Experimental *relation of the Formula Electric Car Physical Parameter at constant Supply Current*

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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 expected2.

Hypothesis

Mathematical relation expectation of the motor speed vs current and load torque versus 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

1. 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.
2. From 48% load, most of the data is shaded because of heating limitation of the motor.

Note addressing hypothesis

1. 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.
2. 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 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 constant Load Torque

Figure 2 Constant Load Torque

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

1. Table 2 of constant values of load torque

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **% Load** | **Desired load torque (lb-ft)** | **Current (A)** | **Motor speed (rpm)** | **Measured load torque (lb-ft)** |
| 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