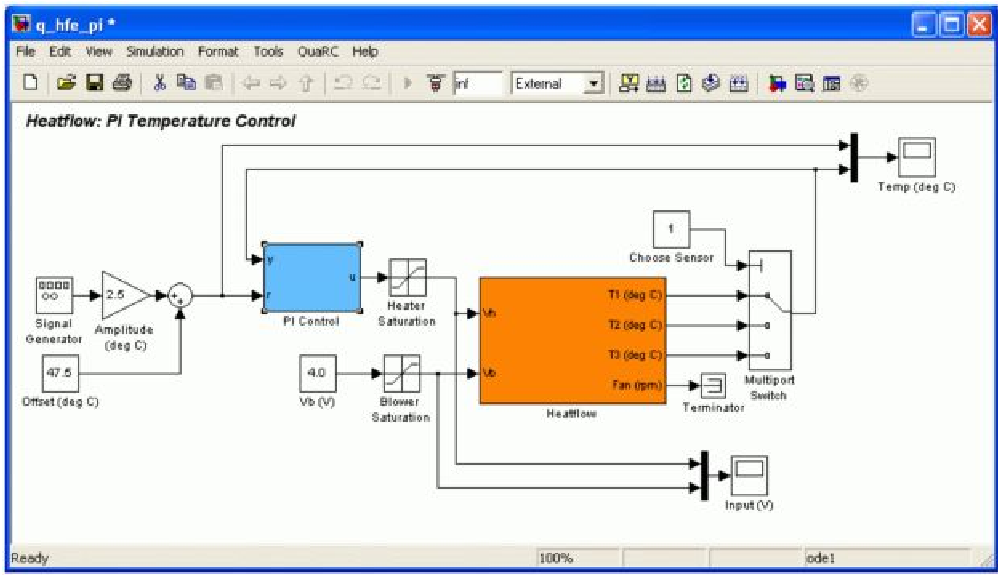

Figure 8: The simulink model of q_hfe_pi

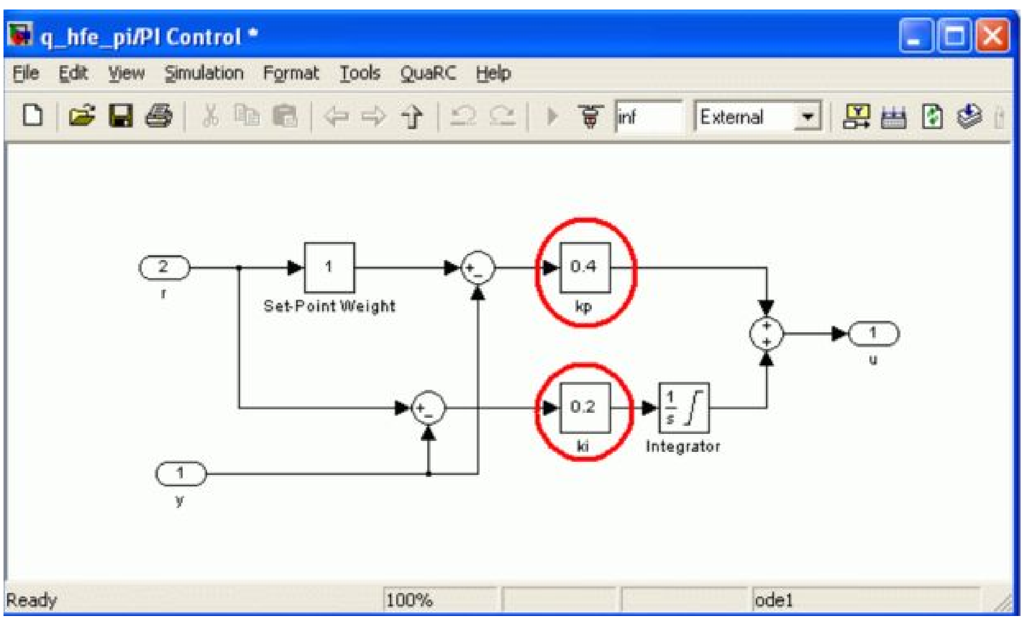

Figure 9: The simulink model of the PI Control in Figure 8

P only controller takes Ki=0 in Figure 9. The temperature responses and the heater voltage of T1 when the simulink model of q_hfe_PI runs with Kp=0.3 can be seen from the Figure 10.

The measured steady-state error from the Figure 10 is 7 degree. The result is consistent with our expectations since P controller has non-zero steady-state error.

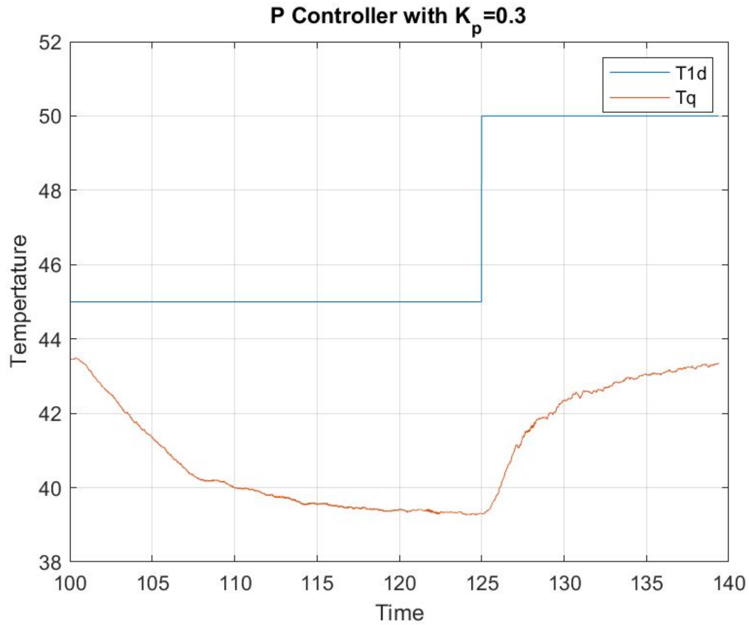

Figure 10: The temperature responses of T1 and the heater voltage of the simulink model in Figure 8 when the Kp = 0.3

6. ess=1/(Kp+1)=~0.77

But it is for unit-step input. In experiment, we give input as 5 unit-step. So ess=5*0.77=3.85. It is less than measured value at previous question because of the non-idealities and discrepancies of real world.

7. Adding an Integral controller to our P only controller makes the steady state error to go to zero. It also increases the amplitude of the overshoots. Generally it gives a better response than a P controller with the appropriate integral time constant.

8. Not having an anti wind up action in the PI controller causes the errors to pile up hence a nonzero steady state error and a smaller overshoot.

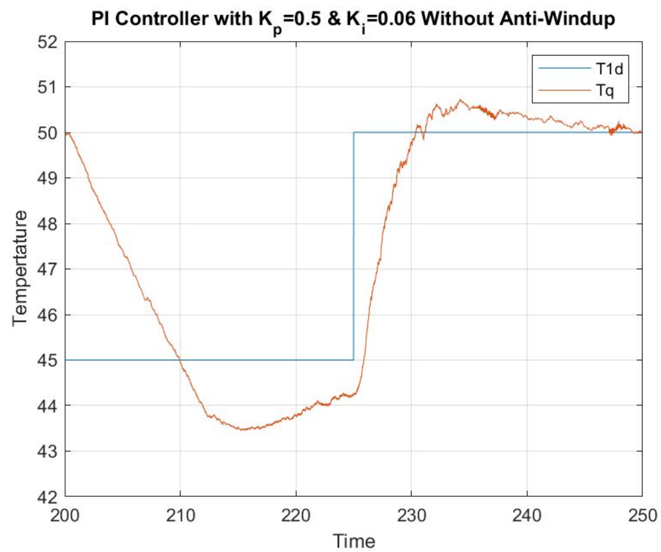

Figure 11: The temperature responses of T1 and the heater voltage of the simulink model in Figure 8 when the Kp = 0.5 and Ki=0.06 without Anti-Windup

9.

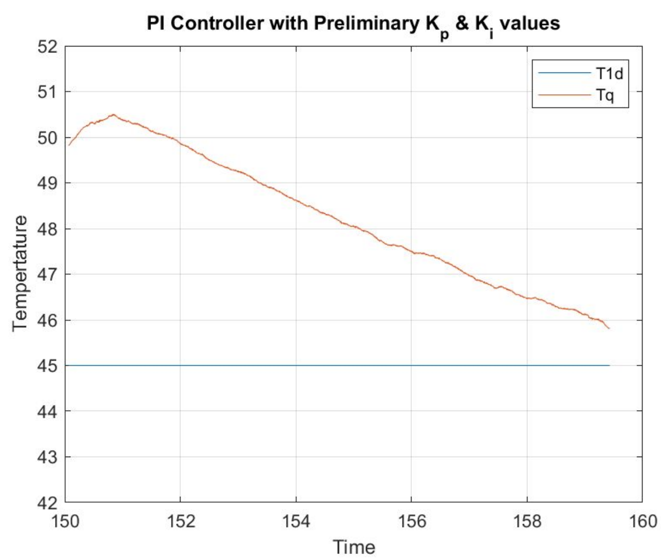

Figure 12: The temperature responses of T1 and the heater voltage of the simulink model in Figure 8 when the Kp = 14.675 and Ki=3.758

The Figure 12 data time interval was not well. But, we also look the datas while doing experiment and it gives us desired peak time which is 15 seconds and desired percentage overshoot which is %15. We actually observe %10 overshoot. The discrepancy can be from the disturbance and measuring errors in real life case. These values are consistent with design requirements.

10.

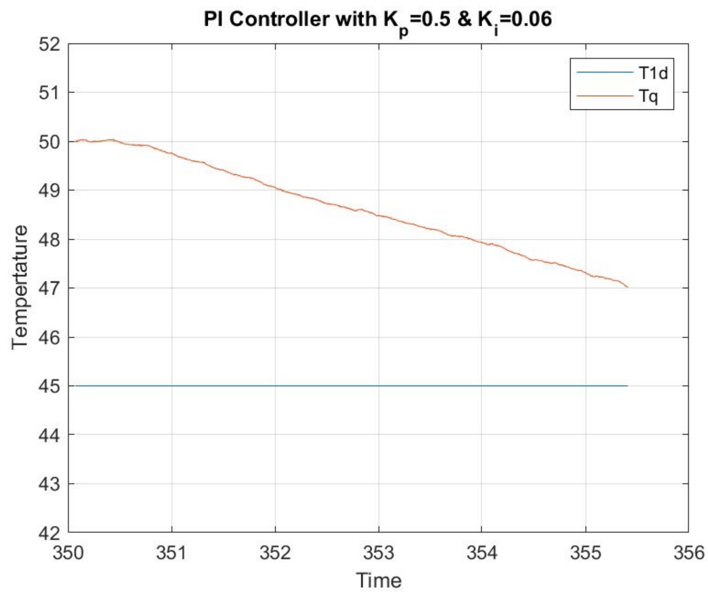

Figure 13: The temperature responses of T1 and the heater voltage of the simulink model in Figure 8 when the Kp = 0.5 and Ki=0.06

The Figure 13 data time interval was not well. But, again from the observing data while while doing experiment was well. The peak time and percentage overshoot was not exceed desired values, so the requirements are now satisfied.

II. <u>Conclusions</u>

In this experiment, we used a device Quanser Heat Flow which we control the device with different controllers. Firstly, we used bump test modeling. Thanks to these modeling, we observed the step response and characteristic of system. Secondly, we used on/off controller. On/off controllers are feedback controllers which switch themselves between two states. They have a deadband which do not work at that band thanks to that it switches less frequently. In experiment, we observed the hysteresis effect of the controller. Lastly, we used PI controller which is most common controller in the industry. We make experiments both P and PI controllers. Only P controllers have a good response but they have a nonsteady-state error. So we used PI controller. When we add an Integral element to our P only controller makes the steady state zero but it also increases the amplitude of the overshoots. In addition to these, we saw that anti wind-up is a very important issue for PI controller. Because without that, steady-state error and overshoot is not as desired .Last part of the experiment was about the tuning the controllers. We tried to make best controller with tuning parameters. We got a good result from that.