Laboratory Exercise 4 (Wk 5)

Ball in Tube

Introduction

We will first discuss instrument linearity as well as manual and auto control of the process. Then we will discuss auto-tuning and the process of controlling the ball for various step increments in auto as well as control in manual.

Log onto eng.utoledo.edu/~wevans and scroll down to the following entries:

Various Videos and Labs
Chapter 17 Siemens Motion Starter Pgm
Chapter 17 AB Motion Starter Pgm
Ball in Tube Lab for EET 4450 ← Load this program
Ball in Tube Lab with Pot Adjust in Manual
Tank over Tank
Siemens Safety Starter Pgm
Siemens Safety Advanced Pgm

Follow the previous lab's directions to download the program onto the processor. Also, use the HMI simulate function to allow the HMI screens to be accessed from the computer screen. Follow the instructor's directions for this.

When powered up, the ball rises to the top of the tube and then back down to the rest position. The HMI screens show the status of the ball at various times. The purpose of the process is to suspend the ball at various heights either automatically or manually.

Ball in Tube Experiment
Fan at base
Laser focused down tube
Ball suspended in the tube

Fig. 4-1

The figure above is the ball-in-tube experiment.

The primary screen for the Lab is:

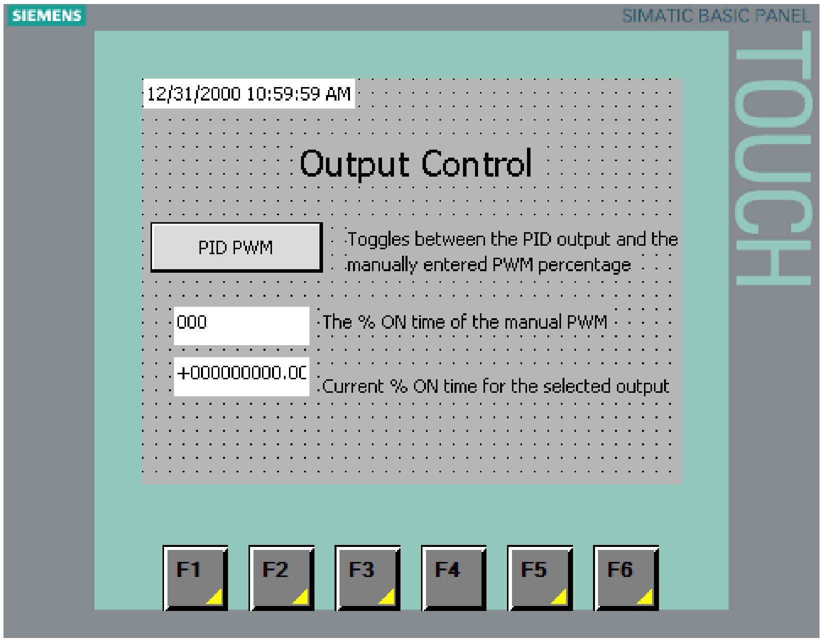

Fig. 4-2

The three function keys are labeled with the following:

F1 - Output Control – screen control to pick the screen above
F2 – Graphs – screen control to pick the graph screen – next page
F3 – PID Param – screen control to pick second screen – next page

The **PID PWM** button toggles between the manual and automatic mode of the PID controller. When in manual, the button says **Manual PWM** and the student can enter the percent output of fan to control the air speed. Air speed is controlled in this mode by entering a number in percent in the blue tab **Output PWM** on the next screen.

Manual

To change the height in manual, set the button above to **Manual PWM** and on the second screen, set the blue tab to a percent from 0 to 100.

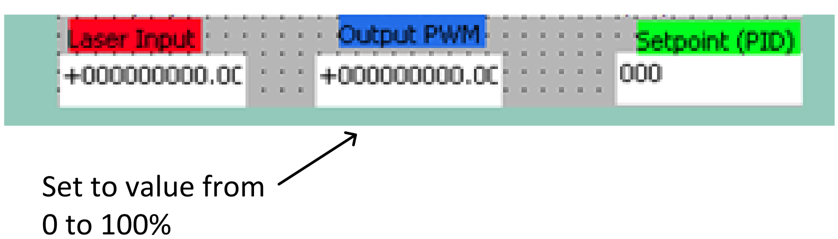

Fig. 4-3

This sets the output to a percent on of the 24 V power supply to the fan. The figure below shows various percent on times for the fan.

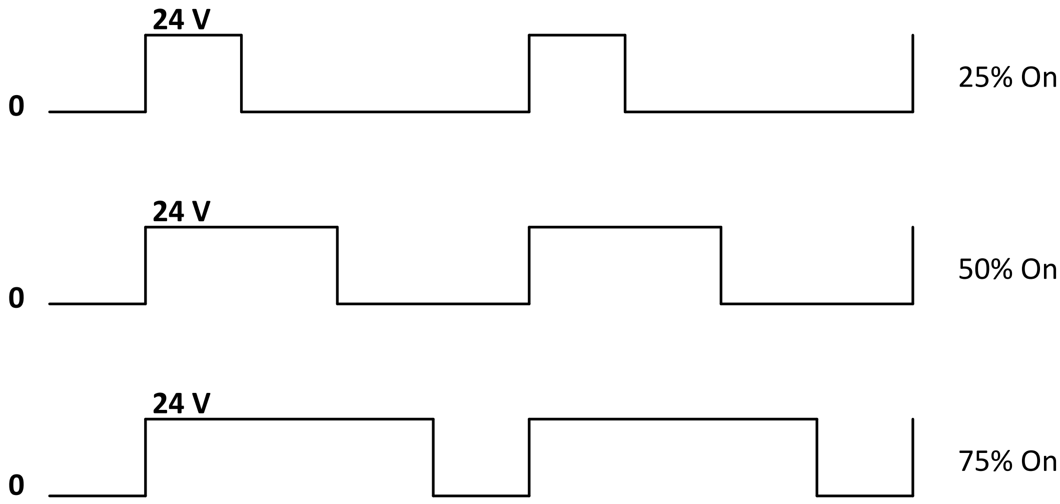

Fig. 4-4

Auto

To change the height of the ball in auto mode, click the button to **PID PWM.** In this mode, the PID algorithm is automatically adjusting the PWM of the fan to achieve a height of the ball set by the percent height on the next screen's green tab **Setpoint (PID)**.

To change the auto set-point, click **Setpoint (PID)**. In auto mode, the value set is a percent of the height of the tube. For instance, 10 or 10% would cause the fan to control the ball to 10% of the total height of the tube (if everything is properly calibrated). The actual height of the ball can be read from the Laser Input at the left of this screen or directly from the yard-stick attached to the tube.

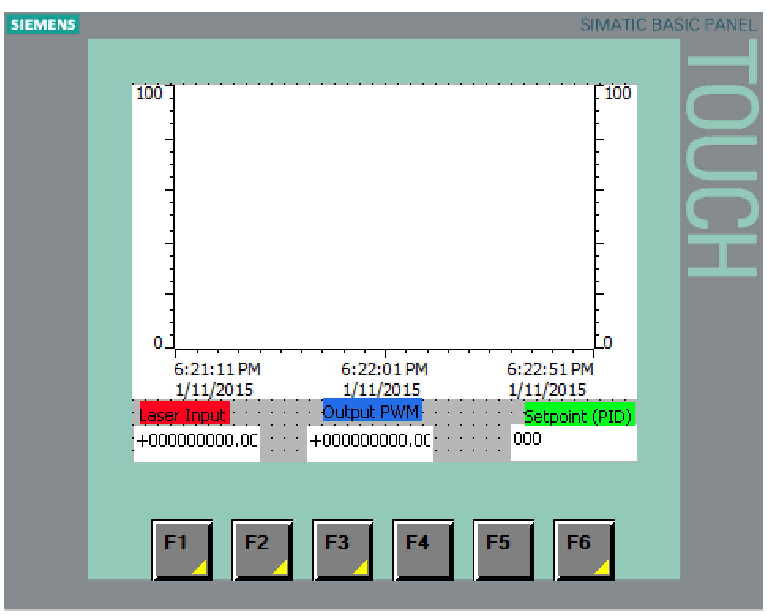

Fig. 4-5

Use the following screen to change tuning parameters for the block:

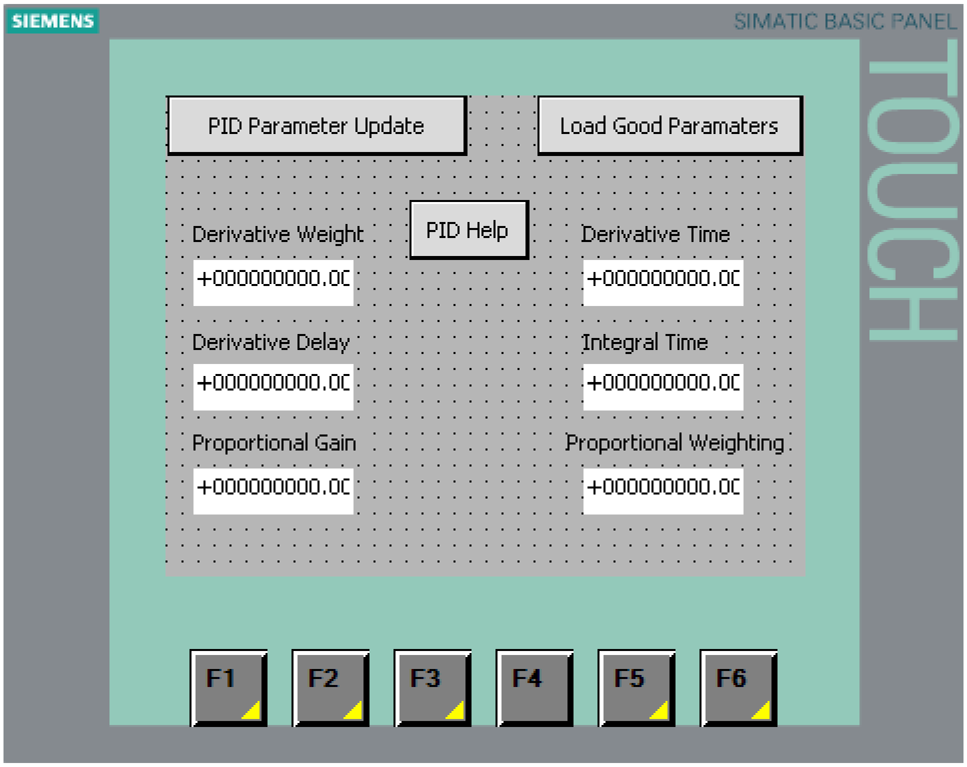

Fig. 4-6

Determining Linearity of Device:

There are two different relationships in this portion of the lab. One involves the laser and the ball's position. The other involves the PWM output of the fan and the height of the ball in the tube.

In each case, the input or (x) variable can be manipulated and the output or (y) variable observed. This lab involves determining the linearity for each of the relationships.

The procedure involves going from the low value to high value in small increments and from high to low in small increments. If the output value saturates (goes to 100%), all remaining input values may be skipped.

1. Collect values of output (y) for laser input vs values of input (x) of ball height (from yardstick). To do this, set the mode to PWM (auto) and adjust output % from 0 to 100 in increments of 10. Then repeat from 100 to 0 in increments of 10.

2. Collect values of output (y), ball height vs values of input (x) or PWM %.

   PWM % represents a number for the percent of time the pulse to the motor is on. To do this, set the mode to manual and adjust the output % in 1% intervals starting at 10%.

There will be a point at which the ball takes off. This threshold will then allow the ball to reach the top without further adjustment. Then move from high values to low values. You will see a relationship that is different when the ball is at the top and the percent is lowered.

3. Graph of Laser Output vs Ball Position:

   You may want to use the graph at the end of the lab report or generate the graph automatically using XLS (in scatter x-y mode).

4. Graph of Ball Height vs PWM%:

   You may want to use the graph at the end of the lab report or generate the graph automatically using XLS (in scatter x-y mode).

Questions:

1. Are these two relationships linear?

2. Is linearity necessary to have an automatic operation?

3. Use the system in auto (**PID PWM**) to control the height of the ball. Set the set-point to a height and observe the ball's movement. Move the **Setpoint (PID)** from a low value such as 20% to a higher value such as 60%. Describe movement of the ball as it moves to 60% height.

4. Now switch to manual (**Manual PWM**) and try to control the height to the same height as in the auto mode. Describe the movement of the ball in this mode. Is it harder to control to a set height?

5. Switch the system back to auto and hold your hand over the tube so as to cause a restriction (but letting some air through). What happens when controlling the ball to a set height?

   If you hold your hands on the vents for a much longer time, what results are observed? **Do not hold your hand near the fan at the bottom of the tube!!!**

6. Do the same procedure of holding your hands on the vents with the system in manual. What happens to the ball's position when controlling the ball to a set height?

7. Now vary the set-point from a high percent to a lower percent while in auto mode. This is the reverse of the step function above. Move the set-point from 60% to 20% and observe and record the graph for the negative step function.

8. Vary the set-point by a great amount while in auto. Set the set-point at 10% and then enter a step to 90%. Record the results. Are these results different than those previously recorded? If they are greatly different, reduce the step to a lesser percent to determine at what point the results seem to be more like the step function from 20 6o 60%.

9. Reverse the process and set the step to 10% from 90%. This is the reverse step. Record the results.

Changing PID Values and Noting Results

In Automatic mode, there are parameters for P, I, and D. Introduce a step for the auto mode from 20% to 60% as done above.

1. Next, consider only the effect of removing a parameter, one at a time. Delete the D parameter while keeping the P and I. Report the stability of the auto controller to a step response with the D parameter removed.

2. Do the same with the - I (Integral) term leaving only the P (Proportional) term. Report the stability of the auto controller to a step response with the I and D parameters removed.

3. Restore the I and D parameters to their original values and, with the device in auto mode, decrease each parameter, one at time, to 50% of its original value. First decrease the D parameter and introduce a step. Then reduce the I. Finally reduce the P to 50%. Report the stability of the auto controller to a step response as each variable is reduced.

4. Use the parameters for your machine to fill in the complete PID equation for your controller:

Now, ignoring the good tuning parameters, try to guess your own best tuning parameters to make the ball stable in the tube. You may just guess or use the one of the examples from the book or one of the three eye-ball explanations below. Do your best to achieve stability when changing in a step-wise fashion using the same step given above – 20% to 60%.

Below are three very different approaches used by various instrument engineers to tune a PID loop. If a method is selected, comment on it and why you chose this method.

Engineer #1:

This is the way I do it.

1) Set I & D to minimum
2) Increase until it just starts to oscillate
3) Reduce gain to 1/2 of oscillation Gain
4) Set I to 2 X period of oscillation

5) then only if required set D to 1/8 of I value.

Check to make sure your actuator (output device) is linear. If there is any backlash in the valve actuator, or control actuator, check this by plotting controller output vs. measured variable on XY in MMI. If you get a circle then this may be your problem.

Engineer #2:

Just think of it as three radio dials - adjust the Gain dial until you are close. Use the Integral dial to get closer. If you need faster response, turn up the Derivative dial.

Your statement about derivative action troubles me. I think of derivative more in terms of ensuring less overshoot.

My favorite analogy for derivative is the ferry boat driver (who aims for zero overshoot). As he approaches his destination / docking point, he throws the engine into reverse (forgive me for my ignorance of the proper nautical terms). This is how derivative works. Yes I suppose the principle allows the ferry driver to make his crossing more quickly ...... but only in a zero-overshoot or minimal overshoot scenario.

(Sorry, but from my point of view, your example matches better a feed-forward then derivative action.)

Engineer #3:

A good, practical and safe approach to tuning closed loops is to start by de-gaining the controller by a known factor (F1) of between 100 and 1,000, setting the Proportional term to zero, setting the Integral term high. Then follow these steps:

1) If not already accomplished, scale the reset term to within +/- 10% of operational calibration by calculation

2) Adjust the Proportional term to zero and the Integral term to maximum (over-damped).
3) Run the system and set the controller to just under critically damped by introducing a small (5%-20%) stepped change to the input signal (or equivalent) and incrementally increasing the Proportional gain until the reset term displays a slight tendency to ring. If the system remains over-damped for all available Proportional values, reduce the Integral term by a factor of 10 and repeat step 3), starting with the Proportional term returned to zero each time.

4) Once set to just under critically damped, decrease the Proportional term and increase steady state gain by factor F1. However, the controller should only be given the gain the process requires. Practical systems are usually comprised of elements capable of a resolution of only one decade better than the steady state accuracy the process requires. (Generally, there is no point of trying to set a loop to achieve stability and accuracy at 1/10,000 when the set point can only be set to 1/100). The higher the system gain, the more critical will be the coupling requirements and the more difficult the loop will be to stabilize.

Electrical Engineering Technology

Lab Report Grade Sheet

Name/Date ____

Course: EET 4450

Lab **Laboratory Exercise 4 – Ball in Tube**

Grading Element	Maximum Points	Your Points
Objective	10%	
Procedure	10%	
Results	20%	
Discussion	20%	
Conclusion	30%	
Spelling/ Grammar	10%	
Total	100%	

Comments: ____

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Instructor: ______________________________

Objective, Procedure, Results:

Conclusion

Discuss the results or your lab and show how the objectives were met. If there were substantial differences or similarities between how the two controllers did a specific task, comment on your observations.