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ECE 492

Motor Controller + Modeling

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Results and Conclusions Report

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I. Introduction

The purpose of this report is to provide a summary of all results and conclusions from findings of other reports for characterizing the motor + controller setup which will be used in the fully integrated car. It will serve to address several key questions regarding throttle limits and optimal throttle operation, as well as gear ratio and efficiency and cooling for the car. Several questions which were posed at the beginning of the project will also be answered in the context of a fully integrated car.

II. Hypothesis

The hypothesis and main goal of this report which summarizes and synthesizes all other findings for the project is that characterization and modeling data and results can be used to make assumptions and predictions about the behavior and characteristics of the future fully integrated car. These predictions will be justified through their use of valid experimental data, as well as predictions for car parameters which are based upon reasonable assumptions using the limited amount of knowledge about the final system currently available.

III. Relevant Data

One of the most important determinations that had to be made by the motor characterization and modeling team for this project is a full operating range of parameter of the motor. This includes obtaining data regarding the minimum and maximum values of torque, RPM, and power supply current draw for the motor + controller system which is currently setup. The graph below in **Figure 1** shows a constant power curve which was obtained at the highest possible electrical power for the car. This data can be found, along with all other experimental data and analysis, on the project website [3].This is the case because just over 200A of current draw were constant across this test, coinciding with the maximum possible accumulator current through a 200A fuse. From this graph, the maximum speed of RPM can be seen at around **4500 RPM,** and maximum possible torque reached was about **92 ft-lbs.** This high RPM value corresponds with a throttle setting of 36%.

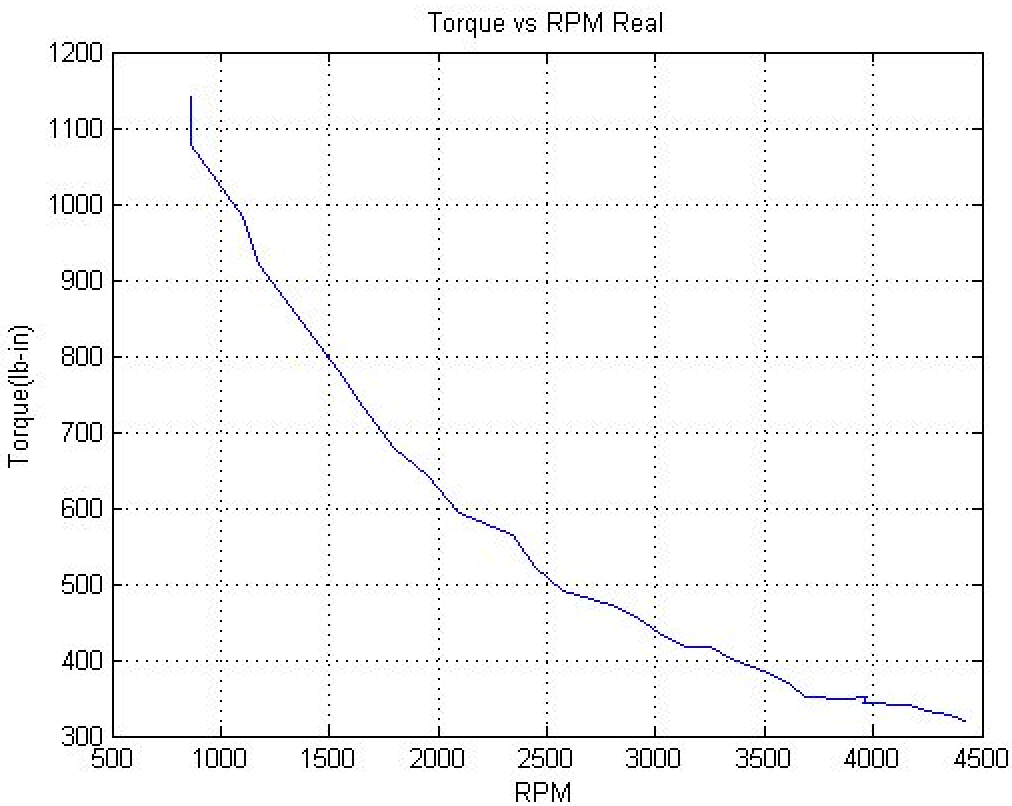

Figure 1

In this same constant power experiment, it was determined that maximum efficiency for the motor was reached at and above 2500 RPM, where the maximum of about 84% efficiency from power supply to motor is reached (see **Figure 2)**. Therefore, the maximum efficiency motor speed in the fully integrated car would be 2500RPM. In **figure 3,** calculations are shown which relate this motor RPM to a wheel speed, and therefore a car speed given a gear ratio of 2.8. This gear ratio was determined by running a straight line test simulation [3], wherein the car was tested running at max power and time was calculated for how long it would take to drive a fixed distance. For the purposes of this simulation, the car wheel size was assumed to be 8 inch radius, and the car's weight was estimated at 800 pounds. This is a figure which was decided upon based on the weight per pack (80 lbs * 4) plus nearly 500 pounds for the car chassis and driver. The graph in **figure 4** shows how a gear ratio of 2.8 was chosen based on the results of this simulation.

Figure 2

Tested Range Speed Motor		
Low	0	RPM
High	2500	RPM
Total	2500	RPM
Gear Ratio	**2.8**	

Wheel Speed	892.8571	RPM
Wheel Radius	8	in.
Circumference	50.26548	in.
Car Speed	**44879.9**	**in./min**
Car Speed	**42.4999**	**mph**
Car Speed	18.99916	m/s
Acceleration time	13	seconds
Max Accel	**1.461474**	**m/s^2**
Max Accel	**0.14913**	**Gs**

Figure 3

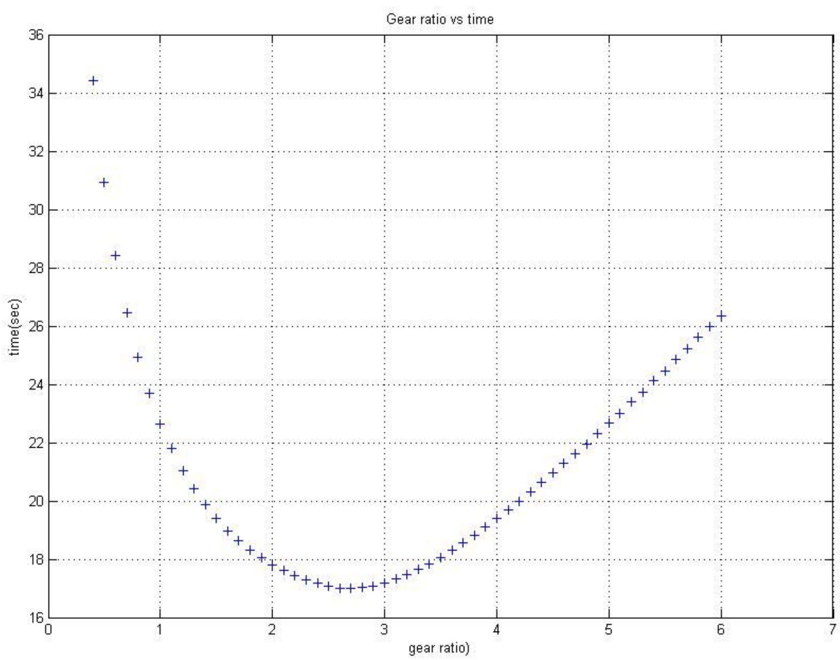

Figure 4

The results of this simulation were able to be used not only to obtain a gear ratio, but also provide an estimate for the maximum acceleration of the car. Running the car at maximum possible power yields a simulation of the highest achievable acceleration, shown below in **Figure 5.** As can be seen from this graph, the maximum speed for the car was able to be reached in about 13 seconds. Using a linear slope from 0 to 76 mph this yields a maximum acceleration of about 0.27Gs.

Efficiency as it pertains to cooling of the motor and controller systems is covered in the efficiency and cooling report written for this project [2]. It discusses the methods used for cooling down the motor system, and provides a breakdown for power losses throughout the system.

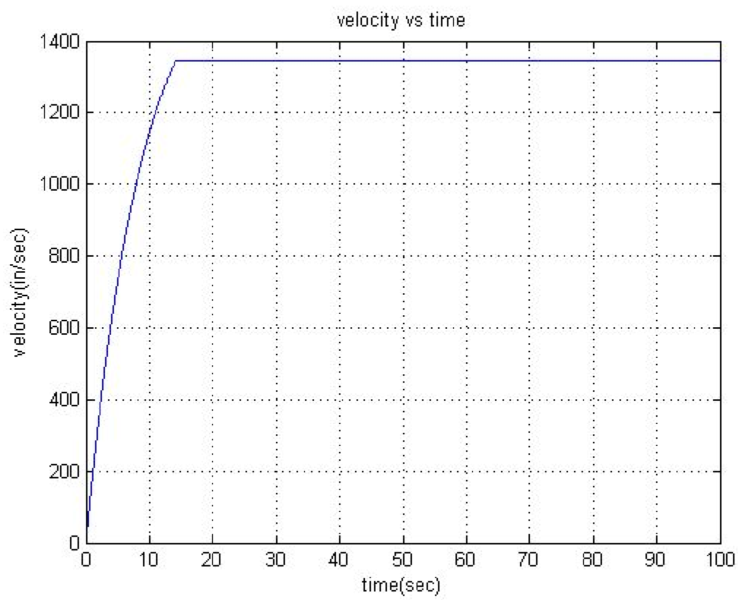

Figure 5

IV. Results and Conclusions

In order to meet the requirements set forth for the motor characterization and modeling team, the following questions must be answered:

- What is the full range of speed in mph that we can be running the car at?
- What is the best (efficiency) speed to be running the car at?
- How long will the battery last running the car?
- What is the gear ratio that we will be using in running the car?
- What is the max acceleration for the fully integrated car?

The data which has been presented and analyzed above in this report can be utilized to provide effective and reasonably accurate answers to each of these questions given the limited understanding of the characteristics of a fully integrated car.

What is the full range of speed in mph that we can be running the car at?

From the parameters in the table shown in **Figure 3** and the calculation of a max motor speed of 4500 RPM, the max speed of the car is determined to be **76 miles per hour.**

What is the best (efficiency) speed to be running the car at?

From the graph shown in **Figure 2**, it can be seen that the minimum RPM for the motor to achieve efficient performance is at or above 2500 RPM. Running at exactly 2500 RPM, using the parameters given in **Figure 3,** the car will run efficiently at **42 miles per hour.**

How long will the battery last running the car?

Using the equation developed in the static characterization report for this project [1], a calculation was made using the efficient speed of 2500 RPM and a steady state torque estimate of 15 ft-lb to find that the motor would be drawing 71A. Given the battery capacity of 60A-h, this corresponds with a time to dissipate the battery of **51 minutes.**

What is the gear ratio that we will be using in running the car?

The simulation run using data from the constant power curve **Figure 1** simulated a car on a straight track accelerating as quickly as possible. The results were printed out to determine which gear ratio (for a car of estimated weight 800lbs) was most suitable in achieving the lowest amount of time to drive a set distance. The graphed results in **Figure 4** show that the optimal gear ratio to use in a straight line is **2.8.**

What is the max acceleration for the fully integrated car?

From the same set of simulated data, the graph in **figure 5** was created. As can be seen from this graph, the maximum speed for the car was able to be reached in about 13 seconds. Using a linear slope from 0 to 76 mph this yields a maximum acceleration of about **0.27Gs**.

Ultimately, the amalgamation of results from several different analyses into this conclusory report show that reasonable predictions and assumptions can be made for the fully integrated car. All of the questions posed at the start of the semester have been addressed with experimental data from running the motor and the best available estimates of real-life parameters for the future electric car.

Appendix A - References

[1] Static Characterization Report:

https://sites.lafayette.edu/ece492-sp16/files/2016/05/Static_Characterization-1.pdf

[2] Efficiency and Cooling Report:

https://sites.lafayette.edu/ece492-sp16/files/2016/05/CoolingAnalysis.pdf

[3] Experimental Data and Analysis

https://sites.lafayette.edu/ece492-sp16/motor-experiment-results/