DC Machine Torque Speed Characteristics

Soham Karanjikar

Written: April 28th 2020

1 INTRODUCTION

The objective of this lab was to understand the parameters and equivalent circuit of a DC Motor. This is somewhat similar to the last lab of a DC machine, which we ran as a generator. The lab mainly goes through torque-speed characteristics of the DC motor and how they can be used in possible motor applications.

All data/measurements taken are provided in the appendix at the bottom of the document.

2 RESULTS

2.1 *Shunt DC Motor Characteristics*

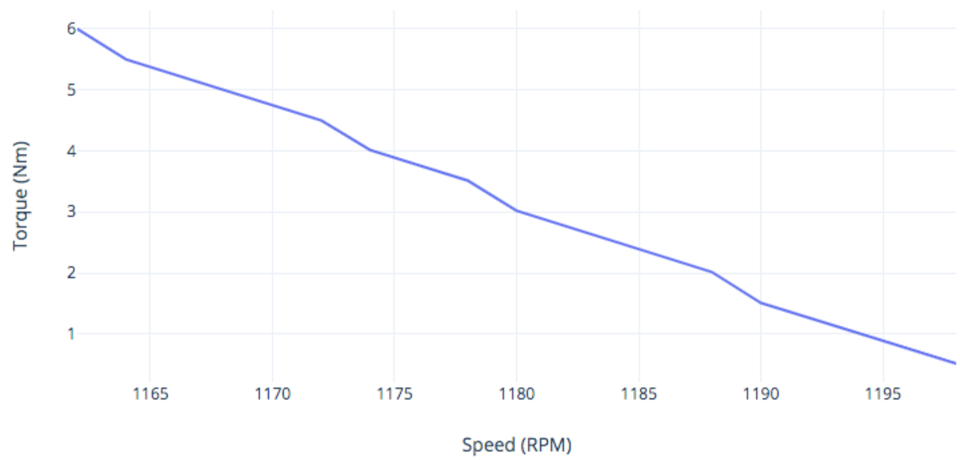
In this section we go through and measure different parameters of the DC motor during shunt operation, the data is shown below:

Table 1: Shunt DC Motor Characteristics

Toque(Nm)	Armature Current(A)	Armature Voltage(V)	Armature Power(W)	Speed(RPM)
0.515	.677	239	162	1198
1.015	.94	239	224	1194
1.510	1.2	238.7	286	1190
2.015	1.46	238.7	349	1188
2.510	1.73	238.6	413	1184
3.020	2	238	478	1180
3.515	2.27	238	542	1178
4.015	2.55	238	606	1174
4.500	2.83	237.9	673	1172
5.000	3.11	237.7	739	1168
5.500	3.39	237.6	806	1164
6.000	3.68	237	874	1162

We can plot torque vs speed to visualize operation during shunt dc motor connection:

Figure 1: Torque vs Speed for Shunt DC Motor



From our last lab we can use the parameters found to plot a theoretical plot.

We can use the equation:

$$T = \lambda_R * I_a + K_f{}^{SH} * I_f * I_a + K_f{}^{SE} * I_a{}^2 \quad \textbf{Equation 1.}$$

and substitute in Ia solved in terms of ω from 11.4, to get this equation:

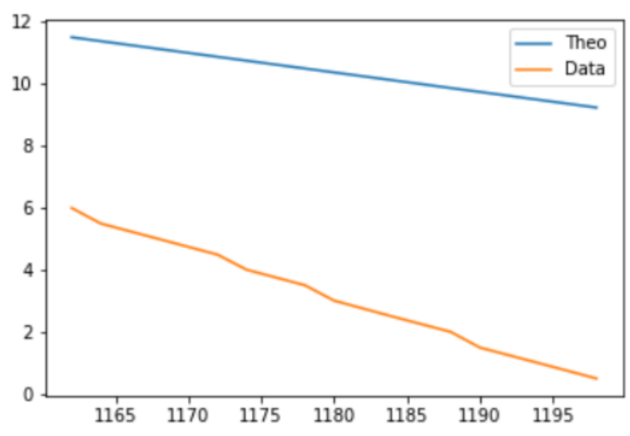
$$Ia = \frac{V - \omega * K_f{}^{SH} * I_f - \omega * \lambda_R}{\omega * K_f{}^{SE} + R_a + R_s} \quad \textbf{Equation 2.}$$

Finally we can combine the 2 above equations and get this plot with the parameters given below:

Table 2: Circuit Parameters

Ra	5 Ohms
Rs	.75 Ohms
Rf	118 Ohms
$K^{SH}{}_f$	2.05
$K^{SE}{}_f$	0.12
λ_R	0.064

Figure 2: Torque vs Speed Theoretical



2.2 *Compound DC Motor Characteristics*

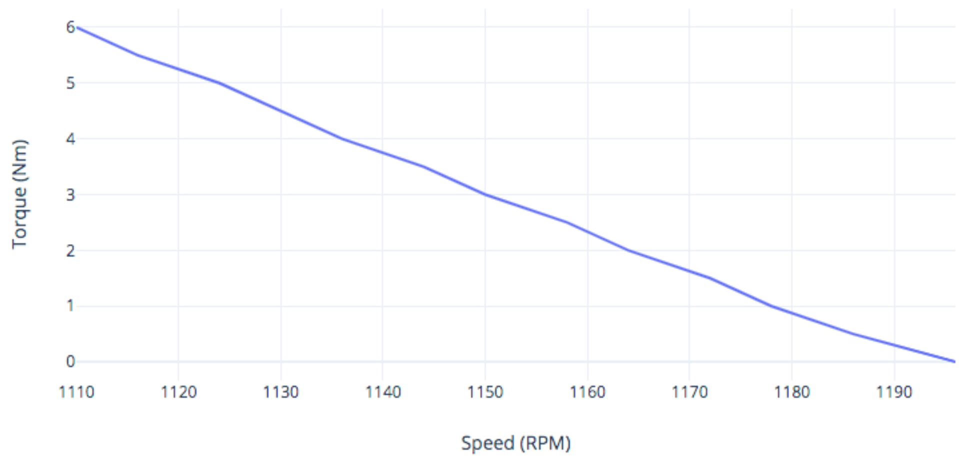
Next we move on to a different configuration where the series branch is not left open and take the same readings:

Table 3: Compound DC Motor Characteristics

Toque(Nm)	Armature Current(A)	Armature Voltage(V)	Armature Power(W)	Speed(RPM)
0.000	.345	239	83	1196
0.500	.665	238.9	158.8	1186
1.000	.92	238.7	219	1178
1.500	1.18	238.5	281	1172
2.000	1.44	238.5	343	1164
2.500	1.70	238	405	1158
3.000	1.96	238	467	1150
3.500	2.21	238	527	1144
4.000	2.48	238	589	1136
4.500	2.74	237.7	652	1130
5.000	3.01	237	714	1124
5.500	3.27	237	777	1116
6.000	3.54	237	840	1110

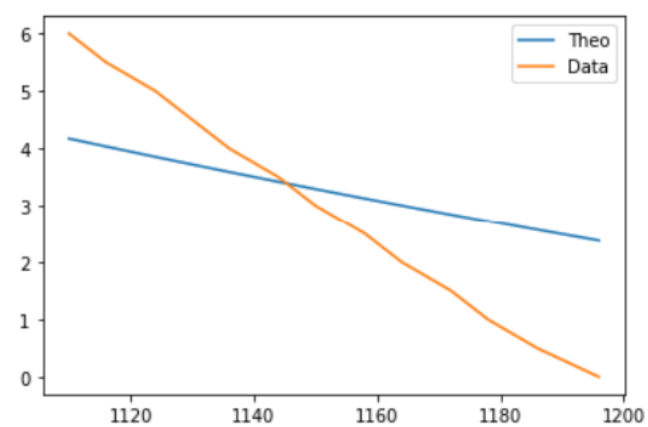
We can plot the Torque vs Speed Characteristics of this configuration to see the differences:

Figure 3: Torque vs Speed for Cumulative Compound



Plotting the expected and measured graphs together gives us this:

Figure 4: Torque vs Speed for Cumulative Compound Expected and Measured



2.3 *Differential Compound DC Motor Characteristics*

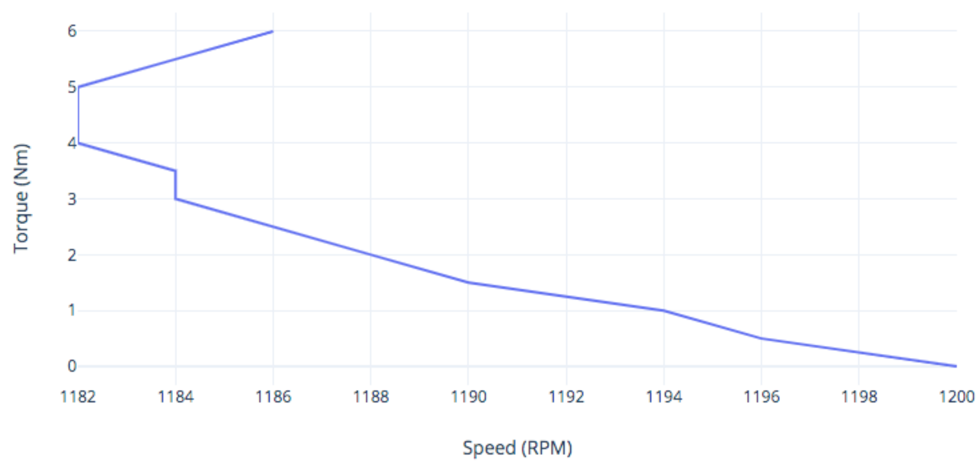
Then we reverse F4 and F4 to change current direction and make a differential connection. We take the same readings from before and get this:

Table 4: Differential Compound DC Motor Characteristics

Toque(Nm)	Armature Current(A)	Armature Voltage(V)	Armature Power(W)	Speed(RPM)
0.000	.342	239	82	1200
0.500	.663	239	158	1196
1.000	.924	239	221	1194
1.500	1.19	238.9	284	1190
2.000	1.46	239	348	1188
2.500	1.73	239	413	1186
3.000	2.01	238	478	1184
3.500	2.29	238	545	1184
4.000	2.57	238	611	1182
4.500	2.86	238	680	1182
5.000	3.16	238	751	1182
5.500	3.46	238	823	1184
6.000	3.78	237	898	1186

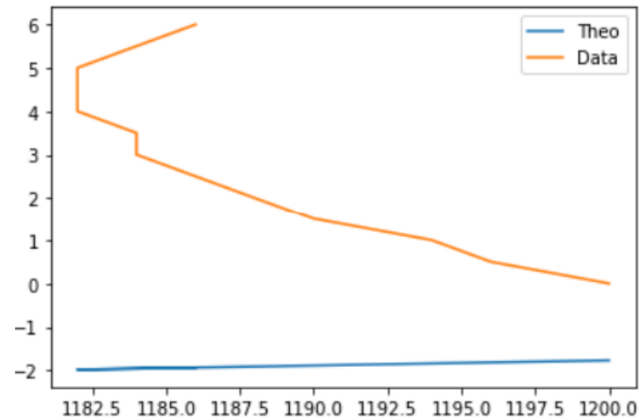
Plotting the torque vs speed characteristics of this data we get the following plot:

Figure 5: Torque vs Speed for Differetial Compound



Next we can do what we had before and plot expected along with the measured to see if they match up:

Figure 6: Torque vs Speed for Differetial Compound, Expected and Measured



Looking at the plots above most of the measured graphs match the expected graphs. The offsets might come from losses or readings that were not taken until the meters were stable. The only one off was the differential compound one which I think may come from the fact that the rheostat value was different that what was used in the first part of the lab.

The difference between the Cumulative and Differential connections is that the differential connection has constant speed and a low-start torque, but the Cumulative has a High-start torque. It is visible through the plots that Cumulative has Higher starting torque, which can be used in applications where you need instant acceleration like elevators. However, differential connections may be used where starting torque does not matter as much but a constant speed is needed to output a constant voltage like a generator.

3 CONCLUSION

This lab gave us a good look into DC motors and how they are operated to work like we want. The experiments we did showed us how to measure the different characteristics of the machine connected in different ways. This lab was short yet very interesting. The plots were somewhat hard to come up with but the torque speed characteristics are what is expected of a motor.

4 REFERENCES

[1] P.W. Sauer, P.T. Krein, P.L. Chapman, *ECE 431 Electric Machinery Course Guide and Laboratory Information*, University of Illinois at Urbana-Champaign, 2005.

5 APPENDIX

Raw Data: All the data used is presented in the tables.