HYBRID ELECTRIC VEHICLE ENTERPRISE
TECHNICAL REPORT

SUMMER VUE ROTOR TESTING

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~ ABSTRACT ~

The objective of the testing was to investigate claims of increased fuel economy due to changes in brake rotor material. The stock cast steel rotors were compared to an aluminum/steel composite rotor. The testing shows an average increased fuel economy of 5 mpge when using the aluminum/steel composite rotor.

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EXECUTIVE SUMMARY

The purpose of this project was to investigate reported fuel economy gains caused by using aluminum/steel composite brake rotors on a Saturn Vue. To investigate these claims, a 2009 Saturn Vue Hybrid fabricated by Michigan Tech's EcoCAR enterprise was repeatedly driven over a drive cycle in Houghton, MI. The Vue was instrumented to allow the recording of data which allowed fuel economy calculations. The results show an average 5 miles per gallon equivalent improvement when the aluminum/steel composite rotors were used.

INTRODUCTION

The main goal of this project was to investigate the reported fuel economy gains caused by using advanced steel/aluminum composite brake rotors. This was accomplished by utilizing an instrumented Saturn Vue Hybrid. The Vue was repeatedly driven over a chosen drive cycle. The instrumentation system output electric current draw from the battery, battery terminal voltage, vehicle speed, and the timestep. The first step of the calculations involved using equation 1 to find the power consumed by the vehicle.

$$Power = Voltage * Current \qquad 1$$

The EPA defines 1 gallon of gas as 33.7 kW-hr of electricity. The next step involved was to find the amount of kilowatt hours used at varying points in the drive cycle. To accomplish this, equation 2 was used.

$$kW - hr = Power(kW) * Timestep(hour) \qquad 2$$

The kW-hrs consumed was then converted into gallons of fuel consumed by utilizing equation 3 taken from the EPA's fuelecomony.gov (1).

$$Gallons = (kW - hr)/33.7 \qquad 3$$

Now that instantaneous fuel consumption is known, it can be converted into miles per gallon equivalent. To accomplish this, numerical integration was used. The velocity output was integrated to obtain the displacement of the vehicle. Using equation 4, instantaneous fuel economy (miles per gallon equivalent) was calculated.

$$mpge = \frac{displacement}{gallons} \qquad 4$$

The mpge was then averaged over the drive cycle. The test was completed four times for each set of brake rotors (four with the stock rotors and four with the aluminum/steel composite rotors).

TECHNICAL APPROACH

The first step of the process for validating the brake rotor fuel economy improvements was developing a drive cycle for the vehicle. The drive cycle is shown in figure 1. The main goal of the route was to have a repeatable route that avoided as much traffic as possible. The chosen route mainly included country roads where other vehicles were hardly seen.

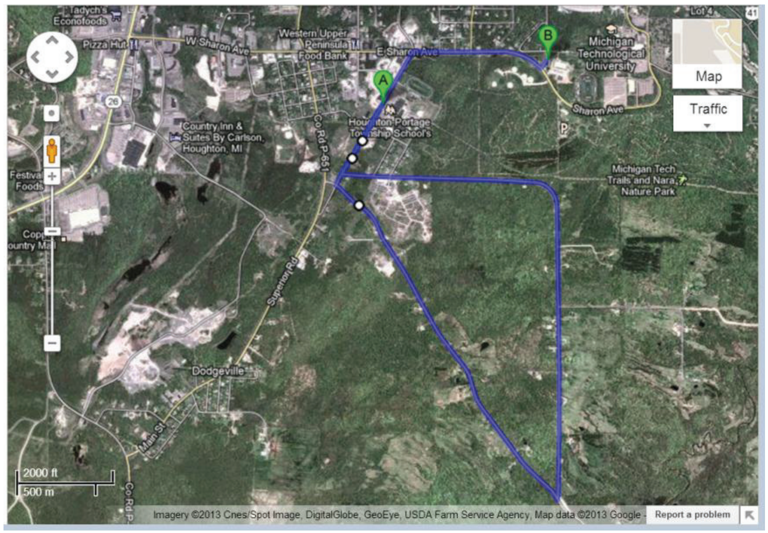

Figure 1Drive Cycle

Once the drive cycle was chosen, testing procedures were developed. The test procedures included: one driver that was consistent over all of the tests, windows open, air conditioning off, maintain as close to 25 mph as possible using a handheld gps unit for guidance. The vehicle began each test with a 95% state of charge. It then ran 2 circuits of the drive cycle. This was completed four times for each set of rotors.

ANALYSIS

Fuel economy was calculated by using data that was taken from sensors and recorded from the vehicles Mototron supervisory controlled by using a laptop. Battery current, voltage, and vehicle speed were recorded along with the timestep that they were recorded at. By following the equations derived in the introduction, an equivalent fuel economy was calculated. To validate the tests, velocity vs. displacement traces were constructed, as shown in figure 2. These traces are used to verify that the vehicle stayed reasonably consistent over the given drive cycles.

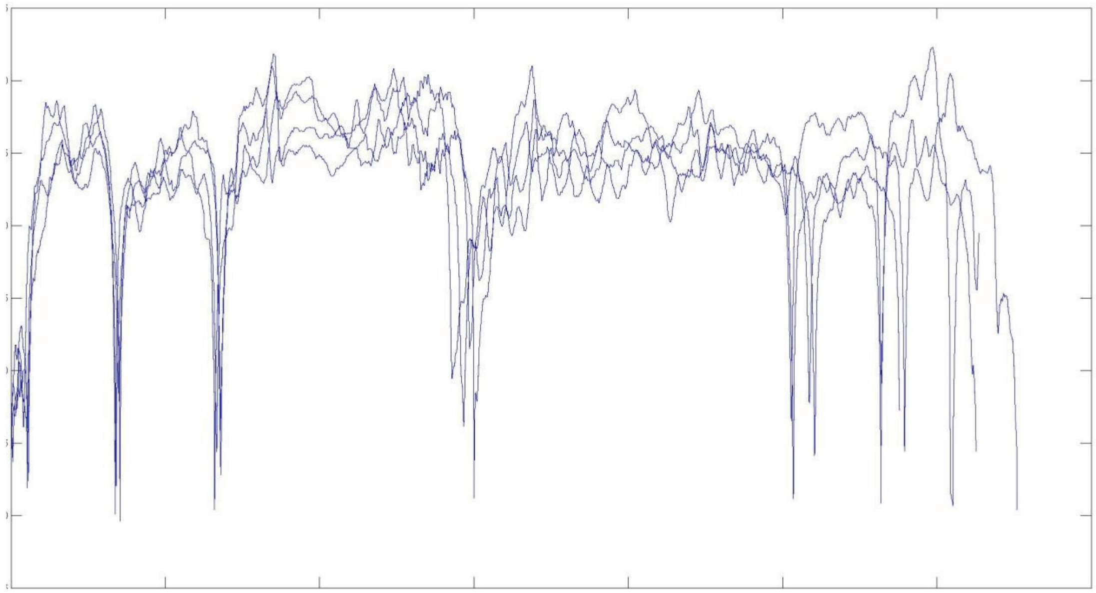

Figure 2 Velocity vs Displacement trace

RESULTS

Table 1 displays the results of the fuel economy testing. The composite rotor had a higher average and peak fuel economy when compared to the stock rotor.

MPGE OF ROTORS	STOCK ROTOR	COMPOSITE ROTOR
Run 1	104.2	112.8
Run 2	119.4	113.3
Run 3	108.0	110.5
Run 4	113.7	128.8
Average	111.3	116.4

Table 1: Fuel Economy Results

CONCLUSIONS

There were two main conclusions from the testing. The first conclusion was that the tests were run over a consistent drive cycle. Due to the accuracy of the equipment used, a 3 mph range for speed driven is acceptable. The gps unit reads to the nearest mph. It does not update instantaneously. Both of these are sources of error that account for the velocity fluctuations.

The second conclusion is that the brake rotors did improve the fuel economy. Both the average fuel economy and the peak fuel economy were higher for the composite rotors. These tests were run at low speeds. It is anticipated that the fuel economy increases would be greater at increased vehicle speeds.

REFERENCES

1) US Department of Energy, Environmental Protection Agency, Fuel Economy.gov, Nissan Leaf Fuel Economy, http://www.fueleconomy.gov/feg/noframes/32154.shtml