



SIMON FRASER UNIVERSITY
THINKING OF THE WORLD

ENSC387: Introduction to Electromechanical Sensors and Actuators

LAB 5: DC MOTORS

DATE DUE: 23:59:59 PM, APRIL 07, 2016

WARNING:

Please be extremely cautious to precisely follow the procedures described in this manual. It is very easy to break this setup by applying too much current.





Please read the entire manual first before attempting anything.

1	Objective	3
2	Required Materials.....	3
3	Introduction	4
4	Lab procedure.....	5
4.1	Setup.....	5
4.2	Polarity reversal.....	6
4.3	Speed control.....	6
4.4	Speed-torque characteristics	6
4.4.1	Armature Control	6
4.5	Field Control.....	6
4.6	Armature Resistance Control.....	7
4.7	Shunt DC Motor Control	7

1 Objective

In this experiment, we will examine some key characteristics of a DC motor. We will use an SCR (Silicon Controlled Rectifier) DC drive to operate a DC motor, a hand-held tachometer to measure the motor speed, AC and DC ammeters to measure the line current and motor current, and, finally, a prony brake to apply a mechanical load to the motor.

2 Required Materials

Description	Photo	Description	Photo
Hioki 3262 Clamp-on Ammeter		SCR (Silicon Controlled Rectifier) Motor Speed Controller	
DC Motor with Prony brake and connector box		Tachometer – Monarch Instruments	

3 Introduction

In engineering applications involving DC motors, it is necessary to know the torque/speed relations so that the right motor can be selected to match the operational requirements. In the following discussions, we are assuming the use of a separately excited motor. In class, we derived the following important equations for such a DC motor:

$$T_m = k i_f i_a \quad (1.1)$$

The above equation states that the motor torque is directly proportional to the armature current for a fixed field flux (field current).

$$V_b = k' i_f \omega_m = V_t - i_a R_a \quad (1.2)$$

The back EMF generated by the armature (V_b) is directly proportional to the rotational speed of the motor (ω_m) and field current. On rearranging the above equation and on substitution, we get:

$$\omega_m = \frac{V_t - i_a R_a}{k' i_f} = \frac{V_t}{k' i_f} - \frac{i_a R_a}{k' i_f} \quad (1.3)$$

Where:

- T_m - motor mechanical torque
- k, k' - motor constants
- i_a - armature current
- V_b - induced armature voltage
- V_t - terminal voltage (across armature)
- R_a - armature resistance
- i_f - field current
- ω_m - angular speed of the motor (rad/s)

The above equation implies that if the load torque increases, the motor speed decreases causing the back EMF to decrease as well. **Provided the power supply can handle the load and maintain a constant voltage to the armature**, the armature current should increase, causing the motor torque to also increase until it is equal to the load torque. Thus, an applied load torque results in an increased armature current, and in a reduction in the motor speed for a constant applied voltage. Based on this equation, we see that there are 3 variables which we can manipulate to control the speed of a DC motor:

1. Terminal voltage
2. Armature resistance
3. Field flux (field current)

Sometimes it is more convenient to drive a DC motor with a single power supply (by connecting the field winding directly across the armature input terminals) – a shunt motor is created. In order to control the speed of such a motor, we can vary the armature voltage, but we no longer have the clear linear relationship between V_t and motor speed. The new relationship is as shown in equation (2.1)

$$\omega_m = \frac{R_f}{k'} \left(1 - \frac{T_m R_f R_a}{k V_t^2} \right) \quad (2.1)$$

Where k is the motor constant and linking current and torque and k' is the motor constant linking speed of rotation and back emf created across the armature. We notice that for a fixed terminal voltage V_t , the motor speed is a linear function of torque, and for non-zero T_m and V_t , the motor speed increases with increasing V_t . For detailed derivation of this formula, please refer to the textbook.

4 Lab procedure

4.1 Setup

Set up the DC motor in the separately excited mode by connecting a 60V source to the field winding. Use the lab power supply for this purpose. You will have to ensure that the dual supplies are linked ("tracking") in order to get 60V from the two 30V supplies. Make sure you did connect the power supply outputs correctly. Using the motor speed controller, connect 40V to the armature winding with the prony brake set to approximately 0 load torque.

4.1.1 Using the tachometer to measure rpm

The tachometer is a point-and-shoot, non-contact type of measuring device. It is turned on by pressing the middle button. Although a variety of modes are available, the default setting, which you will use, is revolutions per minute (rpm), and this should display briefly during power-up before the unit zeroes.

Notice that the Prony brake rotor has a small piece of reflective tape attached to it in one location.

Notice also that the backside of the tachometer features both a light source (illuminated when unit is on) and a light detector.

To measure rpm, with the motor running, hold the tachometer (backside facing rotor) about 2 - 3 cm away from the rotor and look along the "gun-sight" groove on the top of the tachometer, aiming at the tape location so that the light beam "sees" the reflective tape passing by. Press and hold the middle (measurement) button while doing this, and wait 5 to 10 seconds to get a reliable reading. Release the measurement button while still aiming at the rotor to preserve your reading. Make a note of the reading immediately since it will automatically reset after a while. You will find your readings vary slightly, especially when the motor is under load, so decide on a method of getting a good average. You will have to convert your results to radians.

4.2 Polarity reversal

Investigate what happens when you reverse the **polarities** for both the armature and the field connections.

Important:

Turn off **the armature first** and **then the field** supplies before changing the connections. When powering up, energize the **field first, followed by the armature**.

Question: Why are these power-up and shut-down sequences important?

Explain: Investigate reversing only the armature and only the field connections. What happens and why?

4.3 Speed control

In order to control the speed of the DC motor, we will supply a user-controlled DC voltage to the armature while keeping field flux constant. The armature current is proportional to the AC current measured at the input to the SCR DC drive (**Important: DO NOT EXCEED 6 A RMS!**).

Question: What is the relationship between the input AC current and the DC armature current, I_a ? Make measurements of both the AC current and the resulting DC armature current to determine this relationship and report your results. You also should measure the field resistance and the armature resistance (using an ohmmeter) so you can calculate the field current from the applied field voltage. The armature resistance is likely to be $5\ \Omega$ or less, so the accuracy of the measurement may be low with the available equipment.

4.4 Speed-torque characteristics

4.4.1 Armature Control

1. Apply 60V to the field using the DC power supply.
2. Apply 20V to the armature and measure the no-load speed. Engage the prony brake and record the speed and input AC current for 4 different torque loads of your choice. Before taking any measurements, determine appropriate loads by trial and error. Don't run the motor at very low speeds (i.e. stay above 100 rpm at all times in these experiments).
3. Repeat (2) for armature voltages of 30, 40, 50 and 60V.

Analyze results by plotting speed vs. torque for all five cases on the same graph and label appropriately. From the motor speed equation (1.3), the torque / speed characteristic should be a linear function of V_t .

4.5 Field Control

Motor speed can also be controlled by varying the field voltage and therefore the field flux ϕ . It is much easier to control the field of a DC motor since the magnitude of the field current is much smaller than the armature current. Examine the torque-speed and V-I characteristics of a field-controlled arrangement as follows:

1. Apply 40V to the field using the lab DC power supply.
2. Apply 30V to the armature and measure the no-load speed. Engage the prony brake and record the speed and input AC current for 4 different torque loads.
3. Repeat (2) for field voltages of 20, 30, 50 and 60V.

Analyze your experimental results and confirm for yourself whether they agree with the theory according to the motor speed equation (1.3).

4.6 Armature Resistance Control

For an armature voltage of 50V and a field voltage of 60V, and with an external armature resistance of 0, 1, 2, and 4 Ω , take speed / torque measurements (about 4 to 5 readings for each value of external armature resistance). Plot these results and compare them with what you would expect from the DC motor model. Are there any major discrepancies between the two?

4.7 Shunt DC Motor Control

Connect the motor as a shunt motor (connect the field terminals in parallel with the armature terminals and drive the motor from a single power supply). Try to verify the torque/speed equation derived earlier in this write-up for 3 or 4 values of T_m and V_t . Without numeric values for k and k' , you can only characterize the shape of the plot versus what you would expect from the model.