Matlab Modeling of A 2013 Honda Accord Sport

April 2, 2018: Benjamin Farias, Richard Chear, Dylan Teng, Christian Quinones, (MT. SAC STUDENTS)

ABSTRACT: Our objective was to obtain data from a post 1996 car (2013 Honda Accord Sport). With this car we had to run 3 trials with the intent to start from rest and accelerate to 35 MPH then decelerate to 0 mph. To record our data we used an OBDII (*ON BOARD DIAGNOSTICS)* reader, which connected to our phones using an App (OBD FUSION). Throughout the paper we will be displaying mathematical models of different variables and analyzing what the models means and why they look the way they look.

I. Introduction

The objective of our Epic Quest was to create a mathematical performance model of our vehicle based on data recorded from standard driving activities. To gather data, our group must use a post 1996 vehicle that is OBDII compatible, we used a 2013 Honda Accord Sport. With the information gathered from our trials, graphs and equations were mathematically created to interpret the information. Graphs and equations we created are used to explain and understand what our vehicles performance looks like. To get a good understanding of our vehicles performance we performed several trials that consisted of idling for a few seconds, accelerating to a certain speed, maintaining that speed, and lastly braking to a complete stop. Also, with the information we gathered we calculated how fast our vehicle would run the Irwindale Speedway course. With all the gathered information we were able to have a clear overview of the vehicles performance. Data obtained from in real life driving conditions were used to validate our graphs. Also, combining our theoretical models from our virtual course and experimental investigations allowed a clear understanding of our vehicles performance.

II. Methods

In order to collect data for this project we used an OBDII reader device provided to use by our professor. The requirement to use this device was a post 1996 vehicle to record with. With this in mind, we downloaded an application on our smartphone called OBD Fusion to transmit the data to our computers. To connect the OBDII reader to the smartphone, two options are available of wifi and bluetooth. Before starting the trial, the GPS must be turned off so that it may increase our recording intervals to 10 datasets per second. Secondly, we set up the units and variables we wanted to record which were time, distance, speed, acceleration, engine RPM, fuel rate, and engine power for mathematical models. When we recorded each trial it set up a file and logs available to see all the variables we recorded. In OBD fusion you go open up the files section to look at your logs. Then opening a log will show all the available information you recorded neatly categorized under columns to insert to excel for a graph. To export the data (CSV file) we opened the share option to send it to an email so we can open it on our PC. The data can be opened directly using Microsoft Excel as it would lay out the data you recorded in Excel. Finally, importing it to MATLAB required us to convert the CSV file into a M file and layed out the format of the graph into column vectors. With this we can finally plot the mathematical model of the 2013 Honda Accord with the intended purpose to visualize the variables we have recorded.

III. Background and Theory

Based on MotorTrend, the 2013 Honda Accord, has 189 HP, that consumes 27 miles per gallon on city, and 36 miles per gallon on highway. The OBDII reader was able to collect enough data for us to generate mathematical models to visualize the kinematics we have learned from our preceding physics classes. With these models we can predict the outcomes of future trials based on inputting this into MATLAB, this equation can predict future outcomes based on the variables needed such as time when it equals 0 to a given speed, It can output the braking time, the engine RPM depending on what gear the car is in, the fuel usage for a specific course, and modelling what power versus speed looks like.

Due to the constraints of on gathering and collecting the variables to create an exact, precise, and accurate variables consistently, we simulated scenarios of the 2013 Honda Accord idling, accelerating due to stepping on the gas pedal, making speed constant, and decelerating due to putting on the brakes. Based of the experiments we have conducted, we used the data to .generate graphs of time vs. position, time vs. velocity, time vs. acceleration, engine rpm, fuel rate vs. time and rpm vs. speed. Due to the velocity data being the most accurate in our trials, we were able to use it to find other variables. To do this we broke the velocity graph into stages of what the 2013 Honda Accord was doing at different time intervals. From this graph we used the line of best fit function in excel to create presentable data of what our car was doing at those stages. The car's stages may include: accelerating, decelerating, idling, and having constant velocity. To create the outputs for these stages we have to refer to the kinematics equations of acceleration being at a constant rate. To start things off the rate of change of velocity with the respect to time is acceleration. As the mathematical portion can be seen below

$$a=dvdt$$
$$dv=adt$$

Integrating both side we got

$$\int_{vo}^{v} dv = \int_{0}^{\Delta t} adt$$
$$v-v_o=a\Delta t$$
$$v=v_o + a\Delta t \; (1)$$

We arrive to the equation(1) to prove that acceleration is the rate of change of velocity because it is the slope as in reference to y-intercept form of y=mx+b.

To take it further we can derive the position the integral of velocity with respect to time as seen below:

$$v=dxdt$$
$$dx = vdt \quad \text{or} \quad dx=(v_o + a\Delta t)dt$$

Integrating both side we get

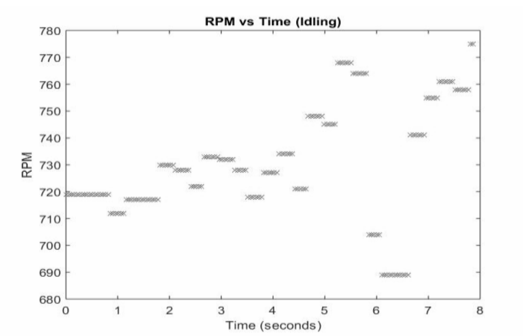
$$\int_{xo}^{x} dx = \int_{0}^{\Delta t}(v_0 + a\Delta t)dt$$

$$x-x_o=v_o\Delta t + ½ at^2$$
$$x=x_o + v_o\Delta t + ½ at^2 \; \mathbf{(2)}$$

Then with the proof of equation(2) we arrive to show the at constant acceleration it is to the 2nd polynomial. In our data the velocity is in the 3rd order due to the momentum and friction forces acting on the vehicle impeding constant acceleration. Based on this the integral of velocity would still give position as proven above but position will be to the 4th polynomial. With this we can conclude that the polynomials that are given can justify the graphs and models we utilize.

In our videos we recorded the trials we conducted,please reference our uploaded youtube video: **"https://youtu.be/LnC8JyD4sjo"** With this we found out the RPM of the car varies from **800-900 RPM**. The RPM would go up when accelerated with the gas pedal up to 7000 RPM. When we put on the brakes the deceleration caused to rpm to go down to 1000 RPM.

Graph 1A:RPM vs. Time(Idling)

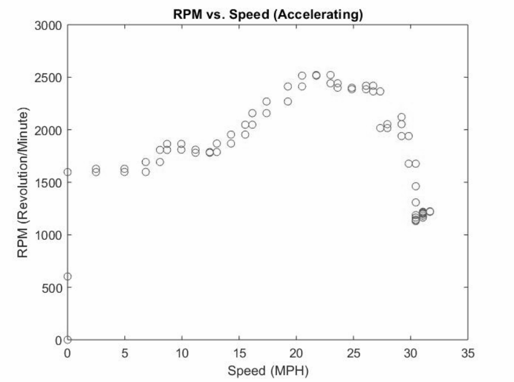


In this portion of our data it can be seen that the vehicle is starting from idle in which we included to prevent any flaws of strange data as the vehicle can be seen accelerating for all graphs. The RPM increased because the radiator fans turned on making them increase from 720 to 780. The equation below shows how we calculated the RPM.

$$y = 0.3 * x^2 + 1.5 * x + 7.2 * 10^2$$

Models and Data for Acceleration

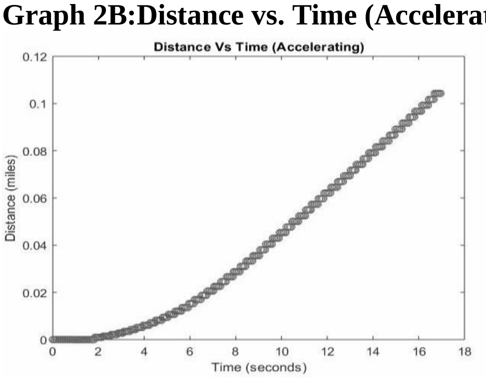
Graph 2A:RPM vs. Speed(Accelerating)



In the above graph is the RPM vs. speed of the vehicle while accelerating. In the graph you can see the RPM increasing until it hits a speed of 20 mph where the RPM can be seen lowering. At this point it can inferred that the RPM is lowering due to the the gas pedal being pushed less, releasing less combustion lowering the RPM of the engine. Modeled to the 3rd power because both are velocities:

RPM(s) =- 0.2*s^3 + 3.7*s^2+92*s+6.8*10^2

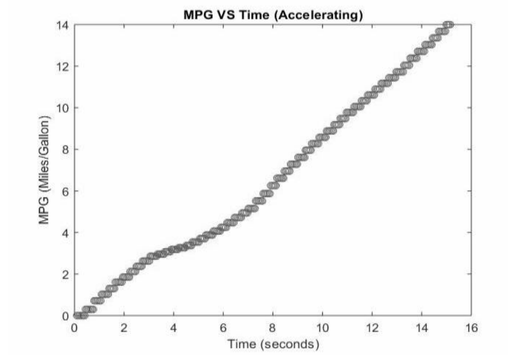
Graph 2B:Distance vs. Time (Accelerating)



The above graph shows the distance vs time while the vehicle is accelerating as it should be straightforward that the vehicle is traveling while the speed is increasing as seen in the slope of the graph, leading to an increase in distance. It should be noted that even though the car is idling, the RPM is not constant. We attribute this to various other car functions requiring a higher engine RPM such as the air conditioning. The model for our rpm:

Y = -5.2*10^{-8}*x^4 - 1.9* 10^{-5}*x^3 + 0.0008*x^2 - 0.0017*x+0.0008

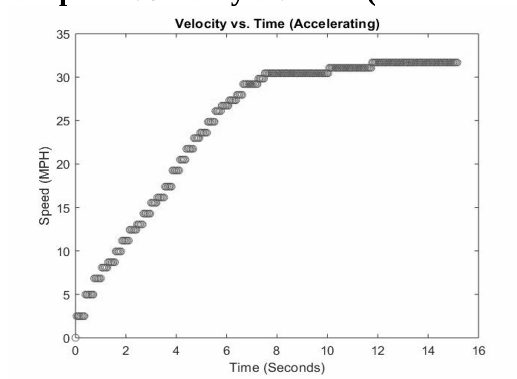
Graph 3B:MPG vs. Time (Accelerating)



The first 2 are torque gears which have high fuel usage as the following gears are longer which provide less torque and more horsepower making the vehicle more efficient. The data in the graph makes sense due to the the more MPG used as the car accelerates because the car is changing to longer gears making it more efficient.The model for this is:

Y = -0.00035*x^3 + 0.03*x^2 + 0.54*x + 0.34

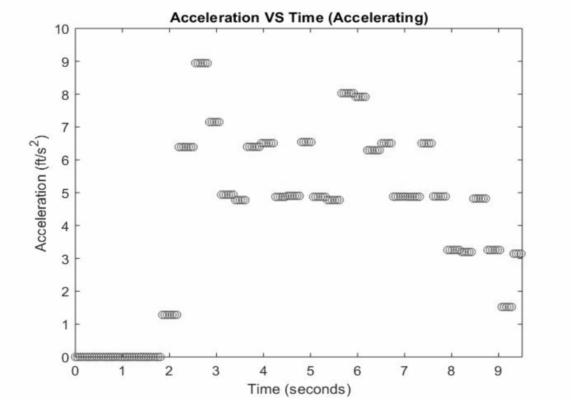
Graph 4B:Velocity vs. Time (Accelerating)



Shown above is the graph of the velocity versus time while the vehicle is accelerating. As shown above the velocity levels-out due to the acceleration lowering once the speed hits 35 mph as the intended speed was reached so the acceleration starts to decrease.

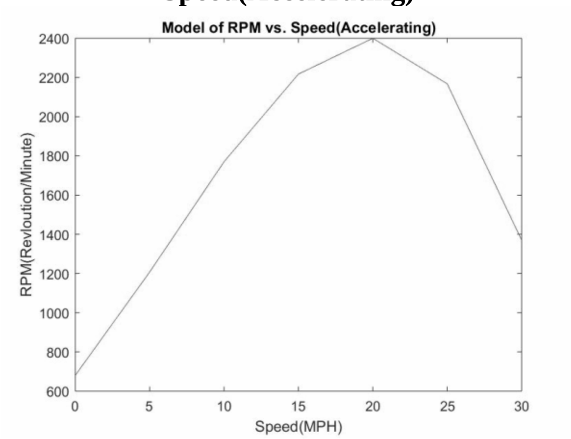
$$v(t) = -0.012 * t^3 + 0.12 * t^2 + 3.7 * t - 11$$

Graph 5B:Acceleration VS Time (Accelerating)



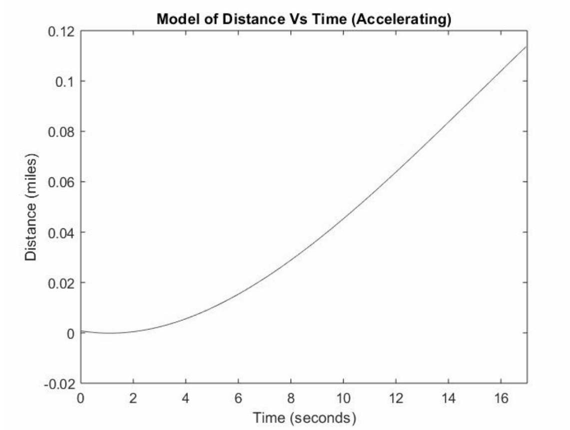
Above is the graph of acceleration vs. time while the vehicle is accelerating. As seen in the beginning of the graph the car is idle so the acceleration is 0 because the car is not moving until it reaches 2 seconds as it jumps in acceleration. At 2.5 seconds there is a gear shift once the acceleration is 9 ft/s^2 as it shifts to lower the acceleration as another gear shift occurs at 6 seconds as the car starts to sharply decrease from 8 ft/s^2in acceleration. From this point the graph does not increase in acceleration again as the car has hit 35 mph. The model for is: a(t) = $-0.057*t^2+0.68*t+2.2$

Graph 6B: Model for RPM vs. Speed(Accelerating)



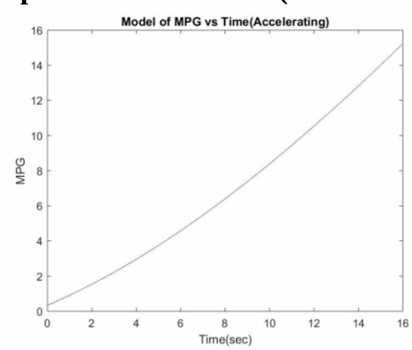
Note that the graph doesn't begin at zero. This is due to the fact that at zero when idling there is still RPM action occurring in the engine. Also this model does make sense since our data shows our RPM starts to drop around 20 MPH.

Model 7B: Model of Position vs. Time



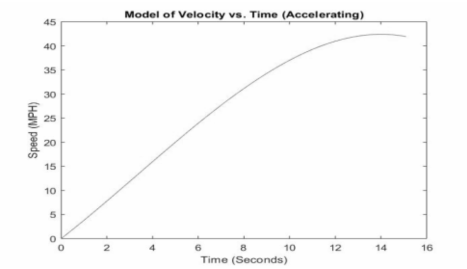
The model above makes sense because at a time of 0 seconds its position is also 0 and as we are accelerating the vehicles position is increasing with time. This model shows the final distance traveled at the time of sixteen seconds with was 0.1 mile. The vehicle was moving in mph so we converted the distance from feet to miles in order to understand it easily.

Graph 8B:MPG vs Time(Accelerating):



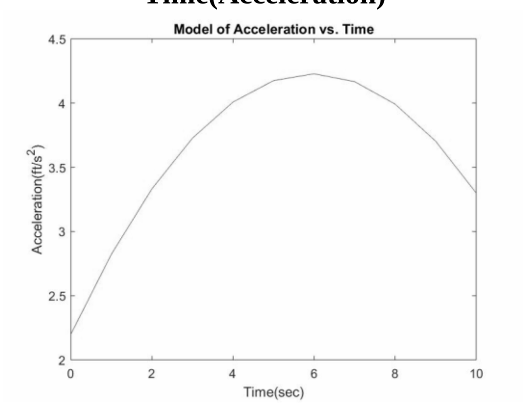
This model makes sense since the car is still in the first two gears as previously mentioned. As time increases our velocity also increases and the car switching to higher more fuel efficient gears, however we haven't reached at least 4th gear with our current speed of 35 mph and that's why our MPG model doesn't reproduce the 32 according to motor trend.

Model 9B: Velocity vs. Time(Accelerating)



The model above is correct because the vehicle increases from rest to 35 mph at 10 seconds. During this trial, we continued accelerating for a total of 15 seconds and maintained our acceleration. Our final speed after a 15 second run was 43 miles per hour.

Model 10B: Model Acceleration vs. Time(Acceleration)

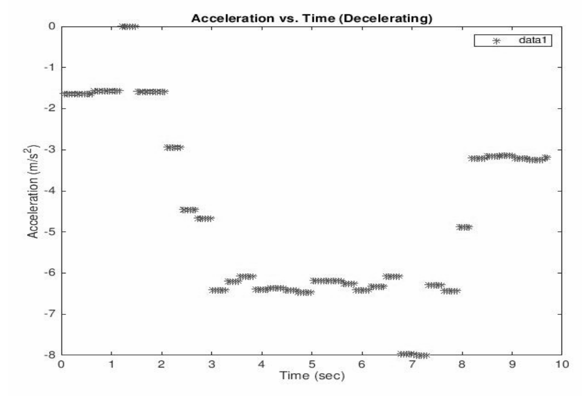


Our model shows that our acceleration increases then decreases a bit as we reach our desired speed. This happened because as we started the run we pressed the gas pedal all the way to increase speed and as we approached the 35 mph mark we slowly released the gas pedal.

Models and Data for Deceleration

In the final part of the section of the vehicle run we recorded the deceleration. In this case the vehicle decelerated to an visible section when we decrease the acceleration on the graph with the disc brake system. In this point of the model we kept the same rules to our equations of velocity being the 3rd power, position being the integral of velocity being the 4th power and acceleration being the derivative of velocity being the 2nd power. With this we were able to come up with plausible data on our graphs and indicate where the disc brake system was applied for the vehicle.

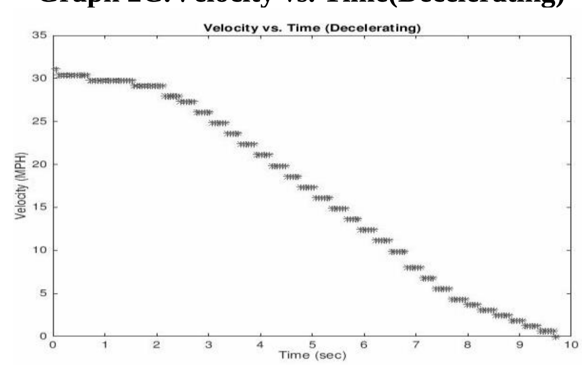
Graph 1C:Acceleration vs. Time (Decelerating)



In the graph above is the acceleration vs. time while the vehicle is decelerating with the brakes. The vehicle uses a disc brake system so everytime the brakes are hit the brake pads are clamped down to hit collide with the disc to create friction slowing it down. It can be visualized at the point of 20 seconds it is shown the graph is decelerating sharply, as after that decline it is at a constant deceleration then once the brakes are let go the car starts increasing in acceleration again but take note even if it is accelerating the graph is still decelerating as it is all negative. The model of that data shown:

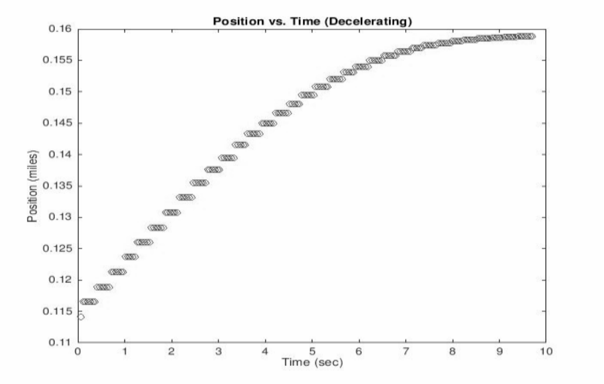
a(t) = 0.24*t^2-2.7*t+0.84

Graph 2C:Velocity vs. Time(Decelerating)



The graph shown above is the velocity vs time decelerating. In the graph above it starts at 30.1 mph at it is decreasing by the rate of time as it correlates to the acceleration vs. time graph as it has a negative acceleration making it slow down in the same time interval. With this the model is v(t) = 0.068*t^3 - 1.1*t^2 + 1.2*t + 30

Graph 3C: Position vs. Time (Decelerating)

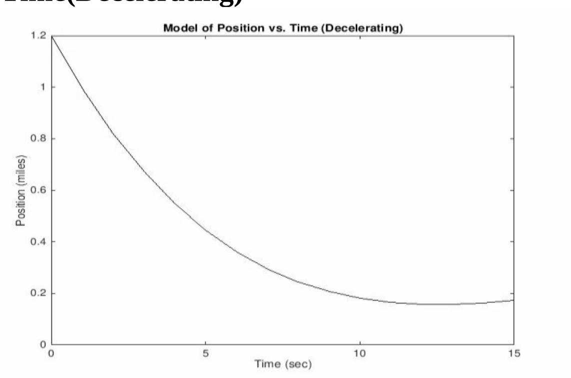


In the graph above shows the position vs time while the vehicle is decelerating. AS seen here the distance increases until it the graph behaves stagnant near the end of the time interval due to the decrease of the velocity heading to zero at the end. With the model:

x(t) = 5.1*$10^{-6} * t^4$ - 0.00011*t^3 +0.0002*t^2 - 0.0082*t + .11

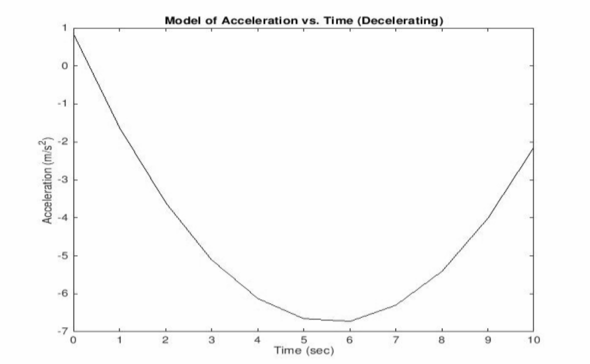
As seen above the position is the 4th power because it is the integral of the velocity which is to the 3rd power.

Graph 4C: Model of position vs. Time(Decelerating)



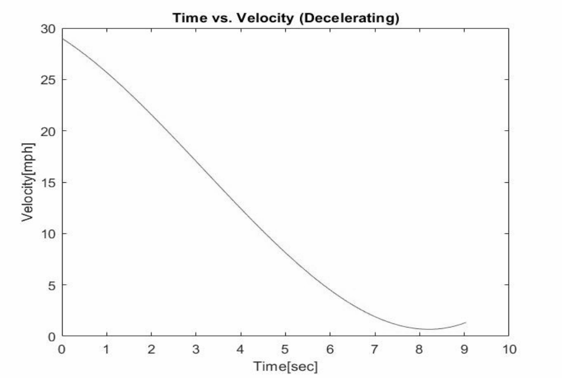
Shown above is the model graph of position vs. time while the vehicle is decelerating. As seen here from time zero the position's slope or velocity decreases due to the car slowing down because of the deceleration due to the brake disc system being applied.

Graph 5C: Acceleration vs. Time (decelerating)



The graph above predicts that the acceleration should be decreasing due to the breaks being used when time is zero as once the brakes are off the vehicle accelerates but still is decelerates.

Graph 6C: Time vs. Velocity(decelerating)

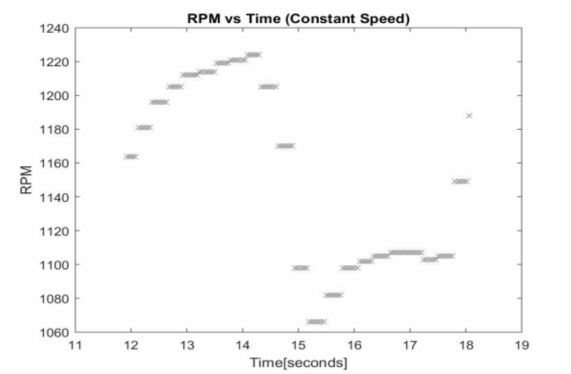


The graph above predicts that the disc brake system would make the velocity decrease as noted it starts out at 30 mph and only decreased from there until resting at 0 mph.

Models and Data for Constant Velocity

In this portion of the experiment we collected the data for the constant velocity where we took into consideration of data that was not applicable to the scenario. Such as acceleration vs. time where acceleration would be zero due to constant velocity, a velocity vs. time graph (displays a linear line for the time interval), a position graph (gives a y=x line). Due to speed being constant it would give irrelevant information.

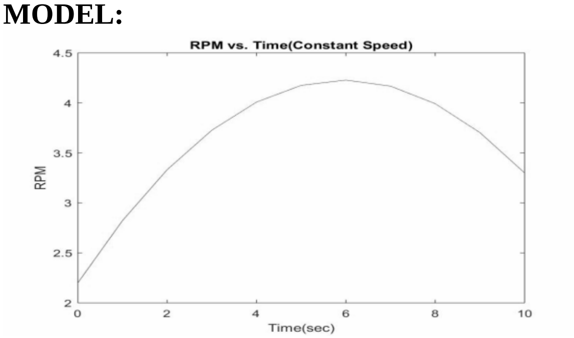
Graph 1D:Graph of RPM vs. Time(Constant Speed)



In the graph above of the RPM vs Time. constant speed, the driver put their foot off the gas pedal at 14 seconds and pushed the gas pedal again at 15 seconds to maintain that speed. The model being: y = -.057*x^2+.68*x+2.2

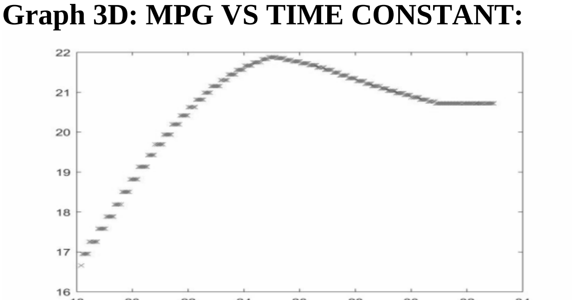
However, theoretically we wanted RPM at a constant speed, we modeled RPM to be constant: RPM(t) = 1151

Model 2D:RPM VS TIME CONSTANT MODEL:



In the model shown above the RPM is increasing then decreasing because of how the gas is throttled then the RPM lowers due to the gas pedal being let go as the RPM lowers due to that.

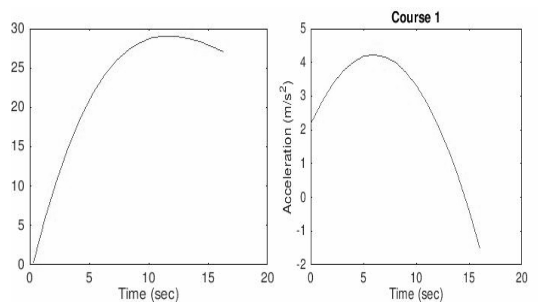
Graph 3D: MPG VS TIME CONSTANT:



In the graph above it shows the MPG vs time while speed is constant. As seen to around roughly 24 seconds the graph is increasing in MPG due to the the gas pedal being pushed as once its let get go to maintain a stable 35 mph it then lowers out creating the average mpg as it plateaus.

MPG VS TIME EQUATION:
Y = 0.005*x^3-.44*x^2+13*x-1*10^2

Course 1: Models and Output Values
Graph 1E: Speed vs Time(Left)
Graph 2E: Acceleration vs. Time(Right)

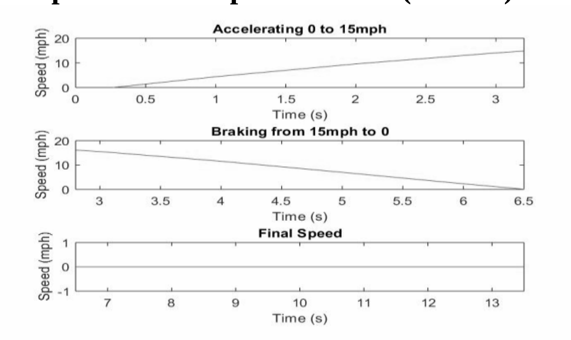


To fully understand how we calculated our values for Course 1 we used a Velocity, Acceleration vs. Time graphs. We plotted these graphs by using our mathematical model equations for velocity and acceleration. Using these graphs helped give us estimations to what our calculated values should be. For instance, the following equation was used to calculate total time: Total_Time=t_accel+(((-distance)+/-sqrt(distance^2-4*a*c))/ 2*a). We used this equation because after reaching 30 mph we had to travel a distance of 100 yds which is 0.0568 miles. By looking at the Velocity vs. Time graph we can assume our acceleration time ~ 12 s and to get to rest of the equation we used a simple kinematic equation ($d=v_o*t+(½)*a*t^2$). For "a" we must look at the Acceleration vs. Time graph and use a matlab function (max_accel = max(a)) and that would give us our value for "a". To get our final speed we went back to the Velocity vs. Time graph and used (max_velocity = max(v)) which gave us our final speed since we want to hold 30 mph for 100yds. Lastly, to get our fuel usage we related the total time we calculated and looked at the fuel usage at a similar time (fuel usage =0.00685307 gal).

$$y = 0.3 * x^2 + 1.5 * x + (7.2 * 10^2)$$

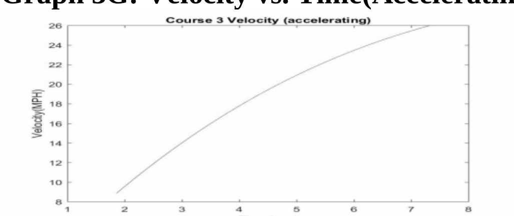
Course 2: Models and Output

Graph 1F: Acceleration vs. Time(Top)
Graph 2F: Deceleration vs. Time(Middle)
Graph 3F: Final Speed vs Time.(Bottom)

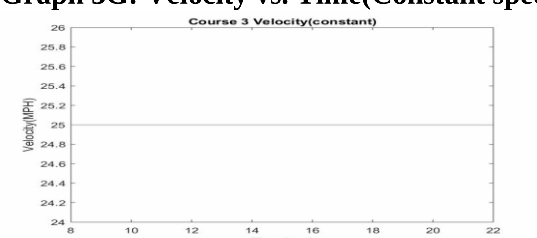


For course 2, the objective was to accelerate our vehicle from rest to 15 mph and brake to a complete stop. The total distance the car traveled was 100 yards. The first model above states that our vehicle's acceleration time from rest to 15 mph in 3.5 seconds. In order to find the time it would take to reach 15 mph we had to find the maximum acceleration using kinematic equations, $a = 0.004\ m/s^2$. Next, graph 2, we found that it took only 3 seconds to brake from 15 mph to rest. Total time it took to travel 100 yards was 6.5 seconds and our final speed as shown on graph 3 is zero because the car came to a complete stop.

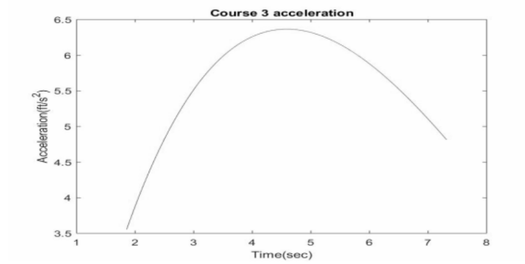
Course 3: Models and Outputs
Graph 3G: Velocity vs. Time(Accelerating)



Graph 3G: Velocity vs. Time(Constant speed)



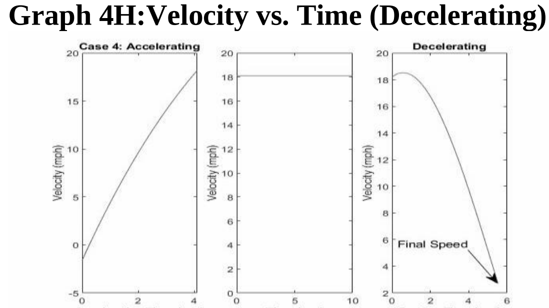
Graph 3G: Acceleration vs Time



For course 3 we used kinematics to get a sense of idea for the range for the car to reach 20mph and according to our model that we previously calculated, it will reach it around 6 seconds, the equation we used was: $-0.012 * t^3 + 0.12 * t^2 + 3.7 * t - 11$. With that being said we can conclude that the acceleration time was also 5.5 seconds to maintain constant speed. For the maximum acceleration we used the model: 0.24*t^2-2.7*t+0.84. We get this graph for our acceleration model:

Here we can see that our maximum acceleration is around $6.4 ft/sec^2$ and it reaches it around 5 seconds, which makes sense from our model. For the total time it took to ran the course we can use the the time it took to finish, we used kinematics $d = (vi + vf/2) * t$ and plug in our known distance, initial velocity and final velocity, and solve for t. Which we got 16.3 seconds for total time on course 3. We can also calculate total fuel used for the course by looking at a linear model of trip fuel and its corresponding time. For case 3 total fuel would be .007 gallons burned.

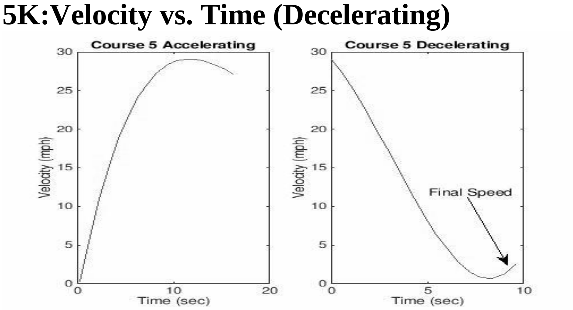
Course 4: Models and Output Values (left to right)Graph 4H: Velocity vs. Time(Accelerating)
Graph 4H: Velocity vs. Time (constant)
Graph 4H:Velocity vs. Time (Decelerating)



For course 4 the objective was to accelerate to 20 mph then decelerate to 0 mph in 200 yards. In the graph above we used our model for the vehicle's acceleration of v = 0.0083*t.^3-

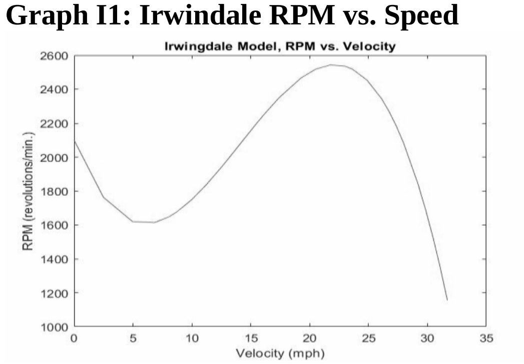
0.42.*t.^2+6.4.*t-1.6 as we just plugged in the time values from the OBDII data to plot the accelerating graph which was ideally supposed to hit 20 mph, although the data hit 18.2 mph. Then we found the decelerating graph values by inputting the time inputs from our OBDII data in decelerating_velocity =0.068.*t1.^3 - 1.1.*t1.^2 + 1.2.*t1 + 18.18. After that we found the distance covered from accelerating and decelerating by multiplying the change in velocity by the time converting miles per hour to miles per second so it would cancel out with seconds to give miles. With this I subtracted the known total distance by the distance I found covered by the acceleration and deceleration and found the distance covered by the vehicle while it was constant. After finding the distance I found the time values by using the kinematics equation of t = V/d to obtain the time it ran before decelerating. With this I had all necessary values to answer the course. For total time I added acceleration time + constant time + brake time to get 20 seconds. For final speed I took the speed when the vehicle deceleration which should be 0 unlike how the graph depicts it probably due to the scaling of the mathematical model equation to the inputs given by the course. For the acceleration time I just took the time for the car to accelerate to 25 mph which was 4 seconds on the graph. For braking time all I had to look at was the graph to see how long it took for the vehicle to stop. For maximum acceleration we went through the kinematics equation of (Vmax - Vo)/t in the acceleration graph to find the max acceleration and obtained 6.6 ft/s^2.

Course 5K: Models and Output
Graph 5K:Velocity vs. Time(Accelerating)
5K:Velocity vs. Time (Decelerating)



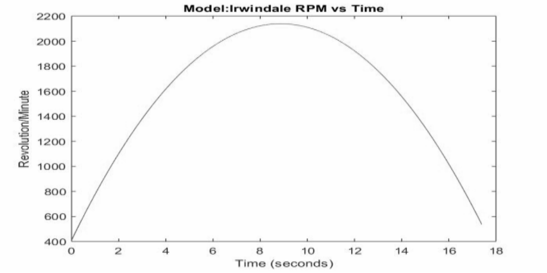
In the graphs above we used the models equations of v=0.0083*t.^3-0.42.*t.^2+6.4.*t-1.6 in acceleration(left) and Dv = 0.061.*t.^3 - 0.58.*t.^2-2.8.*t+29 in deceleration(right). The inputs we used was time from our data sheet recorded by the OBDII reader. With these plotted we found out the total time by summing up the time it took to accelerate and decelerate which was 30 seconds. For final speed we found it through the last point plotted of the deceleration in which it is marked in the graph above but in a realistic scenario the final velocity should be 0 mph. For acceleration time we took the inputs from the OBDII reader to see how long it took for the car to accelerate from rest to 30 mph which was 20 seconds and the same for decelerating which is the braking time for the car to go from 30 mph to 0 mph as we read the time 10 seconds. To find the max acceleration we analyzed the slope of the graph where velocity was increasing the fastest as we got 4.4 ft/s^2.

Graph I1: Irwindale RPM vs. Speed



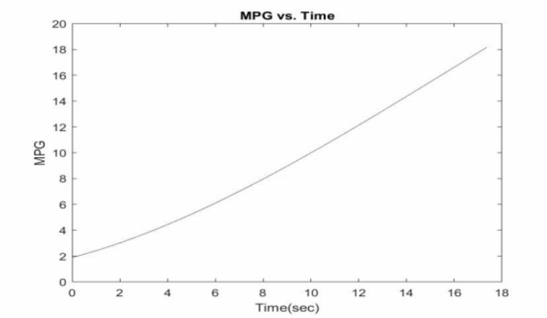
In the graph above a new equation was generated due to the specifications of the Irwindale speedway being 1/8th a mile. From this we inputted the data from our OBDII reader until it reached 1/8th of a mile as we speculated the results will be similar in the model. As seen in the model above the RPM decreases till 5 mph and increases due to the gear shift inside the vehicle as it decreases the velocity along with the RPM. As another gear shift can seen at 30 mph. Model equation:
RPM(s) = -0.45*s^3+19*s^2-184*s+2100

Graph I2:Irwindale RPM vs Time



The above graph I2 shows our vehicles RPM while driving in Irwindales 1/8th mile drag strip. For the first half of the drive the RPMs will continue to increase rapidly due to shorter gears allowing it to increase speed easily. The second half of the drag strip the RPMs start to decrease because the transmission has engaged longer gears meaning that the vehicle does not need as much RPMs as before to increase its velocity. The equation for the above model is RPM(t) $=-22*t^2+(3.9*10^2)*t+(4.1*10^2)$

Graph I3: MPG vs. Time, Irwindale



Graph I3 predicts the Miles Per Gallons on the Irwindale 1/8th mile course. Since MPG is related to velocity we decided to model the equation a third degree polynomial, equation for this model is: $-0.00084*x^3+0.045*x^2+0.33*x+1.1$

This makes sense since we started with the first gear, which we stated that in **Graph 3B** first two gears are torque gears and burn a lot more fuel then the longer fourth or fifth gears. So were not at our optimal gears, which the car will achieve as speed increases.

Conclusion

In order to improve this project, we should communicate with other group members that are using the same app to collect data from the OBDII. Apps collect data differently and getting with other groups and trying to understand how that data is interpreted in the app with other group members would help us with our project. Something that we could have improved on was interpreting MPGs. With the data collected, we struggled the most trying to understand how OBD Fusion interpretes MPG. We were unsure if it was calculated based on time, acceleration, or velocity. For irwindale speedway, we knew the given distance of the dragstrip, 1/8th mile, because of this we were able to take sections out of our obdii data from our car. With these given values we were able to create mathematical models to correlate how long it took our car to travel 1/8th of a mile. For our Honda, it took 17.4 seconds and a speed of 55 mph to complete the course.

References & Acknowledgements

Evans, Scott. “2013 Honda Accord First Test.” *Motor Trend*, Motor Trend, 10 Sept. 2012, www.motortrend.com/cars/honda/accord/2013/2013-honda-accord-first-test/.

Elert, Glenn. “Kinematics & Calculus.” *Kinematics & Calculus – The Physics Hypertextbook*, physics.info/kinematics-calculus/.

“We would also like to thank the staff of Panera for hosting us and feeding us nutritious food. They gave us the will, and caffeine to complete the epic quest. It was truly epic!”