STUDY SENSOR OPERATION BOLIDE FORMULA STUDENT

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The design of formula student car is defined by the SAE regulations. The aspects which have an influence on the driver and public safety are limited by those regulations. Teams must develop and complicate the design of the vehicle in order to be competitive. Aerodynamics is one of the active safety parts since it generates downforce which is due to the object shape and speed of the vehicle. Formula student car air resistance systems were under investigation. Efficiency of the system was confirmed during the laboratory tests and impulse signals were obtained. This article studies the concept of sensor data check. There were several different sensors used to receive the data. Each sensor works in required range and has specified design. All sensors can be divided into two groups: passive and active. Active sensors have its own processor to analyze the data. Passive sensors are just a measure element. Active sensors are more expensive and use digital transmission area. Passives are cheaper and have an analog data. Article has the research results of sensor in 4 different versions of their use.
Keywords: sensors, air resistance, racing car

Aerodynamics is a component of active safety due to the impact of downforce delivered through the geometric shape of the object and its velocity. Was conducted testing system for measuring air resistance Formula Student car.

Question 1 – The track is flat

A×Cd has been measured in a coast down test to be 0.26 m^2

The same test found that the coefficient of rolling resistance μR =0.045

The mass of the vehicle and driver is 290 kg.

The density of air is 1.25 kg/m3

The data for TMA3 file was loaded using appropriate steps explained in the appendix in the TMA.

```
>> D=load('TMA3q1.csv');
>> L=length(D);
>> t=D(1:L,1);
>> v=D(1:L,2);
>> throttle=D(1:L,3);
```

Time – t in seconds, Velocity – v in km/h and Throttle position – throttle

To convert velocity from km/h to m/sec the following step is taken:

```
>> v1=v/3.6;
```

Given data from the TMA is added to MATLAB:

```
>> ACd=0.26;
>> mr=0.045;
>> m=290;
>> p=1.25;
>> d=v1.*t;
```

Since the data of the Velocity is noisy Butterworth type filter of 2 order is used. This filter type is used because of the smother type of graph it can pruduce.

```
>> [x,y]=butter(2,0.1) ;
>> v2=filtfilt(x,y,v1);
```

After the velocity has been filtered, acceleration is found as suggested in the TMA tips using the gradient command in MATLAB:

```
>> a=gradient(v2)/0.05;
```

Finaly Power At Wheels formula is used to calculate:

```
>> PAW=(((1/2)*ACd*p*v2.^2)+mr*m*9.8+m.*a).*(v2/1000);
```

Graph is ploted now:

```
>> plot(t,a)
```

a) Compare the braking and accelerating power.

Figure 1 shows the change in acceleration and braking power. As can be seen the average amount of braking is higher rather than acceleration this is mainly due to the aero effects. The highest amount of acceleration what so ever is not that high and reaches about 6 m/sec^2, where the breaking power reaches the highest point at almost -10 m/sec^2. In conclusion the breaking power is great then acceleration power due to the several factors such as turns or the aero.

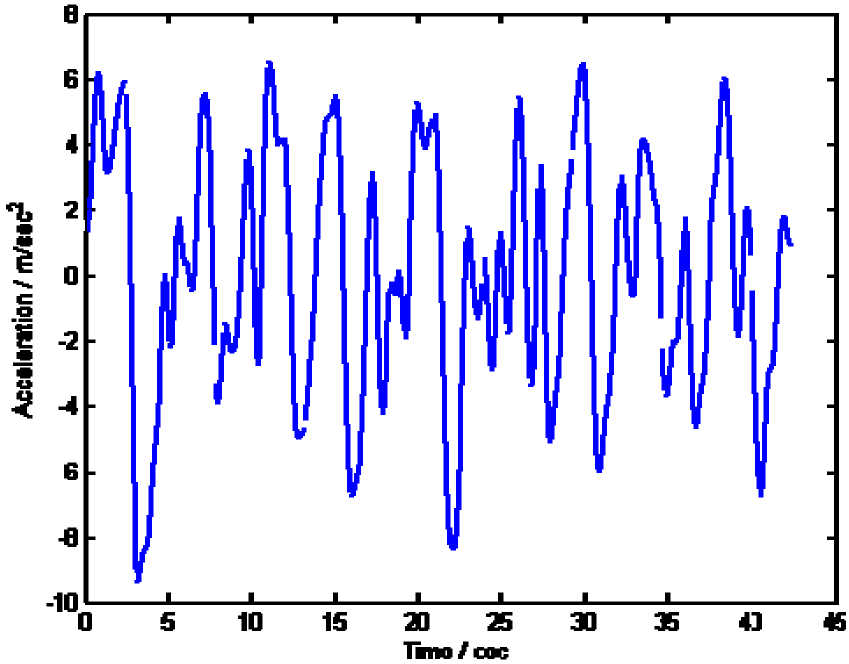

Figure 1 Acceleration vs time

b) Why is the power not in phase with the throttle position readings, at least using the raw data for throttle position?

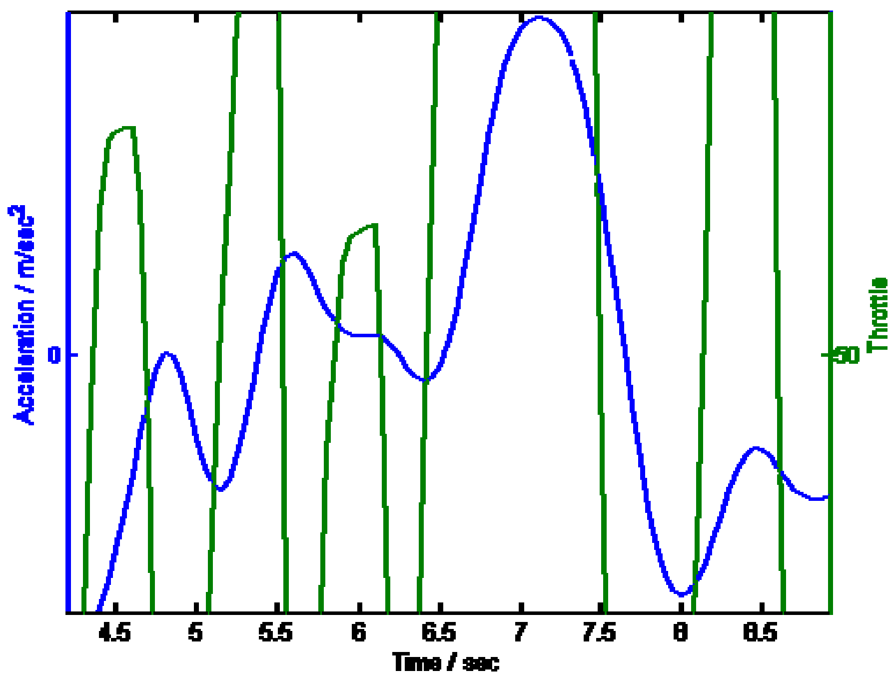

Figure 1.1 Magnitude of Acceleration vs throttle position.

Figure 1.1 shows that there is a delay in acceleration readings compare to throttle position. It is clearly seen between 4.5 and 5 seconds time range. Since we used filter for the velocity readings it applied to the acceleration as well therefore the delay has been created between the raw data and a filtered one. However it is not the big issue since it is known. Also there is a little natural delay which occur in time between the acceleration and actual throttle opening.

Question 2 – Data from the file was loaded using the steps as for question 1.

```
>> D=load('CoastDown51.csv');
>> L=length(D);
>> t=D(1:L,1);
>> d=D(1:L,2);
>> a=D(1:L,3);
```

t is set as a time in seconds, d is set as a distance in meters and a is set as an acceleration in m/sec^2.

The mass is added as m in kilograms, apropriate mass was used using the table provided.

```
>> m=950;
```

Velocity is found using a gradient command in MATLAB, so the velocity is deferential of the distance. The reason to use this method is smoother graph becouse of less noise occur rather then using cumtrapz command which is the integral.

Since coefficient of rolling resistnce and A*Cd quantity has to be found the method of making a trendline first order between the velocity squre and acceleration can be used. Therefore the intercept of this trendline will be :

Intercept = $-\mu_{rr}*g$

And the gradient :

Gradient = $-A*Cd*\rho / 2*m$

Following this equations the required μ_{rr} and A*Cd can be found by applying mathematical steps.

```
>> v=gradient(d);
>> v1=v.^2;
```

To find a trend line polyfit command in MATLAB is used :

```
>> poly=polyfit(v1,a,1)
```

```
ans =   -0.0003   -0.3119
>> ACd=-0.0003/(-1.25/(2*950))
ACd =  0.4560
>> mr=0.3119/9.8
mr =  0.0318
>> calca=polyval(poly,v1);
>> plot(v1,a,'r+',v1,calca)
```

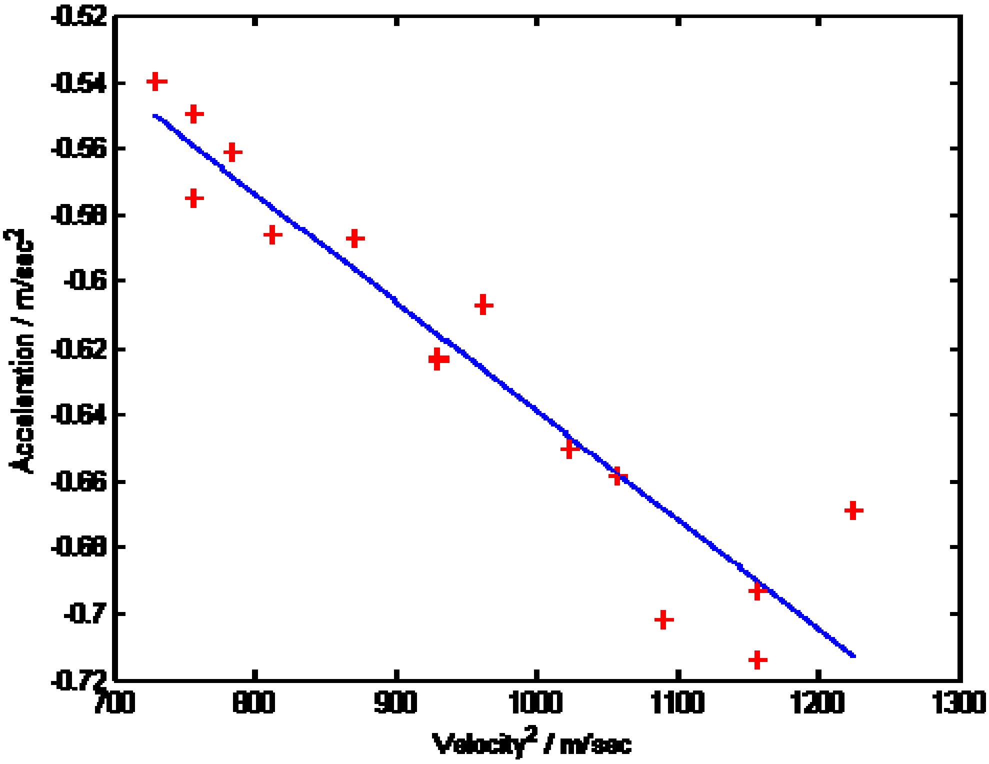

Figure 2 Trendline 1st order on the Acceleration vs Velocity squared graph

Question 3

To begin data file loaded which consists of a big amount of information. However only 4 sensors are going to be studied.

```
>> load('Q3.Mat')
```

To see al the variables in order Vars command is used in MATLAB

```
>> Vars=Vars'
```

When the order of required sensors is found they are converted in to separate data.

```
>> AN1=Data(:,16);
>> t=Data(:,1);
>> d=Data(:,8);
>> AN4=Data(:,19);
>> AN5=Data(:,20);
>> AN6=Data(:,21);
```

To convert distance in to meters the following step is done:

```
>> dist=d.*1000;
```

To display given values correctly the formula used:

Measurand = (Voltage – Zero Offset) / Sensitivity [Course Workbook, p28]

```
>> MC=(AN1- 0.0008)/0.00682;
>> MV=(AN4-0.00)/0.102;
>> BV=(AN5-0.020)/0.066;
>> BC=(AN6-(-0.0263))/0.00686;
```

To display battery power the math channel is created using the formula:

Power = Voltage * Current

Therefore:

```
>> BP=BV.*BC;
```

However the readings are noise and data is filtered:

```
>> [x,y]=butter(2,0.1);
>> BP1=filtfilt(x,y,BP);
```

Graph of the battery power is ploted against distance:

```
>> plot(dist,BP1)
```

To create a channel for motor power the same formula was used as for the battery power:

Power = Voltage * Current

```
>> MP=MC.*MV;
```

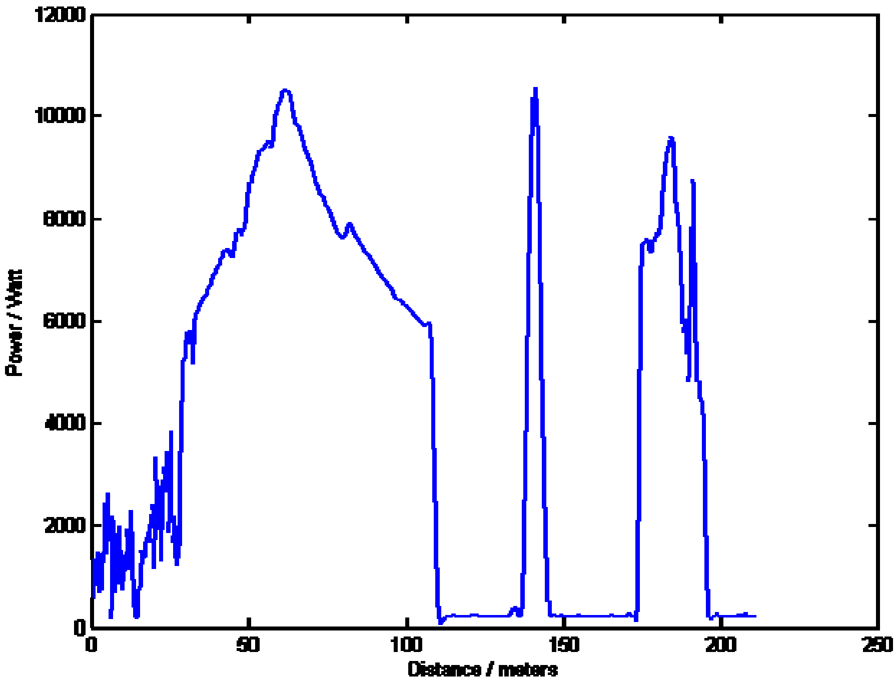

Figure 3.1 Battery Power vs Distance traveled

The data as well was noisy and therefore filtered:

```
>> MP1=filtfilt(x,y,MP);
```

Graph is ploted:

```
>> plot(dist,MP1)
```

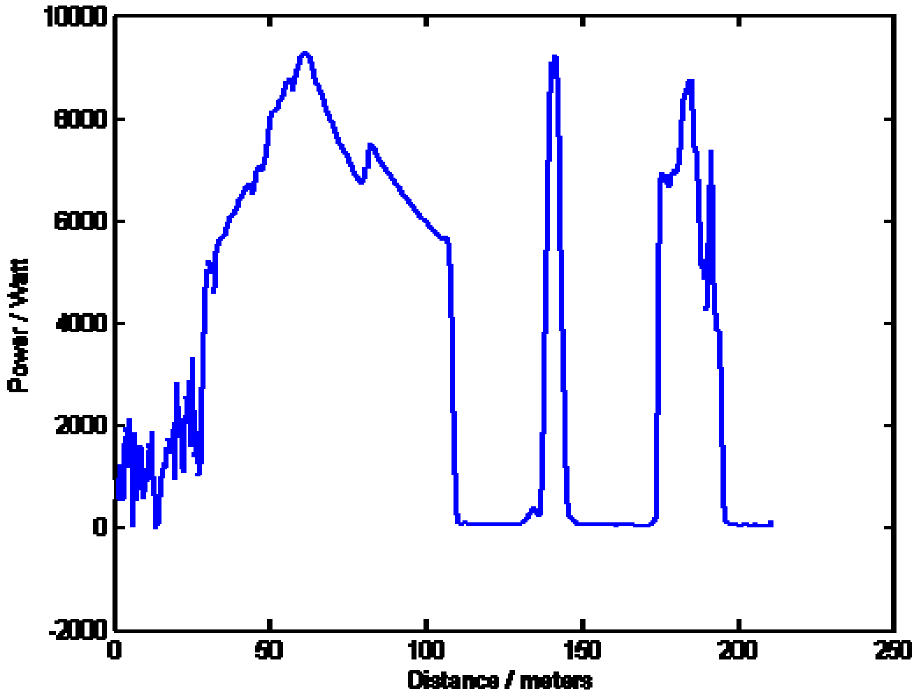

Figure 3.2 Motor Power vs Distance traveled

Since the charge is the amount of amperes taken per time the following formula was used to create the math channel:

Charge = Current / time

However to find the amount per hour the time was converted from seconds to hours:

```
>> t1=t/3600;
>> Charge=BC./t1;
```

General graph of charge changes over distance is ploted:

```
>> plot(dist,Charge)
```

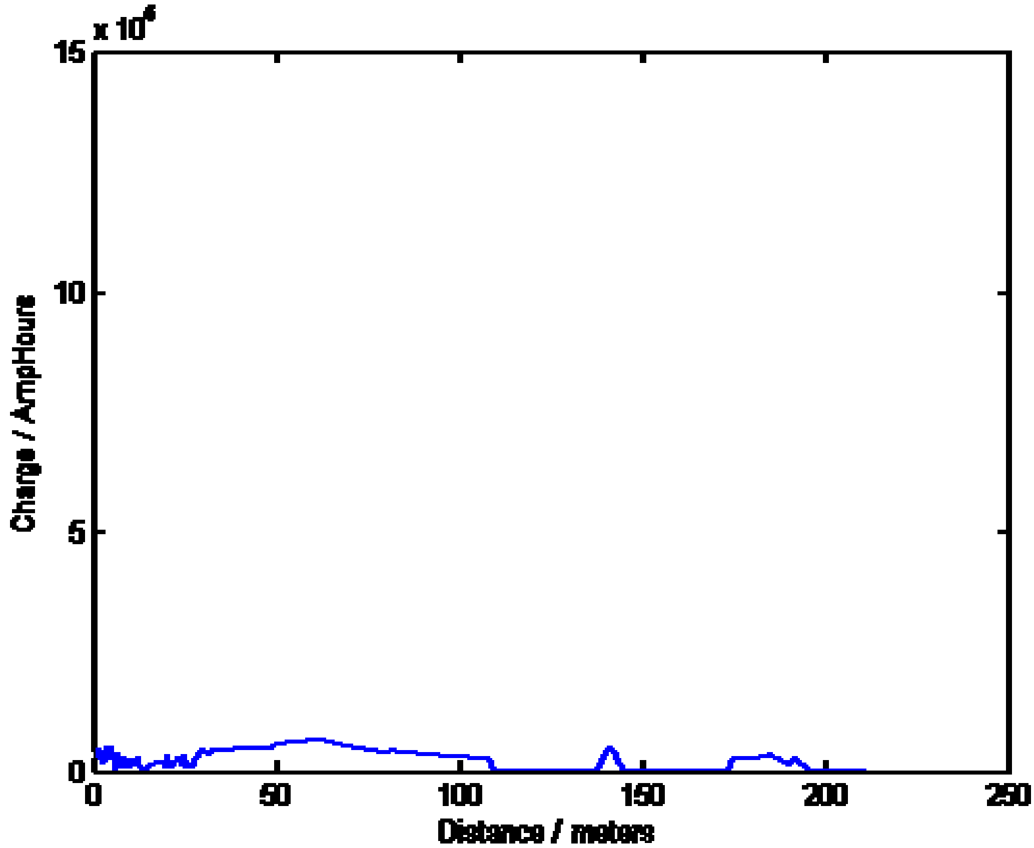

Figure 3.3.1 Overall Charge vs Distance traveled

However to see the highest charge rate graph is magnified:

As can be seen from the graph the highest charge point barely reaches 1 Amps/Hour which is considered as goo rate.

Efficiency for the motor controller can be described as an extent at which input and output power is used. Therefore for the motor controller efficiency channel the following formula is used:

MCE = Output Power / Input Power

where the output power considered as motor power and an input power as a battery power.

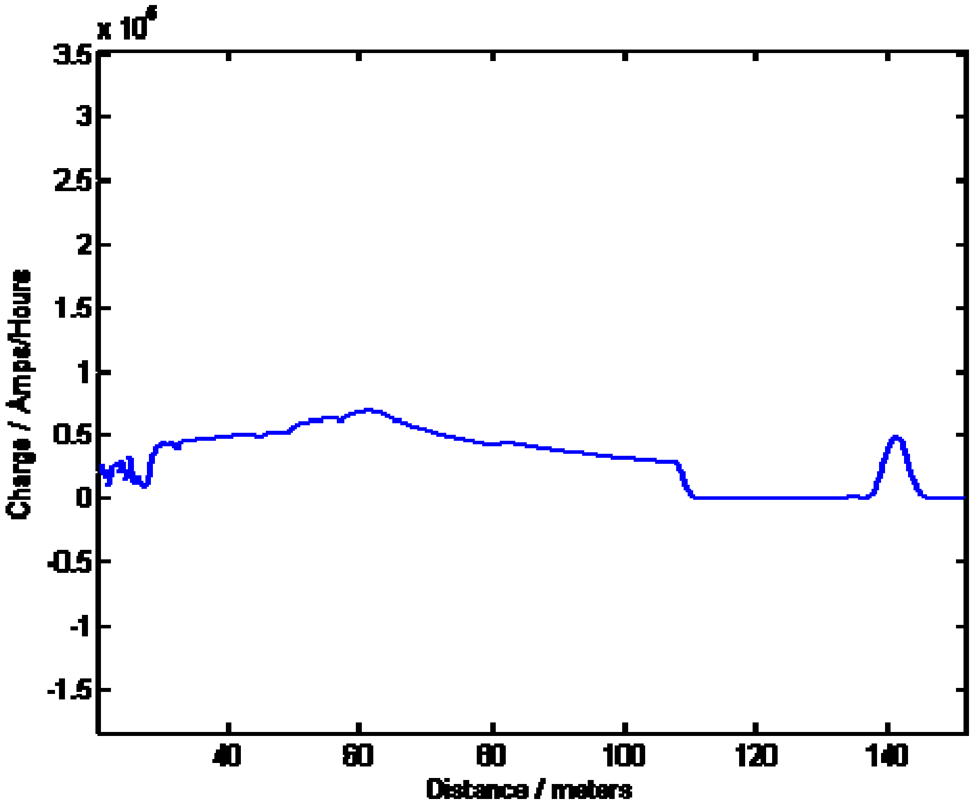

Figure 3.3.2 Magnified Charge vs Distance traveled

>> MCE=MP./BP;

Since the readings are noisy the data is filtired:

>> MCE1=filtfilt(x,y,MCE);

The graph over distance is plotted:

>> plot(dist,MCE1)

As seen from the graph at most time the motor is efficient, however there are some parts where the efficiency drops.

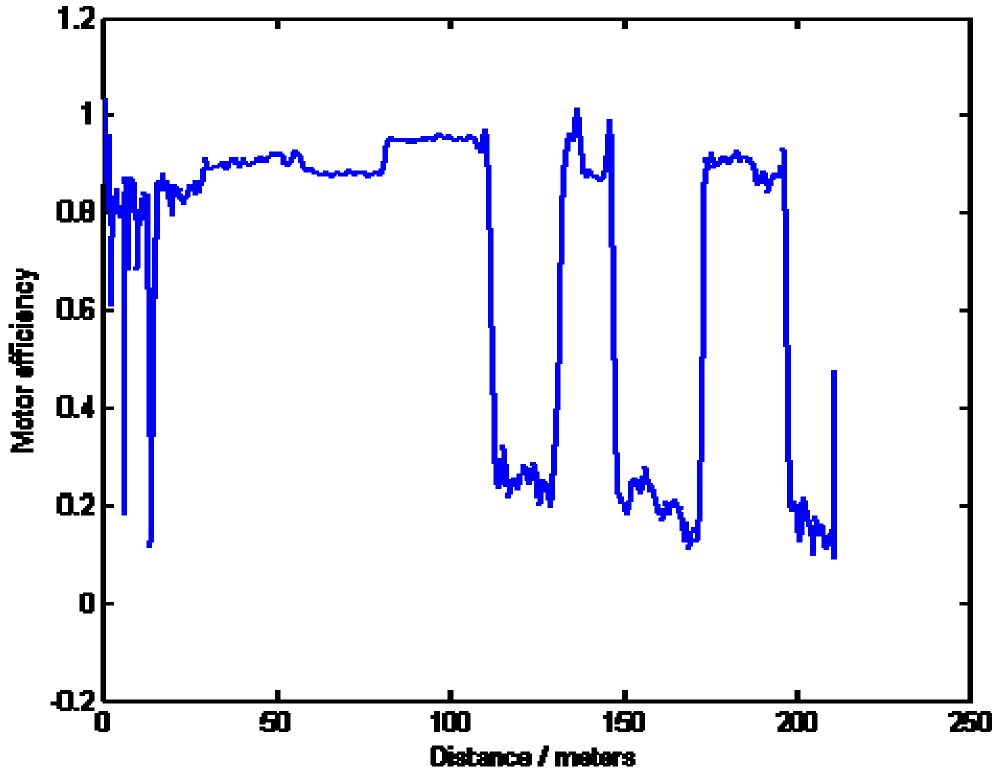

Figure 4.1 Motor efficiency vs distance

The efficiency as well can be seen from the relation of both powers graph:

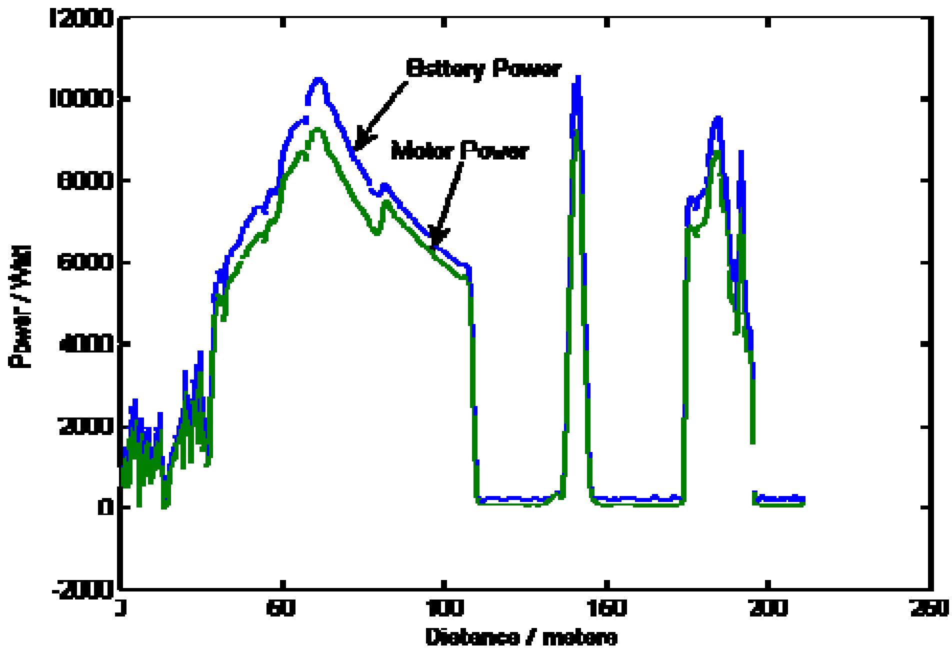

Figure 4.2 Battery and Motor Power vs Distance traveled

The motor power doesn’t reach the maximum power at some points, which is why the efficiency is not 100% at some parts of traveled distance.

ИССЛЕДОВАНИЕ РАБОТЫ ДАТЧИКОВ БОЛИДА ФОРМУЛЫ СТУДЕНТ

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Конструкция автомобилей Формулы Студент определена регламентом SAE. В регламенте ограничиваются только те аспекты, которые непосредственно влияют на безопасность пилота и окружающих. Для создания конкурентоспособного автомобиля, каждый год командам приходится усложнять его конструкцию. Аэродинамика является одной из составляющих активной безопасности автомобиля ввиду влияния прижимной силы, реализуемой благодаря геометрической форме объекта и скорости его движения. Было проведено тестирования системы измерения сопротивления воздуху автомобиля Формулы Студент. В ходе лабораторных испытаний была подтверждена работоспособность системы, получены сигналы импульсов. В данной статье рассмотрена концепция проверки показания датчиков. Для сбора данных использовали набор датчиков разного назначения. Каждый из датчиков работает по своему принципу и имеет свое строение. Всех их можно разделить условно по принципу работы на две категории: активные и пассивные. Активные имеют свою встроенную логику, которая каким-либо образом обрабатывает данные. Пассивные представляют собой простой измерительный элемент. Активные датчики, как правило более дорогие, нежели пассивные и используют цифровую среду передачи. Пассивные более дешевы и передают аналоговые данные. В статье приведены данные по исследованию работы датчиков в 4 различных вариантах их использования.

Ключевые слова: датчики, сопротивление воздуху, гоночный автомобиль