# KON-C2004 - Mechatronics Basics, Lecture, 22.10.2024-12.12.2024



## 3.2 DC servo motor modeling - 21 points

**Opened:** Tuesday, 29 October 2024, 10:00 AM
**Due:** Tuesday, 12 November 2024, 10:00 AM

### Information

Return your answers in a .pdf file into the box at the bottom of the page. Include all the plots in the .pdf file. Return also the model file you built and the scripts containing the calculations.

You can exploit the Solutions - Exercise 2, including the simulink model and a script for running the model and plotting.

When tuning the controller, start increasing the gains upwards from zero. Very much too large gains can cause the simulation model to become unstable. This causes unphysical behaviour which usually means very large voltage and/or velocity oscillation in the simulation results.

Check that the maximum time step of the simulation is low enough, especially if you get plots with sharp corners.

If you want to compare simulation results with two sets of parameters, you can for example run the plotting script once and then comment out the "close all" command in the beginning of the script and then run the script second time with different parameters. Without that command, the old figures are left visible when the new plots for a second simulation run are made in new figures.

You can also comment out the "clear all" and "fig1 = figure('Name', 'Motor angular velocity')" lines. Then the angular velocity for the second simulation run is plotted in the same figure as the old one. You can modify the script to achieve the same for any of the figures. Just uncomment the lines to return to normal operation

Adjust the "t_end" variable in the plotting script to change the end time of the simulation and the time scale of the plots accordingly. Also the y axis scale can be adjusted individually for each plot by changing the variables in the "axis" function calls.

You can use the "Data cursor" tool in Matlab figure window's toolbar to see values at certain points of the curves.

Total maximum points for this exercise is 21.

### Question 1

Use the Simulink model of a DC motor, combined with load inertia, that you built in the previous exercise round (use the model answer if you do not trust your own creation). Turn the previously created motor into a servo motor by adding an angular velocity feedback controller. Use PI control. Do not modify the motor model. Build the PI controller using basic Simulink blocks (i.e. Gain, Integrator, Sum etc.). Show a picture of your model and explain how the system and the controller work (no need to repeat how the motor works). Assume ideal speed measurement and ideal voltage reference tracking.

To keep your Simulink model unclutterred, create a subsystem of the motor model with the voltage as input and angular velocity as output. This is done by selecting all the blocks that will be included in the subsystem, clicking the selection with the right mouse button and selecting "Create Subsystem from Selection".

Maximum points 5

### Question 2

Tune the PI controller (choose the proportional and integral gains) in such a way that the system has a 0...95 % rise time of less than 0.35 seconds, settling time with 5 % accuracy less than 0.7 seconds and an overshoot less than 25 %. You can use any tuning method you want to. UPDATE: First, try gain values between 0 and 2.

The target angular velocity for the motor is 280 rad/s. Use a step reference where the step happens at t=0 seconds (basically a "Constant" block is fine). The motor is nominally a 48 volt motor but it can be overloaded for a short time period. The maximum input voltage is however limited to 60 volts. Tune the controller so that the output does not exceed this during the acceleration (do not use saturation block). Include the gains P and I in your answer.

Plot the controller output (voltage in this case) as well as the proportional and the integral parts of the control signal in one figure. Plot also the angular velocity of the motor in an other figure. Include the figures in your answer and explain why the proportional and the integral parts of the controller output develop as they do.

Use the script template plot_help2.m provided at the bottom of this page to make the plots.

Maximum points 4

### Question 3

Add a delay ("Transport delay" block in Simulink) of 10 milliseconds to your velocity feedback loop to represent the time it takes to make the velocity measurement, transmit it to the PI controller and calculate the new control value. Keep the previously chosen controller gains. How does the delay affect the system response and the output from the controller? How large a time delay can you use before your system becomes unstable?

"Transport delay" block can be found in "Continuous" block library.

Maximum points 2

### Question 4

Remove the previously created transport delay. Try changing the inductance (L) of the motor to 0.1 H. How does it affect the step response? Why?

Maximum points 1.5

### Question 5

Change the inductance back to its original value. Why is the torque output from the motor negative at some point during the step response?

Maximum points 1.5

### Question 6

Plot the electrical input power, mechanical output power (which moves the mass), resistive loss power generated in the windings and total loss i.e. powerin-powerout in the same figure.

Why is there such a big difference between input and output powers at first?

Why the output power from the motor is zero, when steady state is reached?

Explain why the resistive loss power and the total loss power are different, especially in steady state.

Maximum points 4

### Question 7

Let's assume our motor is a brushed DC motor with permanent magnets to produce the stator field. The heat capacity of the rotor is 30 J/K and the thermal resistance from the rotor windings to the surroundings is so large that we can assume all the heat produced in the windings during our short acceleration stays in the rotor. More info on heat capacity.

Plot the temperature of the rotor during the acceleration assuming that the starting temperature is 40 C°. What is the temperature of the rotor after five seconds?

How many times can the motor perform a similar acceleration before its temperature exceeds the maximum temperature of 90 C°? Lets assume that a deceleration is done with a mechanical brake and does not cause heating in the motor.

Try tuning your controller to produce a faster response time. How does it affect the temperature rise? Explain why? How about reducing the gains and thus making the controller "lazier"? You do not have to care about the voltage limits this time.

Maximum points 3

plot_help2.m 7 October 2024, 10:12 AM

### Submission status

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| **Submission status** | No submissions have been made yet |
| **Grading status** | Not graded |
| **Time remaining** | Assignment is overdue by: 104 days 23 hours |
| **Last modified** | - |