ECE 413: Senior Project Development II **Spring 2019**

DC Motor Measurements
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To characterize a *dc motor*, two experiments were conducted. The first experiment makes use of a Prony brake, where torque is calculated though measured force. A relationship between torque & angular speed, and torque & current is then observed. Further, we can determine the torque coefficient of the motor. In the second experiment, other motor parameters are determined such as the armature resistance and inductance, the electromotive force (emf) coefficient, and the friction coefficient.

Prony Brake

Equations

The driving torque T_{em} of a dc motor is given by

$$T_{em} = k_m \Phi_p i_a \tag{1}$$

where, k_m is the torque coefficient, Φ_p is the excitation flux, and i_a is the armature current.

The back emf of a dc motor is given by

$$E = k_e \Phi_p \omega \tag{2}$$

where, k_e is the emf coefficient, and ω is the angular speed of the shaft.

Assuming that the excitation flux Φ_p is constant, $K_m = k_m \Phi_p$ and $K_e = k_e \Phi_p$ can be made in (1) and (2) respectively, without lack of generality.

Recall the relationship between torque and force. That is,

$$T_{em} = r F_{net} \tag{3}$$

where, r is the radius of the drive wheel.

Materials

- two 20-Newton spring scales
- shoelace
- tachometer
- power supply
- ammeter

Procedure

Using the rated voltage of the motor, connect the leads to a power supply such that the drive wheel rotates in the clockwise direction. Using the tachometer and ammeter, record the angular speed and current, respectively. These measurements correspond to the no-load speed and no-load current, respectively. Note that under no load, the driving torque $T_{em} = 0$.

Attach each end of the shoelace to the Newton spring scales. Both ends should be under equal tension when placed under the stationary drive wheel (see Fig. 1). Record the speed, current, and the driving torque. The driving torque is calculated using (3). Note that the net force $F_{net} = F_2 - F_1$, where F_2 and F_1 are the measured forces from the spring scales. Increase the prony brake height in 1 cm increments and record the speed, current, and torque. For higher driving torques, the prony brake height can be increased in 0.5 cm increments.

Repeat the process for the counter-clockwise direction of the motor. Plot speed vs torque and current vs torque. Using the current vs torque plot and (1), calculate the torque coefficient K_m of the motor.

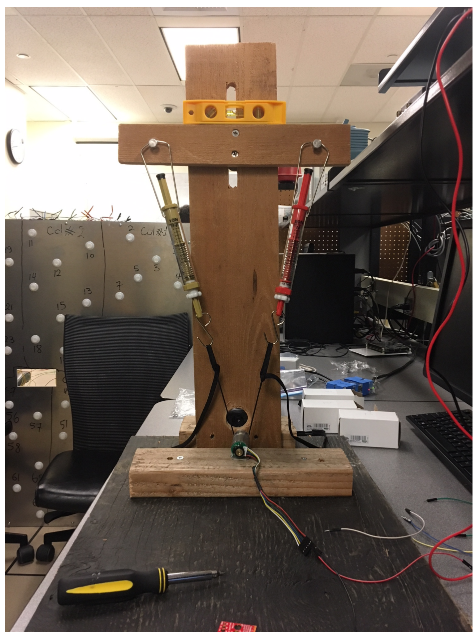

Figure 1: Prony brake setup

Other Measurements

Equations

A dc motor consists of an armature resistance R_a and inductance L_a. When rotating, the motor produces a back emf which is proportional to the angular speed of the shaft, given in (2). The electrical equation of a dc motor is given by

$$v_a = R_a i_a + L_a \frac{di_a}{dt} + E \tag{4}$$

where, v_a is the applied armature voltage, i_a is the armature current, and E is the back emf.

The mechanical equation is given by

$$J \frac{d\omega}{dt} = T_{em} - T_L - B\omega \tag{5}$$

where, J is the moment of inertia of the load, T_L is the load torque (external disturbance), and B is the friction coefficient.

Materials

- multimeter
- power supply
- tachometer

Procedure

Using the multimeter, measure the armature resistance and inductance. Starting at the rated dc voltage of the motor, measure the speed and current using the tachometer and ammeter, respectively. Calculate the back emf E using (4). Note that for a dc applied voltage, $\frac{di_a}{dt} = 0$. Decrement the voltage in steps of 1-2 V and record the speed, current, and emf.

Repeat the process for the drive wheel rotating in the opposite direction. Plot the back emf vs speed. Using the plot and (2), calculate the emf coefficient K_e of the motor.

In addition, plot current vs rpm. Using (5) and (1), along with the K_m value found in the prony brake experiment, calculate the friction coefficient B. Note that $\frac{d\omega}{dt} = 0$ and $T_L = 0$ in this experiment.

References

- *Make a Prony Brake to Analyze Motor Performance*
- *Digital Control of Electrical Drives*