



## **Laboratory Experiment 3: Implementation of a Position Controller**

MTRN3020 Modelling and Control of Mechatronic Systems

the statement: I verify that the contents of this report are my own work

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## 1. Introduction

The purpose of this experiment is to design a position controller for handling with the changes of the desired positions. The desired speed for the speed controller is figured out through the position error which can be measured by the encoder placed at the output shaft of the gear box. The first part is to verify the veracity of the position controller design. And the second part is to simulate the designed controller of a given system with a system of different plant transfer function. The results from experiment and simulation will be discussed at the end of report.

## 2. Aims

This experiment is aimed to manipulate motor-driven system with the arm attached at the end. The control design uses direct analytical design method to design the internal velocity feedback loop and root-locus method to design the external position feedback loop.

## 3. Procedures

### Part A – Design Verification

- 1) Determine the plant transfer function by the file ROT225, then transfer it into the discrete time domain.
- 2) Determine the control transfer function by the direct design method and the rule of zero steady state.
- 3) Figure out the gain (2K) by the root locus diagram of the overall transfer function.

### Part B – Effect of Modelling Uncertainties

- 1) Repeat the design steps to obtain the new plant transfer function from the file ROT335.
- 2) Build the block diagram in Simulink, set the inputs into the system.
- 3) Plot out the results achieved from experimental and simulated data

## 4. Controller Design Calculation

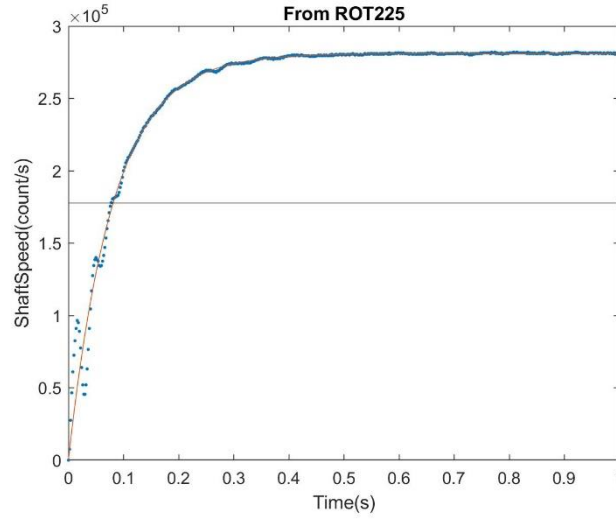


Figure 1 Shaft Speed vs. Time

The plant transfer function of ROT225 system can be figure out by finding the first order approximation to the functional relationship of shaft speed and time, which can be implemented by the curve fitting toolbox on MATLAB.

$$G_p(s) = \frac{8.980}{s * (1 + 0.08113 * s)} \quad (1)$$

Discretize the  $G_p(s)$  respect the z time domain,

$$G_p(z) = \frac{0.002635 * z + 0.002561}{z^2 - 1.917 * z + 0.9173} \quad (2)$$

Combining the discrete version of  $G_p(s)$  with a numerical differentiator,

$$G_p(z) = \frac{0.3764 * (z + 0.9719)}{z * (z - 0.9173)} \quad (3)$$

The desired pole location is given by,

$$z = e^{sT} = e^{-\frac{0.007}{0.0041}} = 0.8430 \quad (4)$$

The poles or zeros leading to ringing or oscillations need to be eliminated. Hence,

$$F(z) = \frac{b_0(z + 0.9719)}{z * (z - 0.8430)} \quad (5)$$

For zero steady state error,

$$F(1) = \frac{b_0(1 + 0.9719)}{1 * (1 - 0.8430)} = 1$$

$$F(z) = \frac{0.07962 * (z + 0.9719)}{z * (z - 0.8430)} \quad (6)$$

Finally, the controller transfer function can be obtained

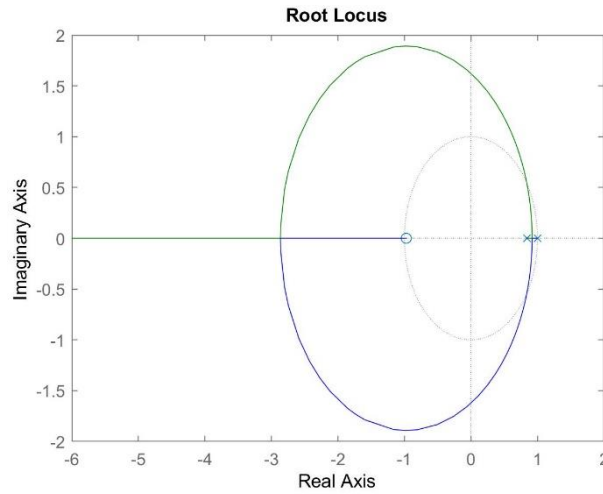
$$G_c(z) = \frac{1}{G_p(z)} \times \frac{F(z)}{1 - F(z)}$$

$$G_c(z) = \frac{0.2115z^2 - 0.0.1940z}{z^2 - 0.9226z - 0.07737} \quad (7)$$

The overall system transfer function can be obtained as,

$$G_{total}(z) = \frac{0.00001451 * z + 0.00001411}{z^2 - 1.8430 * z + 0.8430} \quad (8)$$

The root locus plot has been shown below,



*Figure 2 Root locus of the overall system transfer function*

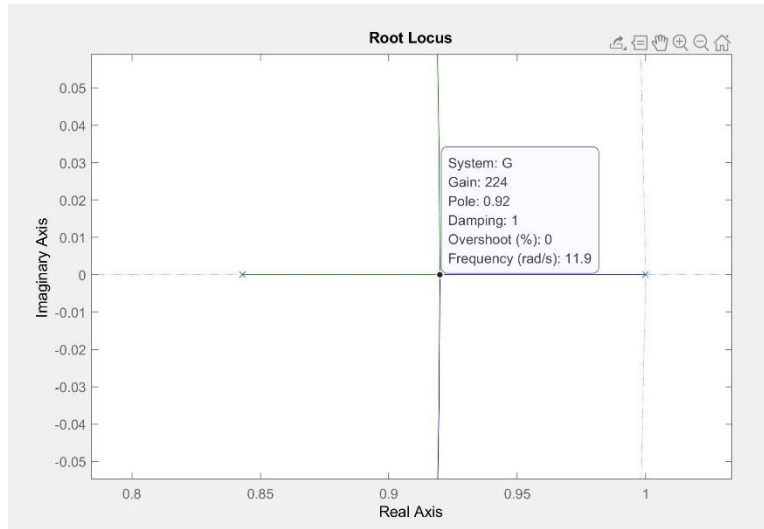


Figure 3 the value of the designed gain

Apply same steps mentioned above to work out another plant transfer function from the file ROT335,

$$G_p(s) = \frac{8.9642}{s * (1 + 0.1035 * s)} \quad (9)$$

## 5. The Block Diagrams

The two block diagrams with different plant transfer functions has been displayed as follows,

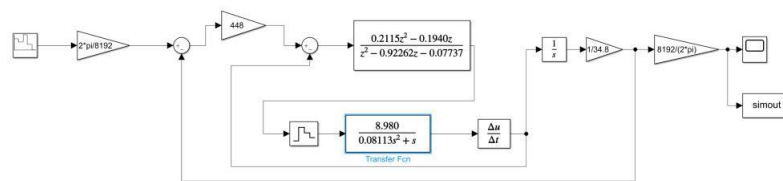


Figure 4 Block Diagram 1

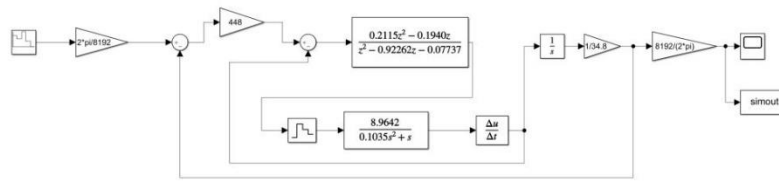


Figure 5 Block Diagram 2

## 6. Consequences of Part A and Part B

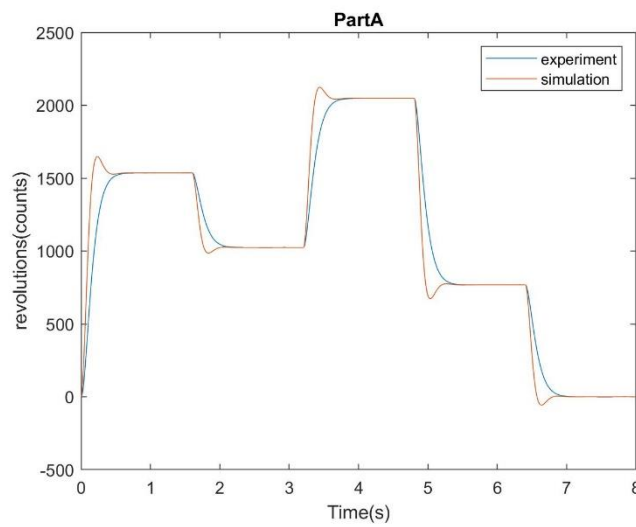
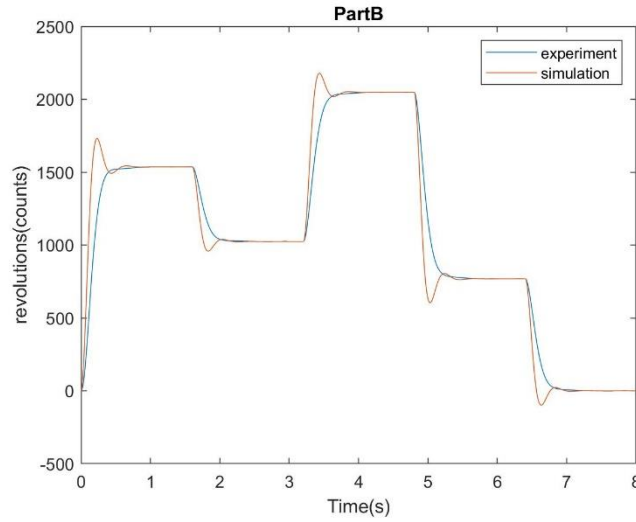


Figure 6 Results of ROT225 system

The controller design is verified through the comparison of the experimental data and simulated data. It can be seen from the above figure that there are overshoots occurred when the desired position is changed every time. This may be resulted from complementing the counts error excessively, so the feedback control need take more time to bring the system back the desired state. Besides, the sample time of inputs is 1.6s and the controller is running in discrete time, so it is hard to response the errors effectively. Although the overshoots exist, there are not any oscillations happened for the steady states.



*Figure 7 Results of ROT335 system*

The comparison of the experimental data and the simulated data has shown the robustness of the designed controller when the controller is applied with a different system. It is clear from the above figure that the system has transient oscillations and overshoots over the responding periods. These will cause slow responses to the desired position changes. On the other hands, the designed controller could not completely satisfy the requirements of other systems.

## 7. Conclusion

Although the experimental data is not exactly same as the data simulated on the computer, the performances of controller designed by the direct method is a reliable in a certain extent. This system has appeared zero steady state error and fairly fast to response the position changes. But it cannot perform well within a different system. It can be furtherly improved by adopting more accurate apparatus in the lab or advanced algorithm in the control system.