Lab Session 07
Linear Model of DC Motor

Exercise 1

Consider a DC motor with the following physical parameters:

- Moment of Inertia $J = 0.01\ kg.\,m^2$
- Damping Friction $b = \ 0.1\ N.\,m.\,s^{-1}$
- Back EMF Constant $K = 0.01\ Nm.\,A^{-1}$
- Electric Resistance $R = 1\ \Omega$
- Electric Inductance $L = 0.5\ H$

a) Change the electrical parameters such as R or L to reduce the time constant τ.

b) Also change the mechanical parameters such as J or b to reduce τ.

c) What are the parameters which are responsible for controlling the speed of the motor? Explain with graphs.

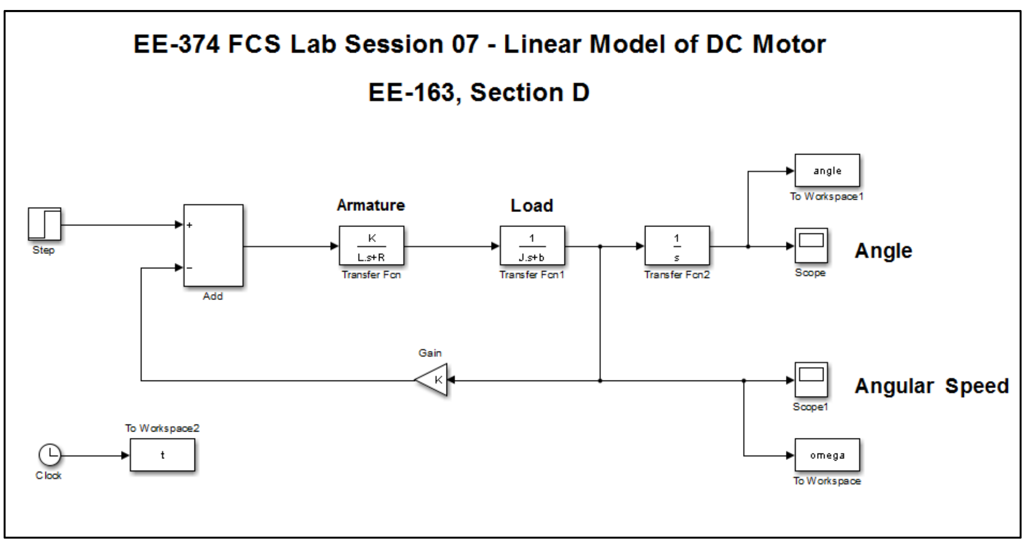

Figure 1: Simulink Model for DC Motor

Using the default parameters, the motor's angular speed and rotation angle are as follows.

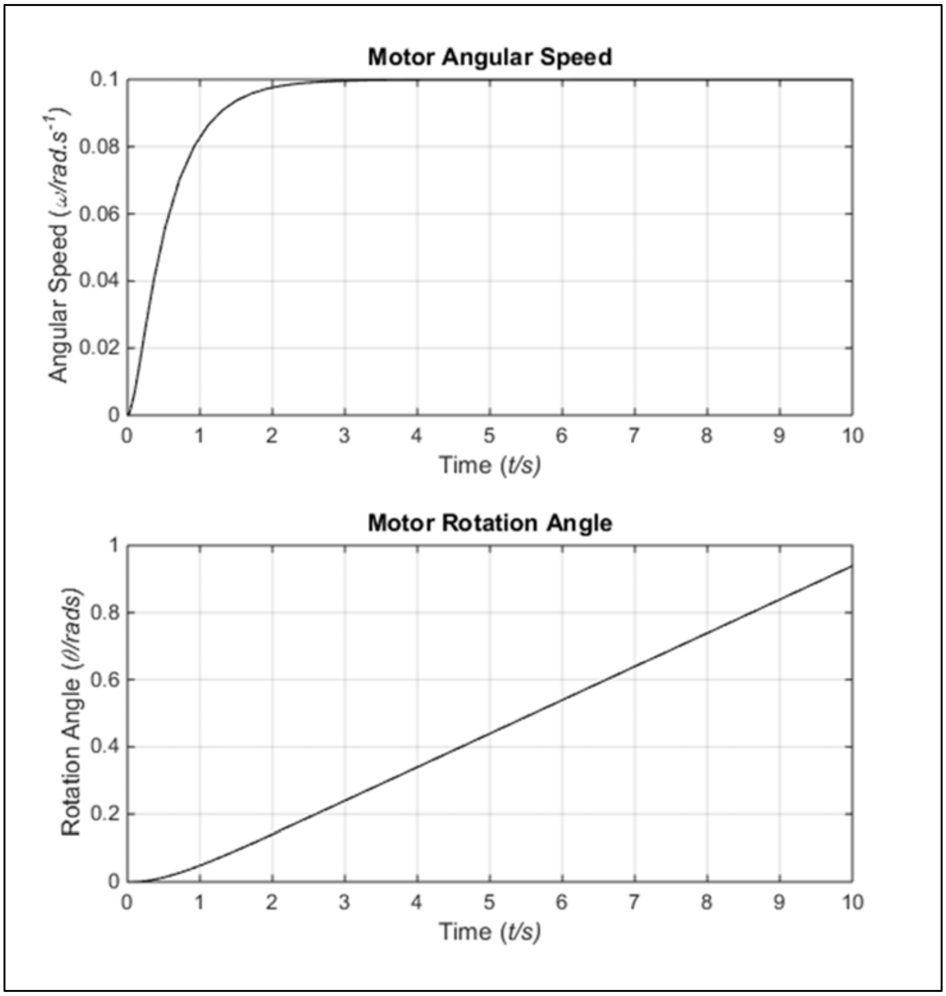

Figure 2: Motor angular speed ω and angle of rotation θ with default parameters

The time constant τ of the armature circuit expressed in terms of the resistance R and the inductance L is $\tau = \frac{L}{R}$. Thus, to decrease the time constant of the motor either L should be decreased or R should be increased.

The effects of R, L, J, and B on the motor's time constant was investigated by varying each of these parameters and plotting its speed against time.

Continued on next page

<u>Effect of Varying Resistance R</u>

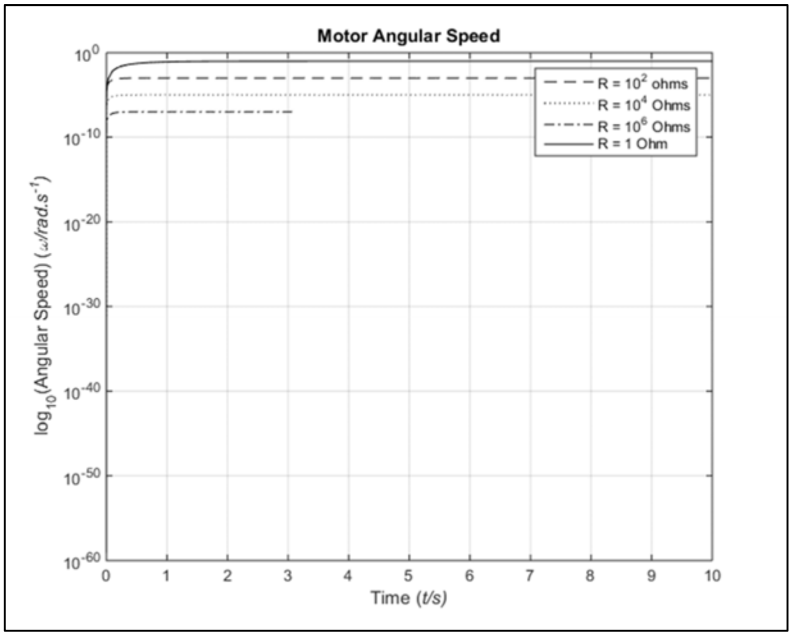

Figure 3: Effect of Varying Armature Resistance

Increasing motor armature resistance leads to a decrease in motor speed as well as a decrease in the motor's time constant, confirming the hypothesis stated above. Because the motor's speed dropped drastically between subsequent readings, a semilog plot has been drawn to better illustrate the relative magnitudes of the motor speeds at different R. Practically, 1 Ω is the best tradeoff between short τ and non-zero speed for these parameters.

<u>Effect of Varying Inductance L</u>

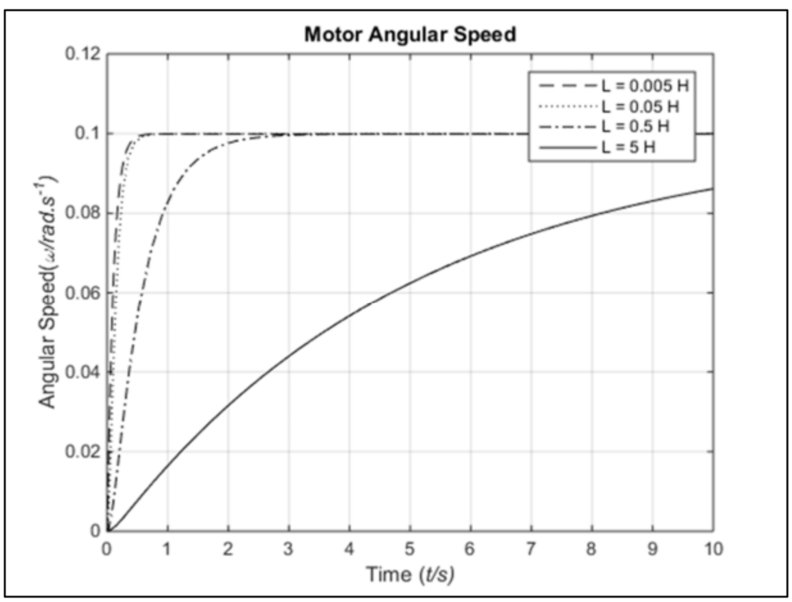

Figure 4: Effect of Varying Armature Inductance

The graph shows increasing inductance leads to an increase in the motor's time constant. Unlike R, L's variation has no appreciable effect on the motor's steady state speed. As is evident from the graph, the motor approaches the same steady state speed of 0.1 rad/s at all values of L. However, it reaches this speed most quickly when the inductance is the smallest. This goes to show that minimizing motor time constant requires minimizing the armature inductance.

<u>Effect of Varying Moment of Inertia J</u>

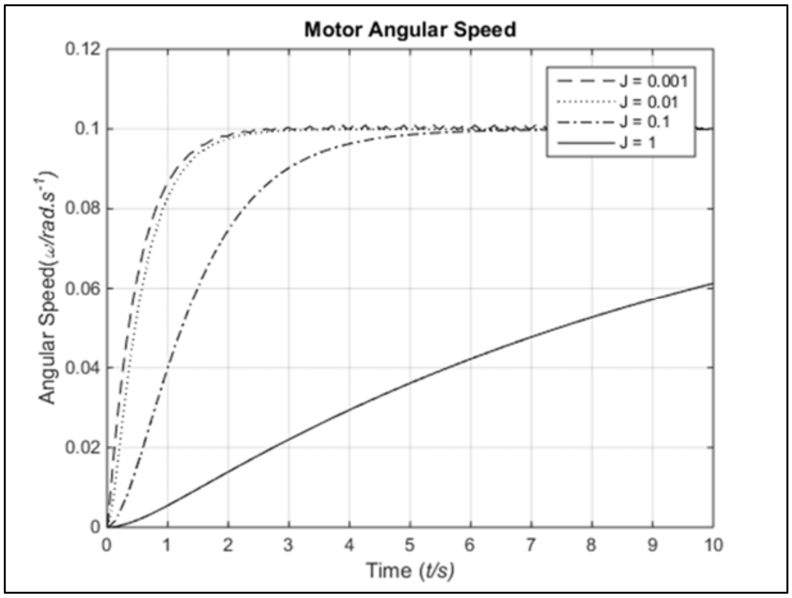

Figure 5: Effect of Varying Moment of Inertia

Decreasing the moment of inertia also decreases the motor's time constant without affecting the steady state speed. The graph clearly shows that for the highest J investigated, the motor has attained ~60% of its steady state speed in 10s, whereas with the lowest value, the steady state speed in slightly more than 2s. This proves that motor's mechanical time constant decreases with its moment of inertia.

<u>Effect of Varying Coefficient of Friction B</u>

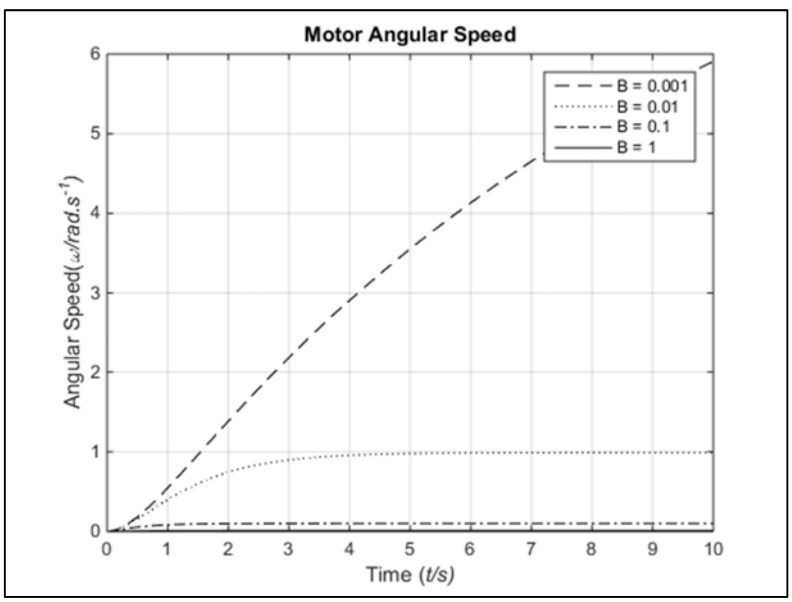

Figure 6: Effect of Varying Coefficient of Friction

The motor's angular speed increases with decreasing coefficient of friction. The graph also provides evidence of the increase in τ with decreasing coefficient of friction. Thus to minimise the motor's time constant or bring it close to 0 for these parameters, its coefficient of friction should be 1 or as large as possible. However, as was the case with armature resistance, this practically stalls the DC motor and reduces its angular speed to 0.

Analysis of Results

- To reduce the time constant of the motor to zero without affecting its angular speed, its inductance L and moment of inertia J should be minimized.

- The closer the inductance and moment of inertia are to 0, the smaller the value of the time constant.

- A small time constant is beneficial because it means the motor attains it steady state (maximum) speed for a given applied voltage.

- The graphs show that armature resistance R and the motor's coefficient of friction B are both responsible for determining the motor's speed.

- Smaller armature resistance and coefficient of friction both lead to a higher steady state angular speed, albeit at the cost of a higher time constant.

- To decrease τ, the armature inductance L was decreased to 0.005 H and the motor's moment of inertia was decreased to 0.001 $kg.m^2$.