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.

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.

1. Supply Current Model

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. 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:

1. 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.
2. 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:

1. 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.
2. 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.
3. 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.
4. Load Torque Model

During data collection, the highest load setting achieved was 100% load. The chosen constant load torques were 0 ft-lb to 40 ft-lb with increment of 5 ft-lb. 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, actual measured load torque, supply current and motor speed corresponding to the load torque.

1. Motor Speed Model

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. 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.

Results

1. Supply Current Model

Figure constant Load Torque

Figure Low constant motor speed

Figure High constant motor speed

1. Load Torque Model

Figure Low constant Motor Speed

Figure High constant Motor Speed

Figure Constant Supply Current

1. Motor Speed Model

Figure Constant Load Torque

Figure Constant Supply Current

Conclusion

Appendix

1. Table 1 of constant values of supply current

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

1. 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 |  |  |  |

1. 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

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