Experimental relation of the Formula Electric Car Physical Parameter at

Constant Supply Current

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4-19-2017

Introduction

By conservation of power mathematical model, at constant current, there is constant power. For a set motor speed, the load torque self-adjusts to ensure the given power is met. When the load torque is held constant, the motor speed will self-adjust to meet the given power too. This results in a hyperbolic relationship between motor speed and load torque as expected[2].

Hypothesis

Mathematical relation expectation of the motor speed and load torque have been done during the theoretical analysis of the relation of the car's physical parameters expecting a hyperbolic 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? What is the current range for this experiment? At around 30% throttle in the log data[3] there is a big current drop from 111A to 0.6A in less than a second, why?

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 50% load, with increment steps of 5% from 0%. Load settings 40% and 45% were not collected at the time mostly for time constrain reason. The chosen constant current were 0A to 160A with increment of 20A. A max of 160 was chosen because we had a current limit of 200A from the power supply used in the dyno room. The TSV (tractive system voltage) should allow for more current t be drawn, to about 300A. Table 1 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 1 has 5 columns, load setting, desired constant supply current, actual measured supply current, motor speed and load torque corresponding to the supply current.

Challenges

a. At 0% load, around 60A the throttle setting stopped responding and the motor was spinning so fast that the program collecting data crashed. We turned off the motor at this point and restarted to resume data collection. The rest of the data collection at this setting of load went smoothly.

b. At 25% load, after 40A the program crashed and suspected to be as a result of the slowness of the computer (in the Dyno room) while sampling many data points, 3 per second. This affected only the manual data we collected, the log data was available to grab from if need be. The torque at this point was high enough that reverberations were felt on the floor.

Note addressing hypothesis

a. At 100% load, not logged in table 1, the motor shaft spun very slow as expected. This is a good foresight to when the car is braking.
b. 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.
c. 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.
d. At around 30% throttle in the log data[3] there is a big current drop from 111A to 0.6A in less than a second, because of a slight miscommunication in the can-bus program. The actual current magnitude of current never drops in the supply. Therefore, the analysis assumes that for that less than second interval, the current never drops from 111A.

Results

Figure 1 shows the torque behavior at constant current when the motor speed is set. The load torque self-adjusts to meet the given power that is proportional to the constant current, resulting in the expected hyperbolic relationship shown. As supply current increases, for a set motor speed value the load torque also increases as seen where the data labels are. At higher load setting (indicating, but not proportional, the resistance the car should be facing, for example due to wind), and high supply current, a higher load torque value could not be achieved because of heating limit of motor reached. An extrapolation of the 160A data would give a load torque higher that the 140A's 62.2 lb-ft load torque. The plot region shown below should be the safe operation region for the motor for the given experimental setup. 62.2 lb-ft was the highest load torque recorded for this entire experiment, giving a load torque range of 0-62.2 lb-ft.

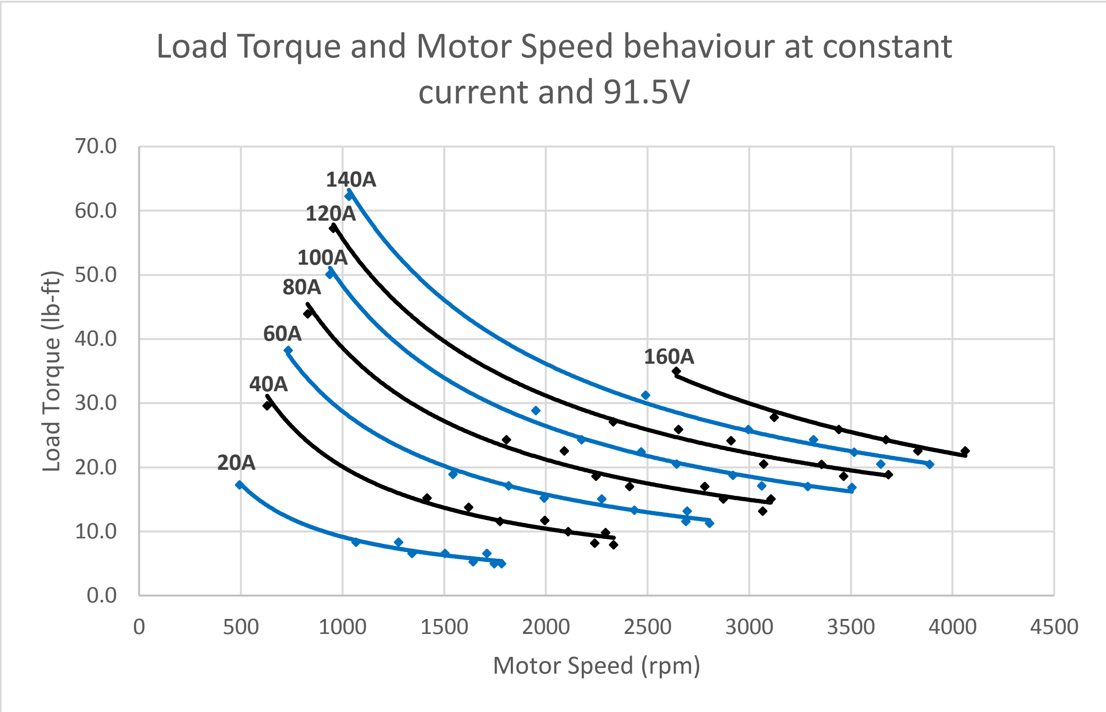

Figure 1 Constant Supply Current

Figure 2 shows the motor speed behavior at constant current when the load torque is set. Motor speed self-adjusts to meet the given power that is proportional to the constant current, resulting in the expected hyperbolic relationship shown. As supply current increases, for a set load torque value the motor speed also increases as seen where the data labels are. At higher load setting (indicating, but not proportional, the resistance the car should be facing, for example due to wind), and high supply current, a lower motor speed value could not be achieved because of heating limit of motor reached. An extrapolation of the 160A data would give a motor speed just above the 1031 rpm of the 140A motor speed. The plot region shown below should be the safe operation region for the motor for the given experimental setup. 4063 rpm was the highest motor speed recorded for this entire experiment, giving a load torque range of 0-4063 rpm.

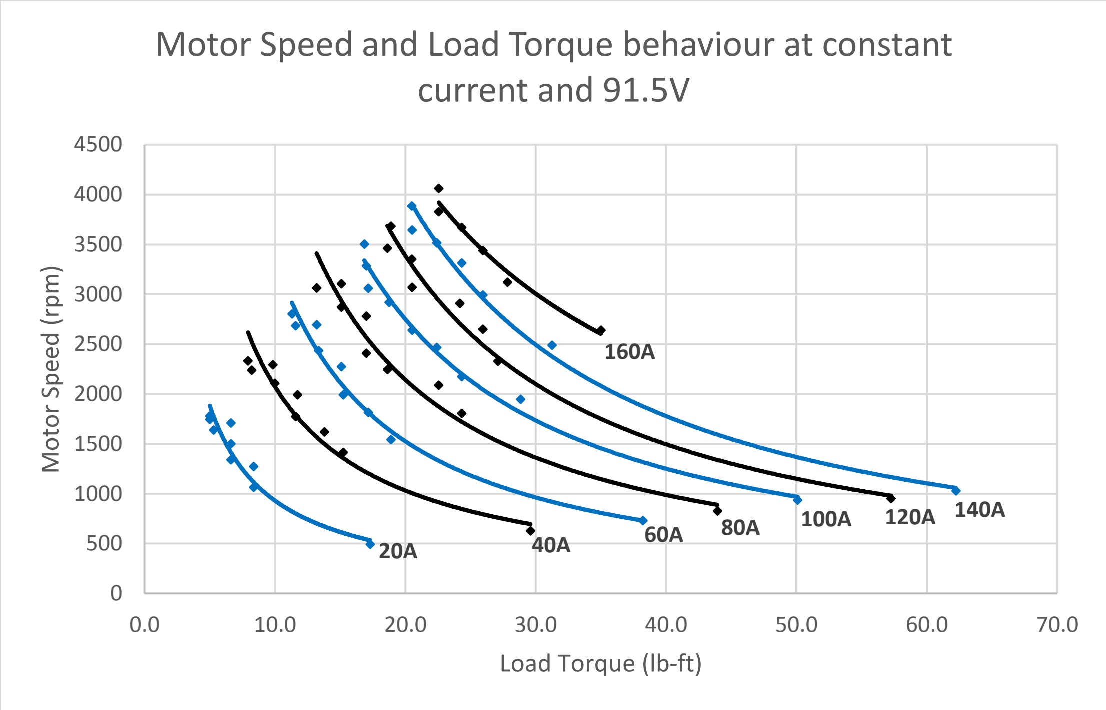

Figure 2 Constant Supply Current

Conclusion

When current is held constant, motor speed self-adjusts at a set load torque value to meet the power which the current is proportional to. This is also true for load torque when motor speed is set to a value for a given constant current. 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 1 of constant values of supply current

% Load	Desired current (A)	Measured current (A)	Motor speed (rpm)	Load torque (lb-ft)
0	0.0	0.1	0	0.0
5	0.0	0.1	0	0.1
10	0.0	0.1	0	-0.1
15	0.0	0.1	0	-0.1
20	0.0	0.1	0	-0.3
25	0.0	0.1	0	-0.3
30	0.0	0.0	0	0.0
35	0.0	0.0	0	0.0
50	0.0	0.1	0	-0.3

0	20.0	20.2	1783	5.0
5	20.0	19.9	1746	5.0
10	20.0	18.9	1642	5.3
15	20.0	23.7	1710	6.6
20	20.0	21.1	1503	6.6
25	20.0	19.1	1342	6.6
30	20.0	22.2	1276	8.4
35	20.0	19.0	1066	8.4
50	20.0	19.0	494	17.3
0	40.0	38.2	2333	7.9
5	40.0	37.1	2240	8.2
10	40.0	44.6	2294	9.8
15	40.0	41.3	2109	10.0
20	40.0	44.8	1995	11.7
25	40.0	40.6	1774	11.6
30	40.0	42.4	1620	13.8
35	40.0	41.9	1415	15.3
50	40.0	40.7	629	29.6
0	60.0	61.3	2805	11.3
5	60.0	59.1	2688	11.6
10	60.0	67.4	2695	13.2
15	60.0	61.4	2435	13.4
20	60.0	64.6	2275	15.1
25	60.0	57.1	1992	15.3
30	60.0	58.3	1817	17.2
35	60.0	55.3	1543	18.9
50	60.0	60.3	732	38.2
0	80.0	76.3	3067	13.2
5	80.0	87.1	3107	15.1
10	80.0	80.5	2872	15.1
15	80.0	86.9	2782	17.0
20	80.0	76.1	2412	17.0
25	80.0	77.6	2246	18.6
30	80.0	86.5	2090	22.6
35	80.0	81.6	1806	24.3
50	80.0	74.0	828	43.9
0	100.0	109.1	3505	16.9
5	100.0	102.8	3288	17.0
10	100.0	96.0	3061	17.2
15	100.0	100.1	2920	18.8
20	100.0	98.8	2643	20.5
25	100.0	101.1	2468	22.4

30	100.0	96.7	2176	24.3
35	100.0	100.0	1950	28.8
50	100.0	99.8	938	50.1
0	120.0	124.5	3684	18.9
5	120.0	117.7	3465	18.6
10	120.0	124.6	3355	20.5
15	120.0	114.6	3071	20.5
20	120.0	118.9	2911	24.2
25	120.0	124.5	2652	25.9
30	120.0	118.0	2332	27.1
35	120.0			
50	120.0	116.8	955	57.3
0	140.0	142.6	3887	20.5
5	140.0	134.6	3647	20.5
10	140.0	141.7	3517	22.4
15	140.0	144.1	3316	24.3
20	140.0	139.7	2995	25.9
25	140.0			
30	140.0	141.6	2490	31.3
35	140.0			
50	140.0	137.5	1031	62.2
0	160.0	163.2	4063	22.6
5	160.0	154.0	3830	22.6
10	160.0	159.3	3672	24.3
15	160.0	158.9	3440	25.9
20	160.0	156.2	3123	27.8
25	160.0			
30	160.0	167.4	2642	35.0
35	160.0			
50	160.0			

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

[3]Diego, Richard and Hussein, Zainab. *4-5-30percent* Spreadsheet. April 5, 2017