Lab 3: Basic Control Actions

References:

Ogata, Katsuhiko. Modern Control Engineering, 5th ed. Prentice Hall, New Jersey: 2009.
Horowitz & Hill. The Art of Electronics 2nd ed. Cambridge University Press, MA: 1989.

Introduction

The proportional, PI, and PID controllers are among the most basic of feedback controllers. They are implemented easily and quickly, perform effectively in light of plant uncertainties, and are widely used in industrial electronic, pneumatic and hydraulic motion control and power systems. They are valuable as a pedagogical tool because an intuitive understanding of the feedback mechanism serves as the basis for the material encountered in a classical controls course.

This laboratory exercise will focus on the hardware implementation and physical effects of basic feedback controllers. Issues such as calibration and signal interfacing will be encountered and resolved. In addition, the effects of proportional only, PI, and PID control will be observed through the various exercises and an intuitive feel for the three types of controllers will be developed. The mathematical background for the three types of controllers will not be covered here.

Objectives

Completion of the laboratory exercise will have required you to:

1. Identify the portion of the unity feedback closed loop control system (Figure 2 of the Prelab) to which each component of the motor and cylinder control experiments belong.
2. Tune the proportional, integral, and derivative gains to achieve a desirable output response.
3. Understand the individual contributions of the proportional, integral and derivative terms in a closed loop PID system.

Experimental Procedure

Experiment 1: Speed Regulation of Motor using Proportional Control

In this experiment, you will develop a proportional controller and plot motor speed versus time for two different step inputs of motor reference speeds. You will observe the effects of proportional control. See Figure 1 for a sample block diagram. This template will be available to you in the lab.

- ***Recall the usage of the trainer stand and Simulink software. If you do not remember how to use one or both, refer to the handouts from the first lab and go over them now.*** Details regarding the setup procedure will henceforth be skipped.
- Connect hoses for the hydraulic system. Use the BD90 valve as the actuator and the hydraulic motor as the plant.
- Connect the wiring between the MW2000 signal conditioner, the tachometer feedback signal and the BD90 valve driver (gray box on the valve plate). Recall that the tachometer feedback signal must be read by the A/D input channel 7.
- Start Matlab and Simulink. Copy the file N:\HydarulicsLab\me460\motor_template.mdl and place it in your own working directory C:\ME460_SP18\AB*x*.
- Motor_template.mdl is an incomplete block diagram. ***Complete it so that you have a unity feedback system with a proportional only controller.*** The proportional gain should have a value of one. Refer to the Prelab if you are unfamiliar with proportional controllers. Do not modify the conversion blocks.
- Set the Reference velocity gain in the block diagram to 500 RPM.
- Plot the variable Reference Signal and Output Velocity RPM on the same scope.
- Plot 15 seconds of data with the y-axis ranging from 0 to 1000 RPM by modifying the scope parameters.Have your instructor check the wiring, block diagram and hose connections.Start the hydraulic system. Set the system pressure at 300 psi. Start your Simulink controller.
- Observe the difference between the Output Velocity and the Reference Signal at steady state. Record the error. (Include the plot in your Lab Report)

Without stopping the controller, change the gain from 1.0 to 1.5. Again record the error. Do the same for a gain of 2.0.

- Change the Reference Velocity from 500 to 700. Record the errors for the three gains again at this new speed. Calculate percentage differences.
- Try different combinations of reference speeds and gains and try to develop a feel for what is going on. ***Don't increase the gain much above 2.0.*** Try to understand the trends, and the reasons for the trends. (Use a table to track the gain, error, and reference signal and include the table in your report)
- Stop the controller. Stop the hydraulics.

Experiment 2: Speed Regulation of Motor using PI Control

The PI controller implemented in this experiment will reduce steady state error.

- Modify the block diagram so that the controller is both integral and proportional.
- Set the integral control gain to 0.0 and the proportional control gain to 1.0.
- Build the controller. Plot the same variables as before.
- Set the reference speed at 500 rpm.

- Have an instructor check the block diagram.
- Start the hydraulics and set system pressure at 300 psi.
- Run the system.
- Stop the controller. Save the data.
- Repeat the above for an I gain of 10.0 and 25.0 (restarting the controller each time to see the full response).
- Stop the hydraulics.

Experiment 3: Position Regulation of Cylinder using PI Control

A PI controller will now be used with a different plant – the hydraulic cylinder – to further demonstrate the uses of PI control.

- Copy the N:\HydaulicsLab\me460\cylinder_template.mdl into your own directory. Opening this Simulink model brings up PID closed-loop control template for the hydraulic cylinder. For this lab, you will only be modifying the indidual gain blocks.
- Disconnect the hoses from the motor and connect them to the hydraulic cylinder. ***NOTE!! Valve port C1 must to go to the top cylinder port, while C2 must go to the bottom cylinder port.***
- Change the wiring. The feedback signal comes from the BNC connector labeled linear pot. (sensor box on the top left of trainer stand), and should be connected with Channel 6 on the MW2000.
- Leaving the I and D gain equal to zero, change the P gain to 3.0.
- Have an instructor check your wiring, hosing and block diagram.
- Start the hydraulics. Set the system pressure to 300 psi. Start the controller – the cylinder will return to a 0” position.
- At 5 seconds, the reference will be a step to 2”. Observe the dynamics.
- Stop the controller. Save the data.
- Change the P gain to a higher number such as 10.0. Repeat the above.
- Repeat the above for I gains equal to 1.0 and 2.0.
- Try to develop a feel for what integral gain does for the system.

Experiment 4: Position Regulation of Cylinder using PID Control

Finally we will implement a PID controller.

- Set the P gain equal to 10.0. Set the integral gain equal to 0.5. Set the derivative gain to 0.0.

- Start the controller (step response) and save the data.
- Now, set the D gain equal to 5.0 leaving the P gain and I gain at their current settings. Start the controller and save the data.
- Note the differences between this and the comparable PI controller.

Lab Report

1. Relate all blocks and connections labeled in Figure 2 of the Prelab to the physical system that was implemented in the Speed Regulation of the Motor using PI control (Experiment 2).
2. In the proportional motor speed control, a steady state error between the measured speed and the reference R(s) was observed. Was it possible to decrease the error? Why does this error exist (hint: friction plays only a very minor role and recall the open-loop transfer function you identified for this system in Lab 2). Is it possible to remove this error completely using just proportional control? Why or Why not?
3. If we attempted position regulation of the cylinder using just P control, would it have been possible to get zero steady state error? Why? Use plots along with arguments to explain you answer. Note that in this case the transfer function is second order.
4. What effect does integral control have? How does increasing the I gain affect the step response and steady state error of the motor and cylinder systems? Use plots along with arguments to explain you answer.
5. What effect does derivative control have? Why would it be necessary to filter the error signal before taking its derivative? When might derivative gain be useful? Use plots along with arguments to explain you answer.