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| **MEMORANDUM** | |  | |
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| **To:** | Denis Gingras, Lecturer, Department of Mechanical Engineering, Cal Poly SLO | | |
| **From:** | Rahul Goyal & Keyanna Henderson | | |
| **Date:** | March 11, 2019 | |
| **Subject:** | Hydraulic Positioning System | | |

This document summarizes the results of the Hydraulic Positioning System experiments performed during February and March 2019. The objectives of these experiments were to create a closed-loop Simulink model reflecting the behavior of a hydraulic positioning system, observe the effect of different controllers on system behavior, and analyze the system’s transfer function using block diagram algebra and root locus sketching. The experimental apparatus consisted of a compressed air supply, servo-valve, piston, and movable mass. A Simulink-based controller was used to output a voltage to the servo-valve (via a servo amplifier) such that the piston, and therefore the position of the mass, could be controlled.

The methodology in developing a Simulink model that accurately represents the system involved determining gains and model parameters experimentally. With the system depressurized, data was collected at a range of input voltages to increase accuracy and account for bias when determining the potentiometer and flow rate gains. The slopes of the best-fit lines were inputted in a model that controls variables based on deviation from steady-state. To determine the model parameters, namely the ratio of the bulk modulus of the fluid to the total volume of fluid (β/Vt), and flow to pressure gain (Kce), the system was pressurized and run with a P-only controller. The proportional gain was increased incrementally until the hydraulic positioning just barely reached instability. At his point the system was considered to be marginally stable, and data collected was assumed to have a damping ratio of 0 in subsequent analysis. Damping in the system would be caused by viscous friction, which was neglected due to its small size in comparison to static friction and friction between system components. This reasonable assumption allowed for an adequate simplification of developed equations which allowed for the calculation of β/Vt and Kce. With all gains and model parameters determined, the Simulink model was completed and verified with other controllers against experimental results for accuracy.

Further analysis of the system's open-loop transfer function showed that it is a type 1 system when using a P-only or PD controller. By sketching the root locus of the open-loop system, as well as the poles of the closed-loop proportionally controlled system, we found that P-only systems could be approximated as second order. Adding an integral component to the controller changes the system to a type 2 system. As expected for a type 1 system, the results show no steady-state error regardless of the controller used for a step input, but finite steady-state error for a ramp input, unless an integral component was present in the controller. Noticeably, using a derivative component helped improve the response time of the system due to its derivative kick. It also allowed for higher proportional gains without driving the system to instability. Thus, we found the best controller for a system expecting step inputs to be a PD controller and the best controller for a system expecting ramp inputs to be a PID controller.

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