Experimental relation of the Formula Electric Car Physical Parameter at Constant Motor Speed

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Introduction

By conservation of power mathematical model, at constant motor speed, a set increase in load torque results to an increase in supply current to maintain the given constant motor speed. Also for the same constant motor speed, with a set increase in supply current, load torque increases to maintain the constant values of motor speed. This results in a linear relationship between load torque and supply current as expected[2]. 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 that the theoretical expectation, while the load torque be lower than the theoretical expectation.

Hypothesis

Mathematical relation expectation of the load torque versus current have been done during the theoretical analysis of the relation of the car's physical parameters expecting a linear relationship[2]. 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 motor speed were 0 rpm to 4000 rpm with increment of 500 rpm. A max motor speed of 4000 rpm was chosen because previous years recorded 3500 rpm to be highest experimental motor speed. Table 3 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 3 has 5 columns, load setting, desired constant motor speed, actual measured motor speed, load torque and supply current and corresponding to the motor speed.

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 and 2 show the supply current relation to load torque at constant values of motor speed. As load torque 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. 184.9A was the highest supply current recorded for this entire experiment, giving a supply current range of 0-184.9A. Compared to the theoretical expectation[2] the supply currents observed in figure 1 and 2 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. Low and high motor speeds have been divided into their separate graphs because the low motor speed relation has very small ranges of supply current and load torque resulting them appearing like a smudge on a combined plot.

Figure 1 Low constant motor speed

Figure 2 High constant motor speed

Figure 3 and 4 show the load torque relation to supply current at constant values of motor speed. As supply current increases, so does the magnitude of load torque because motor speed 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. 42.2 lb-ft was the highest load torque recorded for this entire experiment, giving a load torque range of 0-42.2 lb-ft. Compared to the theoretical expectation[2] the supply currents observed in figure 3 and 4 are lower because the motor and motor controller system is not ideal and owing to system power loss, experimental results should in fact experimental

results should in fact produce less load torque than the ideal case. Low and high motor speeds have been divided into their separate graphs because the low motor speed relation has very small ranges of supply current and load torque resulting them appearing like a smudge on a combined plot.
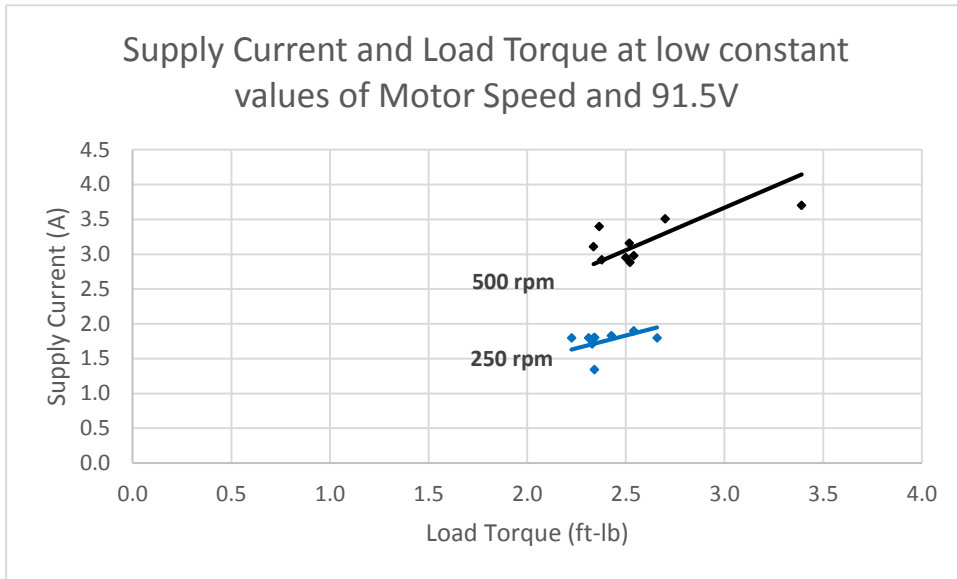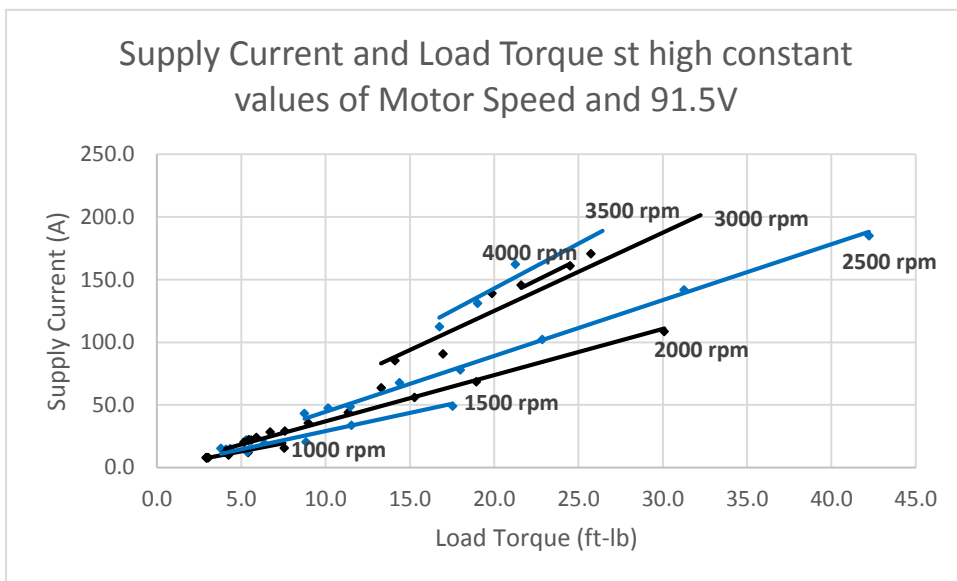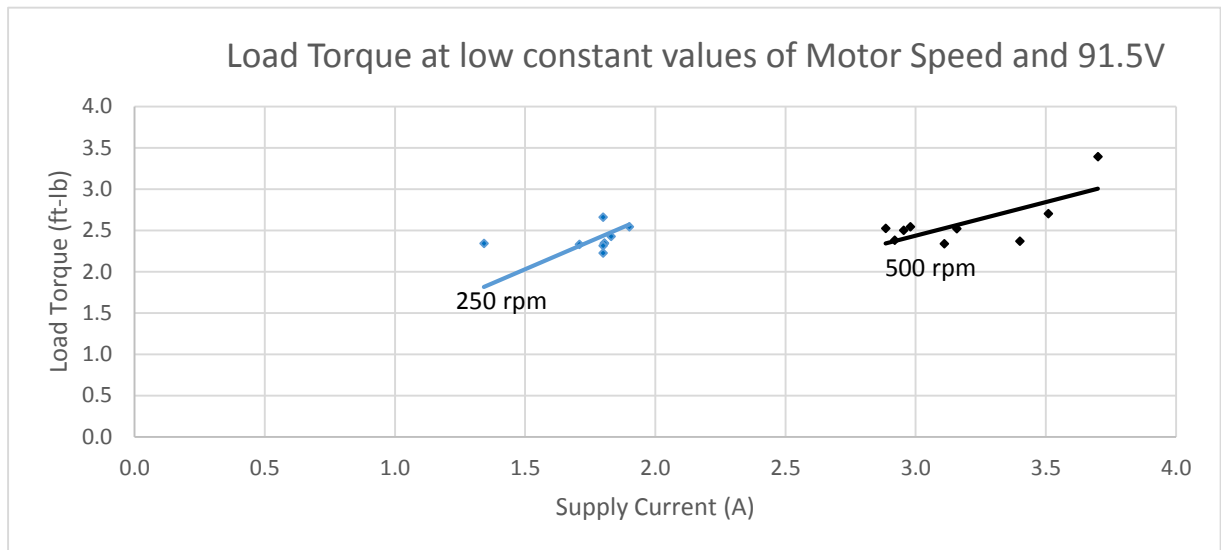

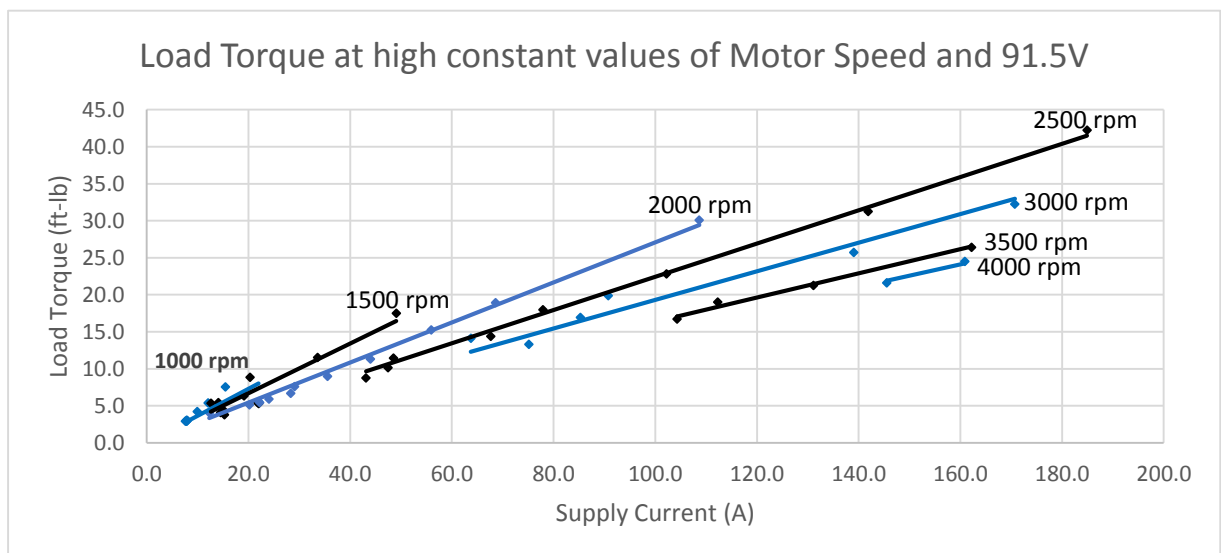*Figure 3 Low constant Motor Speed*

Figure 4 High constant Motor Speed

Conclusion

When motor speed is held constant, , at constant motor speed, a set increase in load torque results to an increase in supply current to maintain the given constant motor speed. Also for the same constant motor speed, with a set increase in supply current, load torque increases

to maintain the constant values of motor speed. Both these are linear relation between load torque and supply current, consistent with theoretical expectation[2]. Noted also is that the magnitude of supply current drawn is higher that theoretical expectation, while the load torque 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 3 of constant values of motor speed

% Load	Desired motor speed (rpm)	Measured motor speed (rpm)	Load torque (ft-lb)	Current (A)
0	0	0	0.0	0.2
5	0	0	0.0	0.1
10	0	0	0.0	0.2
15	0	0	0.0	0.1
20	0	0	0.0	0.1
25	0	0	0.0	0.2
30	0	0	0.0	0.2
35	0	0	0.0	0.1
74	0			
84	0			
90	0			
100	0	0	0.0	0.2
0	250	257	2.5	1.9
5	250	237	2.3	1.8
10	250	240	2.3	1.8
15	250	240	2.3	1.8
20	250	243	2.2	1.8
25	250	243	2.3	1.3

30	250	242	2.3	1.7
35	250	259	2.4	1.8
74	250			
84	250			
90	250			
100	250	229	2.7	1.8
0	500	510	2.7	3.5
5	500	510	2.5	2.9
10	500	486	2.5	3.0
15	500	492	2.5	3.2
20	500	493	2.3	3.1
25	500	518	2.4	3.4
30	500	490	2.4	2.9
35	500	492	2.5	3.0
74	500			
84	500			
90	500			
100	500	491	3.4	3.7
0	1000	980	3.0	8.0
5	1000	991	2.9	7.8
10	1000	995	2.9	7.8
15	1000	993	3.0	7.6
20	1000	979	3.1	7.8
25	1000	1032	4.2	10.0
30	1000	1002	5.4	12.1
35	1000	968	7.6	15.5
74	1000			

84	1000			
90	1000			
100	1000	983	5.6	22.0
0	1500	1555	3.8	15.3
5	1500	1510	4.1	14.5
10	1500	1498	4.3	15.1
15	1500	1512	5.4	12.6
20	1500	1490	6.4	19.1
25	1500	1523	8.8	20.3
30	1500	1480	11.5	33.6
35	1500	1526	17.5	49.1
74	1500	1463	5.4	14.1
84	1500			
90	1500	1565	5.4	21.8
100	1500	1551	5.3	22.0
0	2000	1986	5.9	24.0
5	2000	2012	6.7	28.3
10	2000	2006	7.6	29.1
15	2000	1992	9.0	35.5
20	2000	1988	11.3	44.0
25	2000	2007	15.3	56.0
30	2000	1945	18.9	68.6
35	2000	1992	30.1	108.7
74	2000			
84	2000	1185	4.0	12.3
90	2000	1859	5.1	20.2
100	2000	1848	5.4	22.2

0	2500	2468	8.8	43.1
5	2500	2506	10.1	47.5
10	2500	2490	11.5	48.5
15	2500	2512	14.4	67.6
20	2500	2495	18.0	77.9
25	2500	2464	22.8	102.2
30	2500	2501	31.3	141.8
35	2500	2398	42.2	184.9
74	2500			
84	2500			
90	2500			
100	2500			
0	3000	3063	13.3	75.2
5	3000	2969	14.1	63.7
10	3000	3032	17.0	85.3
15	3000	2982	19.9	90.7
20	3000	3005	25.7	139.0
25	3000	2947	32.2	170.7
30	3000			
35	3000			
74	3000			
84	3000			
90	3000			
100	3000			
0	3500	3479	16.8	104.3
5	3500	3485	19.0	112.3
10	3500	3420	21.3	131.1

15	3500	3445	26.4	162.2
20	3500			
25	3500			
30	3500			
35	3500			
74	3500			
84	3500			
90	3500			
100	3500			
0	4000	3959	21.6	145.5
5	4000	3965	24.5	160.9
10	4000			
15	4000			
20	4000			
25	4000			
30	4000			
35	4000			
74	4000			
84	4000			
90	4000			
100	4000			

Reference

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

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