ME360: FUNDAMENTALS OF SIGNAL PROCESSING, INSTRUMENTATION AND CONTROL

Laboratory No. 7 − PID Control and the Parker-Hannifin Hydraulic Station

The format of the lab is quite a bit different from your previous labs. Not as many details are given to you. Think of this lab as testing some of the knowledge and software experience you received in the previous lab. In Lab 6 you implemented a PI control for the DC motor in the Control Systems Lab. This week you will add derivative control and implement a PID controller for a hydraulic cylinder in the MechSE hydraulics lab.

Hydraulic Station Precautions

EXTREME CAUTION *should be followed when working with the Station. Common sense safety practices should be followed and close attention paid to the instructor at all times.*

READ *the following safety guidelines before attempting the procedure.*

- **Energize the Station only after the hydraulic circuitry has been checked by your TA!**

- Check all connections to valves and actuators, including quick connect couplings. Verify that they are securely connected and that the safety lock on the quick couplings is activated.

- Do not rub your eyes with even a little of the hydraulic fluid on your hands. Use the towels in the lab to remove the fluid from your hands and then wash your hands when you are done hooking up the station.

- Do not exceed system pressure of 300 psi for this experiment.

- Do not disconnect any hoses while the system is running.

    - Routinely check the system for leaks. Shut-down the system immediately if oil leaks occur.

PID control of a hydraulic piston-cylinder assembly

Loading real-time SIMULINK model

- Login to your station's PC and start MATLAB and enter the "`simulink`" command at the MATLAB prompt. The SIMULINK library window should appear.
- Choose "Open" under the "File" drop-down menu.
- Locate the file "N:\HydraulicsLab\me360\cylPIDshell.mdl" and open it.
- Save this Simulink file with a unique name (must be different than the original name) to the c:\me360 directory on the PC's local hard drive.
- Finally change Matlab's working directory to the directory you just saved your Simulink file, C:\me360.

Setting the reference command signal

- Double-click the signal generator block in the model. This block sets the reference input R(s) to the system. The reference command signal is the desired system response, or in our case the desired position of the piston. Verify that the reference signal is a square wave with amplitude 1.0 inch and a frequency of 0.1. When your controller implementation is running this reference will cause the piston to step back and forth from -1 inch to 1 inch every 5 seconds.

Setting the A/D and D/A sampling rate

- Choose "Parameters" under the "Simulation" drop-down menu.
- Enter/(Verify) "0.001" seconds in the "Fixed step size" text box. Then click "OK". This sets a sampling rate of 1 / 0.001 s = 1000 samples per second.

Implement a PID controller to regulate the position of the hydraulic cylinder. Here you will need to add the necessary Simulink blocks to implement the controller. As in the prelab, implement the derivative with the transfer function 100s/(s+100). Make sure to add at least two “Scope” blocks to monitor the position or height of the cylinder and the desired position input also call the reference input.

Building executable version of model

- Select "Build Model" under the “Tools->Code Generation" drop-down menu. Wait for the model to compile. A C-code version of the model is first created, and then this code is compiled to produce the executable version. Compilation is complete when the message "### Successful Completion of Real-Time Workshop" is printed in the Matlab command window.

Connecting the PC A/D and D/A hardware to the EHCB (This should already be done for you. This is here for students doing the lab at a make-up time)

- Locate the MW2000 signal conditioner with analog and digital inputs and outputs. Connect a coaxial cable from Analog Output Channel 0 to the electrohydraulic valve EHV input located on the left panel of the EHCB. This allows us to send a control signal to the valve.
- Connect another cable from the pot connector located on the left panel of the EHCB to Analog Input Channel 6. This allows us to sample and feedback the current position of the piston.

Controlling the piston-cylinder assembly

- Start the hydraulic Station and set the oil pressure to 300 psi. Ask your TA for help here.
- Start your Kp gain at 1 and Ki and Kd at 0.
- Start your real-time controller with two steps. First select “Simulation->Connect to Target” to initialize your run and then select “Simulation->Start”. Open your Scope blocks and observe the response. Does the system response track the input? Is there overshoot and/or steady-state error in the response?
- Slowly increase the proportional gain (steps of 1 at first then steps of 5). How does the proportional gain effect the rise time, settling time, overshoot and steady-state error in the transient response? Is there an upper limit on Kp above which the control has an adverse effect on the system's response? If yes, what is the upper limit value?
- Now take some time and experiment with different values of Kp, Kd and Ki. Use the following limits as a guide 0 < Kp < 100, 0 < Kd < 10, 0 < Ki < 100. Try just a PD controller by zeroing Ki. Note effects of increasing Kp and Kd. Try just a PI control by zeroing Kd. (You will find that with integral control added you will also need a larger Kp gain to allow the system to settle in less than 5 seconds.) Note observations.

- Tune the PID control gains to achieve $e_{ss} = 0$, $M_p = 0\%$, $t_r \approx 1.5$ s. Record the gain values that best meet these performance characteristics. You may find that some the PID gains can be kept at zero and still achieve these specifications.

- Tune the PID control gains to achieve $e_{ss} = 0$, $M_p = 1\%$, $3.0 \le t_r \le 4.0$ s.

- Draw conclusions about the effect of Kp, Ki, and Kd on rise time, settling time, overshoot and steady-state error. Make sure to note these in your datasheet.