

Experimental relation of the Formula
Electric Car Physical Parameter at
Constant Load Torque



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Introduction

By conservation of power mathematical model, at constant load torque, a set increase in motor speed results to an increase in supply current to maintain the given constant load torque. Also for the same constant load torque, with a set increase in supply current, motor speed increases to maintain the constant values of torque. This results in a linear relationship between motor speed and supply current as expected². Because of the lossy nature of the motor and motor controller system, it is expected that the supply current drawn in experimental setup be higher than the theoretical expectation, while the motor speed be lower than the theoretical expectation.

Hypothesis

Mathematical relation expectation of the motor speed vs current have been done during the theoretical analysis of the relation of the car's physical parameters expecting a linear relationship². However, some points of concern for this report relate to the observation of raw log data collected during experimentation. This report is to answer why there is an oscillation behavior in the torque for low load setting, does a negative torque mean the load torque is unstable? At 0% throttle there is a 0.1A recorded, is this an offset current?

Methods

Dynamometer data resulting from the constant values of individual parameters of supply current, load torque and motor speed was collected as stipulated in the *Experiment Setup for Dyno Data Collection*¹. The Motor and Motor Controller system takes in inputs of supply voltage, throttle and load to give outputs of supply current, load torque and motor speed. The voltage is held at a constant 91.5V for this experiment, and the outputs resulting from change in throttle and load settings. For each of the following test setups, percentage load is expected to be set from 0% to 100%, adjusting the throttle to achieve a given constant value of the parameter being held constant.

During data collection, the highest load setting achieved was 100% load. The chosen constant load torques were 0 lb-ft to 40 lb-ft with increment of 5 lb-ft. A max of 40 lb-ft was chosen as a reach for this experiment because data collected from previous years recorded a max load torque of 20 lb-ft. Table 2 in the appendix shows the dataset for this test setup, the regions shaded off are where data could not be collected because the motor heat up quickly and significantly. At this point the motor was turned off and let to cool down. Table 2 has 5 columns, load setting, desired constant load torque, supply current, motor speed and actual measured load torque corresponding to the load torque.

Challenges

- a. At 5% load, the program crashed as current was approaching the limit of 200A while the motor speed was almost 4000 rpm. The motor was turned off and let to cool before the next data collection. No data was collected for higher load torque at this load setting.

- b. From 48% load, most of the data is shaded because of heating limitation of the motor.

Note addressing hypothesis

- a. At 0% throttle, there is 0.1A being drawn instead of 0A. This 0.1A is the nominal current required to power the can-bus (through which experimental data is collected) and motor controller, rather than the previous hypothesis of a 0.1A offset.
- b. The log data shows small negative magnitudes of mechanical torque (load torque) at low load setting. This is not because the torque is unstable, rather, at low load setting there is hardly anything holding the torque gauge resulting to some bounce as it floats in midair. This explains the oscillatory behavior observed at the beginning of the sample data collected. For the experimental analysis of this data, this negative torque was zeroed, on the basis that at 0% load there is no torque because there is no resistance that the car should be working against.

Results

Figure 1 shows the supply current relation to motor speed at constant values of load torque. As motor speed increases, so does the magnitude of supply current to maintain the given constant load torque. An extrapolation of the graphs would have all the plots start at the origin. The plot region shown below should be the safe operation region for the motor for the given experimental setup. 175.7A was the highest supply current recorded for this entire experiment, giving a supply current range of 0-175.5A. Compared to the theoretical expectation² the supply currents observed in figure 1 are higher because the motor and motor controller system is not ideal and owing to system power loss, experimental results should in fact draw more current than the ideal case.

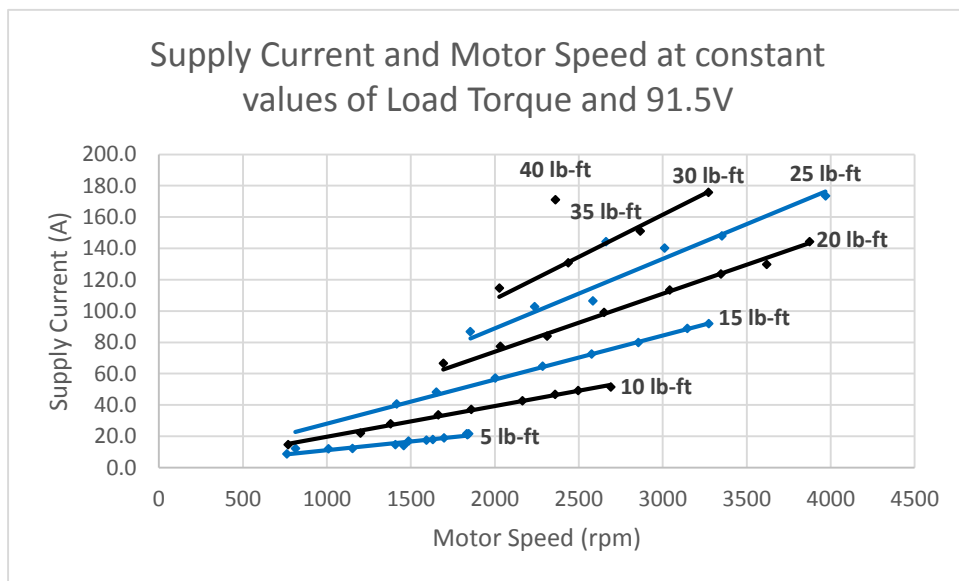


Figure 1 constant Load Torque

Figure 2 shows the motor speed relation to supply current at constant values of load torque. As supply current increases, so does the magnitude of motor speed because torque is constant. An extrapolation of the graphs would have all the plots start at the origin. The plot region shown below should be the safe operation region for the motor for the given experimental setup. 3969 rpm was the highest motor speed recorded for this entire experiment, giving a motor speed range of 0-3969 rpm. Compared to the theoretical expectation² the motor speeds observed in figure 2 are lower because the motor and motor controller system is not ideal and owing to system power loss, experimental results should in fact produce less motor speed than the ideal case.

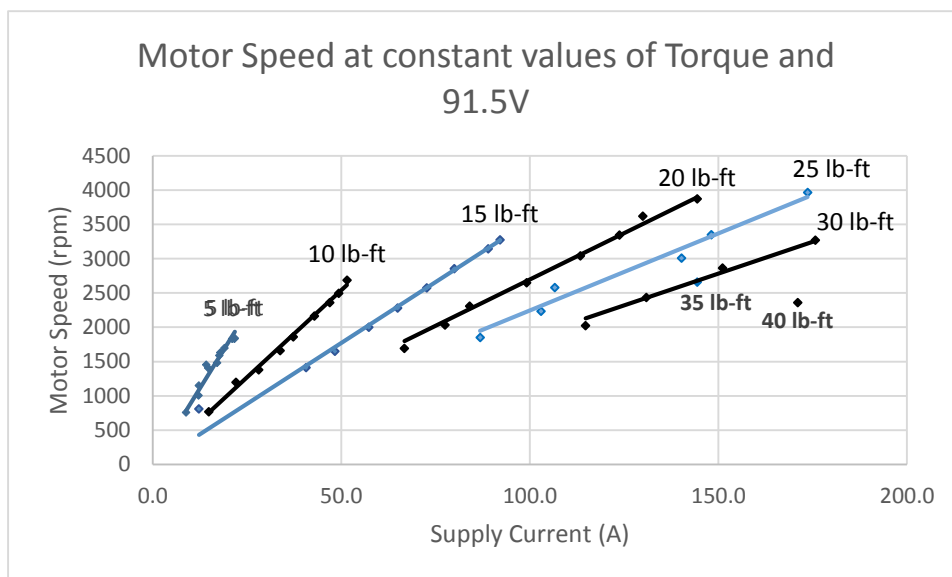


Figure 2 Constant Load Torque

Conclusion

When load torque is held constant, a set increase in motor speed results to an increase in supply current to maintain the given constant load torque. Also, with a set increase in supply current, motor speed increases to maintain the constant values of torque. Both these are linear relation between motor speed and supply current, consistent with theoretical expectation². Noted also is that the magnitude of supply current drawn is higher that theoretical expectation, while the motor speed is lower than the theoretical expectation because the motor and motor controller system is not ideal. Therefore, the experimental results are consistent with the theoretical expectations, following a mathematical model of conservation of power. The hypothesis concerns addressed in the method section suggest the raw data set analyzed for this experiment is credible.

Appendix

Table 2 of constant values of load torque

% Load	Desired load torque (ft-lb)	Current (A)	Motor speed (rpm)	Measured load torque (ft-lb)
0	0.0	0.2	0	0.0
5	0.0	0.1	0	0.0
10	0.0	0.2	0	0.0
15	0.0	0.1	0	0.0
20	0.0	0.1	0	0.0
25	0.0	0.2	0	0.0
30	0.0	0.2	0	0.0
35	0.0	0.1	0	0.0
48	0.0			
54	0.0			
74	0.0			
84	0.0			
90	0.0			
100	0.0			
0	5.0	21.0	1836	5.1
5	5.0	19.0	1697	5.0
10	5.0	17.6	1593	5.0
15	5.0	17.1	1485	5.0
20	5.0	14.7	1408	5.3
25	5.0	12.2	1153	5.0
30	5.0	12.1	1009	5.2
35	5.0	8.8	762	5.1
48	5.0			
54	5.0			
74	5.0	14.1	1458	5.4
84	5.0	17.9	1631	5.4
90	5.0	21.7	1845	5.1
100	5.0	21.6	1832	5.0
0	10.0	51.5	2690	10.1
5	10.0	49.3	2496	10.1
10	10.0	46.9	2359	10.2
15	10.0	42.8	2164	10.0
20	10.0	37.2	1860	10.1
25	10.0	33.8	1663	10.2
30	10.0	28.1	1380	10.1
35	10.0	22.0	1200	10.9
48	10.0			

54	10.0	14.8	770	10.7
74	10.0			
84	10.0			
90	10.0			
100	10.0			
0	15.0	92.0	3274	15.1
5	15.0	88.9	3145	15.6
10	15.0	79.9	2854	15.1
15	15.0	72.6	2576	15.1
20	15.0	64.9	2284	15.1
25	15.0	57.3	2002	15.1
30	15.0	48.2	1653	15.3
35	15.0	40.6	1415	15.2
48	15.0	12.2	813	15.1
54	15.0			
74	15.0			
84	15.0			
90	15.0			
100	15.0			
0	20.0	144.4	3873	20.7
5	20.0	129.9	3620	20.2
10	20.0	123.8	3347	20.5
15	20.0	113.4	3041	21.5
20	20.0	99.1	2651	20.5
25	20.0	84.0	2310	20.1
30	20.0	77.5	2033	20.5
35	20.0	66.7	1693	20.8
48	20.0			
54	20.0			
74	20.0			
84	20.0			
90	20.0			
100	20.0			
0	25.0			
5	25.0	173.6	3969	24.6
10	25.0			
15	25.0	148.1	3352	25.1
20	25.0	140.2	3011	25.8
25	25.0	106.6	2583	24.9
30	25.0	102.9	2237	25.1
35	25.0	86.8	1855	25.3
48	25.0			

54	25.0			
74	25.0			
84	25.0			
90	25.0			
100	25.0			
0	30.0			
5	30.0			
10	30.0			
15	30.0			
20	30.0	175.7	3271	30.0
25	30.0	151.1	2867	30.4
30	30.0	130.9	2438	29.6
35	30.0	114.8	2027	31.0
48	30.0			
54	30.0			
74	30.0			
84	30.0			
90	30.0			
100	30.0			
0	35.0			
5	35.0			
10	35.0			
15	35.0			
20	35.0			
25	35.0			
30	35.0			
35	35.0	144.4	2662	35.7
48	35.0			
54	35.0			
74	35.0			
84	35.0			
90	35.0			
100	35.0			
0	40.0			
5	40.0			
10	40.0			
15	40.0			
20	40.0			
25	40.0			
30	40.0			
35	40.0	171.0	2361	40.1
48	40.0			

54	40.0			
74	40.0			
84	40.0			
90	40.0			
100	40.0			

Reference

¹Hussein, Zainab. *Experiment Setup for Dyno Data Collection*. April 4, 2-17

²Hussein, Zainab. *Theoretical relation of the Formula Electric Car Physical Parameters of Load Torque, Supply Current and Motor Speed*. March 24, 2017