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Vehicle Testing laboratory Assignment-1

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TITLE:

EPA VEHICLE COASTDOWNS AND DRIVE CYCLES

Executive Summary:

- To plot the graph between velocity vs time for target coast down test.
- To plot the velocity error vs time.
- To calculate the root mean squared error for each test run and describe the changed ABC coefficients between each test run for error.
- To plot the target coast down test to calculate the theoretical ABC coefficients and to compare the best test run ABC on chassis dyno.

INTRODUCTION:

Purpose of testing:

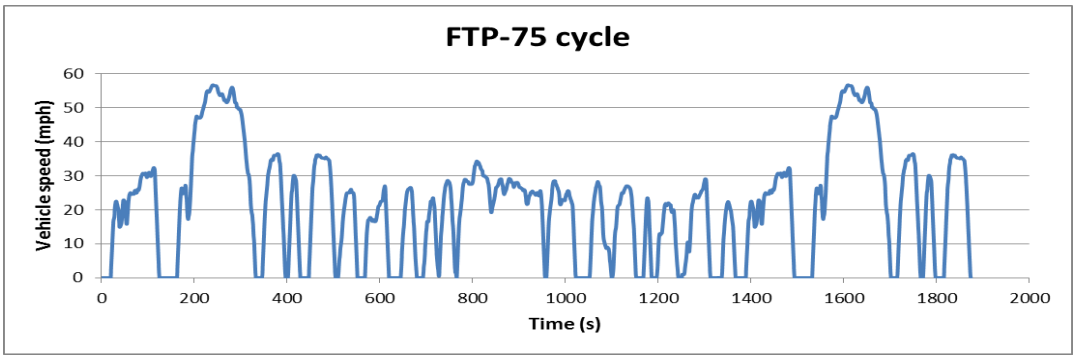
- For typical driving conditions the vehicles used to be tested over specific driving cycles.
- The manufactures test different vehicles to meet their standards set by cycles and one up the competitors.
- The main purpose of testing of a vehicle is to survive long in the market and to provide a comfortable, safe and high-performance vehicle to customers that work efficiently for longer period.
- The manufactures during testing they need to check the quality, durability, technologies function properly throughout their working life.
- During testing of a vehicle, the engineers must think highly innovative applications to test the vehicle to ensure the performance in highly effective and modern way.
- The test engineers need to react accordingly with the growing rate of innovations in industry.
- To test and evaluate advanced vehicle technologies intended to advance vehicle efficiency and reduce the consumption of petroleum.
- They mainly help in refining the quality of the vehicles and also, help to reduce down the vibrations and the noise in the vehicle while enhancing overall performance of the products to serve the best in the market to customers.

General Information About Topic:

- The vehicle testing is to refine the quality of the vehicles, to reduce vibration and noise, to improve efficiency, quality, performance of the vehicle. The vehicle is needed to test under different road conditions under different drive cycles for better improvement of the vehicle. There are specific vehicles that are needed to be tested under standard conditions. The drive cycles used across world-wide are
    a) U.S drive cycle –

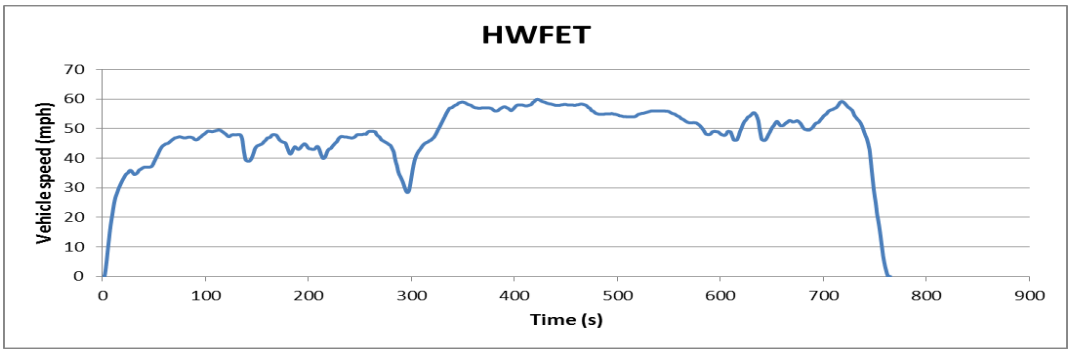
❖ **FTP-75 Cycle**

- The FTP cycle was created by US EPA (Environmental Protection Agency) to represent a commuting cycle with a part of urban driving including frequent stops and a part of highway driving.



❖ **Highway Fuel Economy Test Cycle:**

❖ The highway fuel economy test cycle (HWFET) is used for to know the economy of the fuel over highway driving cycle.

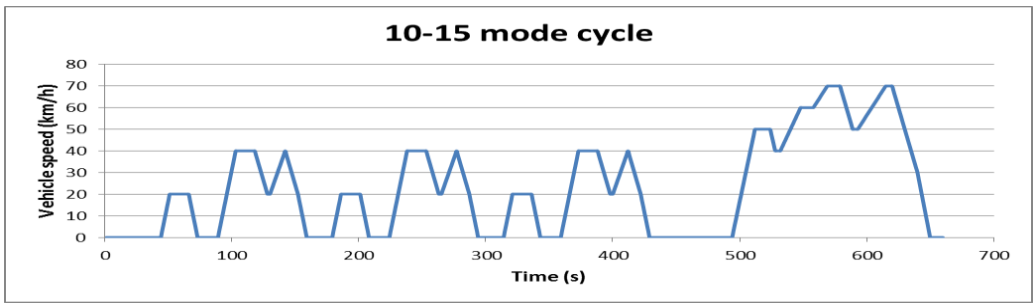


❖ The main characteristics of the highway fuel economy test cycle are

b) Japanese driving cycle:

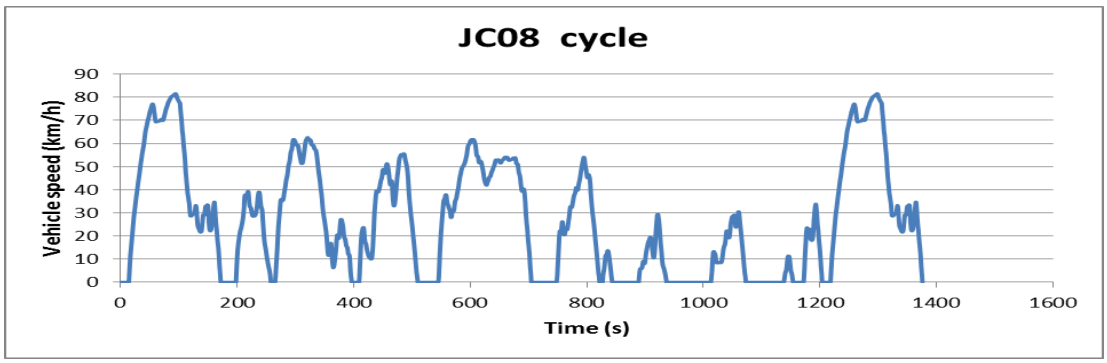
❖ **The 10-15 mode driving cycles:**

- The Japanese driving cycle is used mainly in determining the fuel consumption and emissions from the vehicle. This cycle has disadvantages as the NEDC.



❖ **JC08 Cycle:**

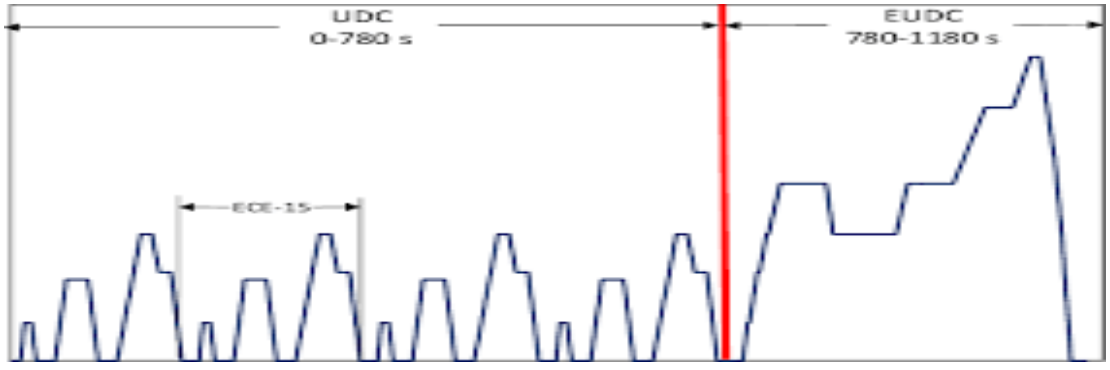
- When the Japanese authorities and manufactures decided when 10-15 drive cycle has NEDC disadvantage then switched JC08 Cycle. Also, the cycle is performed in both cold and warm start with strong accelerations and de-accelerations.



c) European drive cycle:

❖ **NEDC drive cycle**:

- The NEDC drive cycle is used to know the emission levels of vehicles engines and fuel economy in passenger vehicles.



Materials and Methods:

Materials:

- The EPA National Vehicle and fuel emissions laboratory:

    - The NVFEL is used for evaluation and certify the vehicle. Here, the vehicle is tested in a dynamometer test cell and the driver in the vehicle operates the vehicle by following different driving cycles. For the exhaust a hose is connected to the tail pipe. To collect engine exhaust. In addition, the carbon is measured to calculate the amount of fuel burned and other pollutants are measured by gas analyzers weighted in a special clean room. Few vehicles may differ (electric vehicles).

Methods:

- The two types of tests are conducted during driving of the vehicle-
    a) City Test
    b) Highway Test

a. City Test:

    - In city test, the vehicle is accelerated to the given distance. As it is short segment driveway test, the vehicle needs to stop and accelerate according to road conditions. The trip lasts for 23 minutes with 17 stops in it. Most of the time its spent on idling time. The city test has many stops and breaks in the freeway.

b. Highway Test:

    - In highway test, it's a long test where the driver needs to drive the vehicle for 10 miles of 48mph. There are no stops and breaks on the freeway. The very little idling takes place during driving the vehicle.

c. During driving the vehicle, the wind drags, and the inertia exerts for a dynamometer.

d. EPA Coast-Down tests:

    - During EPA coast-down tests, the aerodynamic, tire rolling resistance, drive train frictional losses and other factors are used to generate the information used on dynamometer to calculate the EPA's MPG ratings
    - The long track is need for the test and the resistance level is encountered to operate the vehicle on the road.

- This test is performed multiple times on a flat straight and on a dry road in both directions of the track.

  - (Letvi−1= 0 for i= 0).
  - M is the mass of the vehicle on its test weight, divided by the acceleration due to gravity.
  - t is the elapsed time in the driving in seconds (Letti−1= 0 for i= 0).

Results and Discussions:

- C is the Vehicle The chassis Dynamometer road load coefficients:

  $FR=A + B \cdot v_i + C \cdot v_i^2 + M (v_i-v_{i-1}/t_i-t_{i-1})$

  Where,

  - FR is the total road-load force to be applied at the surface of the roll.
  - I is a is the counter to indicate a point in time over the driving schedule.
  - A counter to indicate a point in time over the driving schedule.
  - B is the Load from drag and rolling resistance, which are a function of vehicle speed.
  - V is the linear speed aerodynamic effects.

- The given ABC coefficients of coast down are

  a) Test Run 1
  A = 98.00 N
  B = 0.7000 N/KPH
  C = 0.05000 N/KPH^2
  b) Test Run 2
  A = 78.00 N
  B = 0.7000 N/KPH
  C = 0.05000 N/KPH^2

  c) Test Run 3
  A = 78.00 N
  B = 0.5600 N/KPH
  C = 0.05000 N/KPH^2

  d) Test Run 4
  A = 78.00 N
  B = 0.5600 N/KPH
  C = 0.04500 N/KPH^2

Conclusion:

Task-1:

- The root mean square values are
  - R= 116.6624
  - R_1= 116.6624
  - R_2= 92.9449
  - R_3= 78.6288
  - R_4= 39.7106
- The ABC coefficients are A= 98.000, B=0.7000, C=0.500.
- Difference between the theoretical and best test run obtained is A= 20N, B=0.14N/kph, C= 0.005N/'kph^2.

Task-2:

- Yes, the test for the drive cycle was valid.

- The minimum root means square error for a 60 second window of the drive cycle is R_1= 82.0094 for "t" seconds.

References:

- https://www.jstor.org/stable/6170?seq=1#metadata_info_tab_contents
- https://www.epa.gov/greenvehicles/testing-national-vehicle-and-fuel-emissions-laboratory
- https://www.google.com/search?q=EPA+National+Vehicle+and+Fuel+Emissions+Laboratory+para&rlz=1C1RXMK_enUS971US971&biw=1536&bih=818&sxsrf=AOaemvJMdJpIpytd0Y_0KvvWntRVNgbwCw%3A1631855932548&ei=PCVEYeL1ILGqwbkPwZSNwAQ&oq=EPA+National+Vehicle+and+Fuel+Emissions+Laboratory+para&gs_lcp=Cgdnd3Mtd2l6EAMyBQghEKABMgUIIRCgATIFCCEQoAEyBQghEKABOgcIABBHELADOgYIABAWEB46BQghEKsCSgUIOhIBMUoECEEYAFDZM1juQmDrTGgBcAJ4AIAB4gGIAcEFkgEFMS4zLjGYAQCgAQHIAQjAAQE&sclient=gws-wiz&ved=0ahUKEwjig7yJoYXzAhUxVTABHUFKA0gQ4dUDCA8&uact=5
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- https://www.atesteo.com/en/testing/vehicle-testing-road-tests/
- https://www.epa.gov/vehicle-and-fuel-emissions-testing

Appendix:

MATLAB Script:

- Task-1:

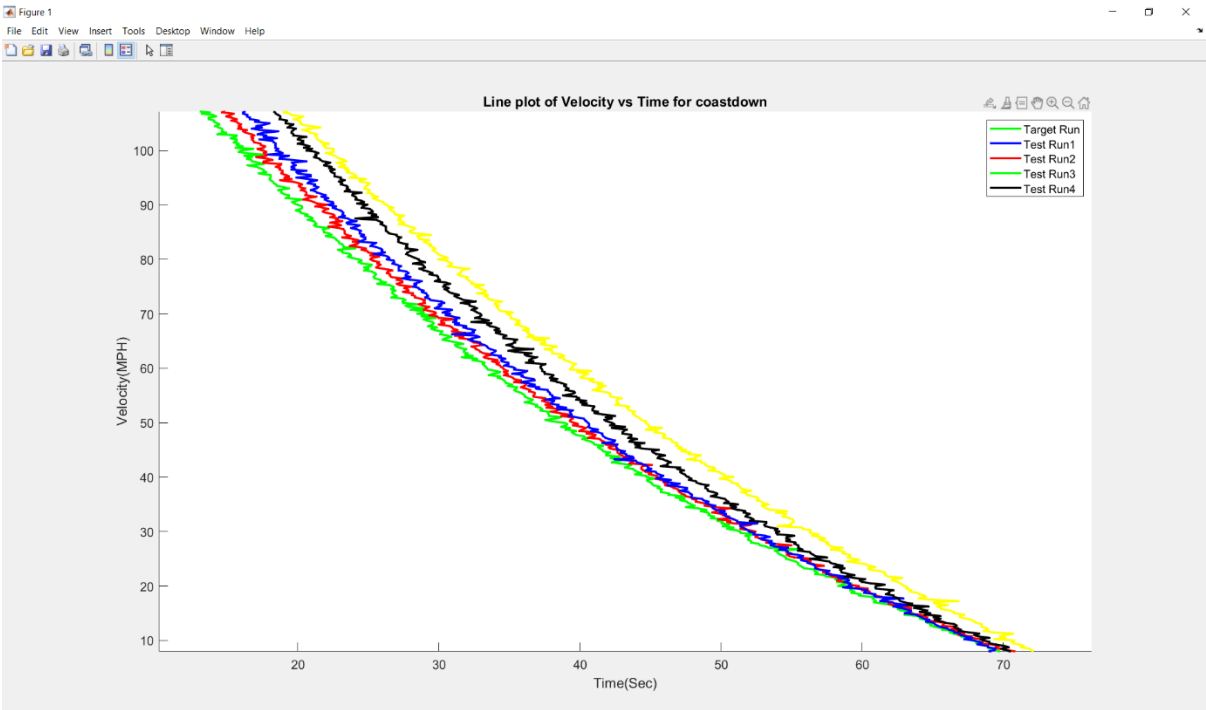
1) Plot velocity vs. time for the target coast down test, as well as all of the tests run in the chassis dyno. Make the plot readable and

digestible! (Font size is readable, lines are distinguishable, clear labels, etc.).

Script:

```
clc
hold on
plot( V,T,'y+-','Markersize',2,'Linewidth',2);
plot( VT1,T,'g+-','Markersize',2,'Linewidth',2);
plot( VT2,T,'r+-','Markersize',2,'Linewidth',2);
plot( VT3,T,'b+-','Markersize',2,'Linewidth',2);
plot( VT4,T,'k+-','Markersize',2,'Linewidth',2);
hold off
title('Line plot of Velocity vs Time for coastdown')
xlabel('Time(Sec)')
ylabel('Velocity(MPH)')
legend({'Target Run','Test Run1','Test Run2','Test Run3','Test Run4'},'Location','NorthEast');
set(gca,'fontsize',12)
%%
```

Graph:



2) Plot the velocity error vs. time (test run velocity - target velocity) and calculate the root mean squared error for each test run. Describe how you changed the ABC coefficients between each test run to reduce the error.

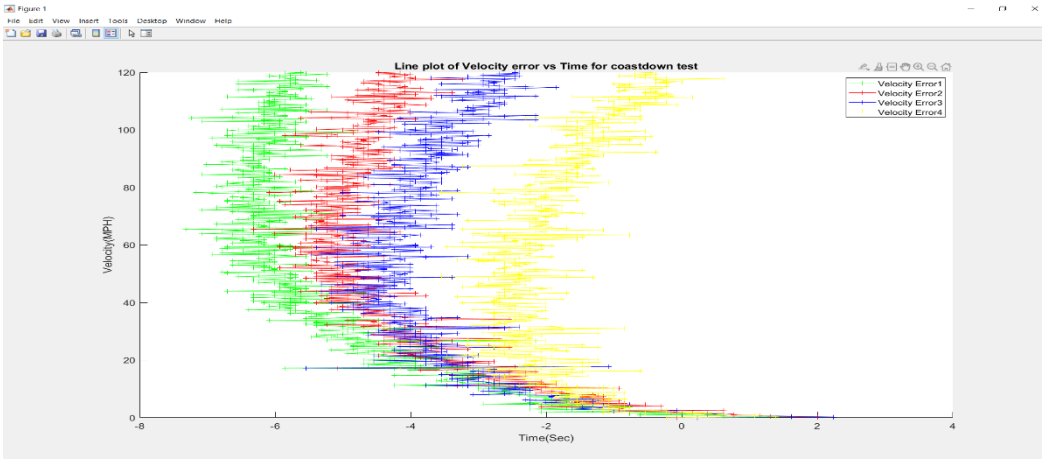
Script:

```
%function rmse(data,estimate)
%r = sqrt %(sum((data(:)- estimate(:))*2)/ nume1(data))
%Figure 1
% hold on
plot( V,T,'g+-','Markersize',1,'Linewidth',1);
plot( VT1,T,'r+-','Markersize',1,'Linewidth',1);
plot( VT2,T,'b+-','Markersize',1,'Linewidth',1);
plot( VT3,T,'y+-','Markersize',1,'Linewidth',1);
plot( VT4,T,'k+-','Markersize',1,'Linewidth',1);
hold off
title('Line plot of Velocity vs Time for coastdown test')
xlabel('Time(Sec)')
ylabel('Velocity(MPH)')
legend({'Target Run','Test Run1','Test Run2','Test Run3','Test Run4'},'Location','NorthEast');
set(gca,'fontsize',12)
%
%%

Le = length(T);
E1 = VT1-V;
E2 = VT2-V;
E3 = VT3-V;
E4 = VT4-V;
RMSE1 = (sqrt((sum(E1)^2)/ Le));
RMSE2 = (sqrt((sum(E2)^2)/ Le));
RMSE3 = (sqrt((sum(E3)^2)/ Le));
RMSE4 = (sqrt((sum(E4)^2)/ Le));
```

b)

```
clc
plot(Times,DriveCycleSpeedmph,'r--')
hold on
plot(Times,ActualSpeedmph,'b--')
legend('DriveCycleSpeedmph','ActualSpeedmph')
```

Graph:

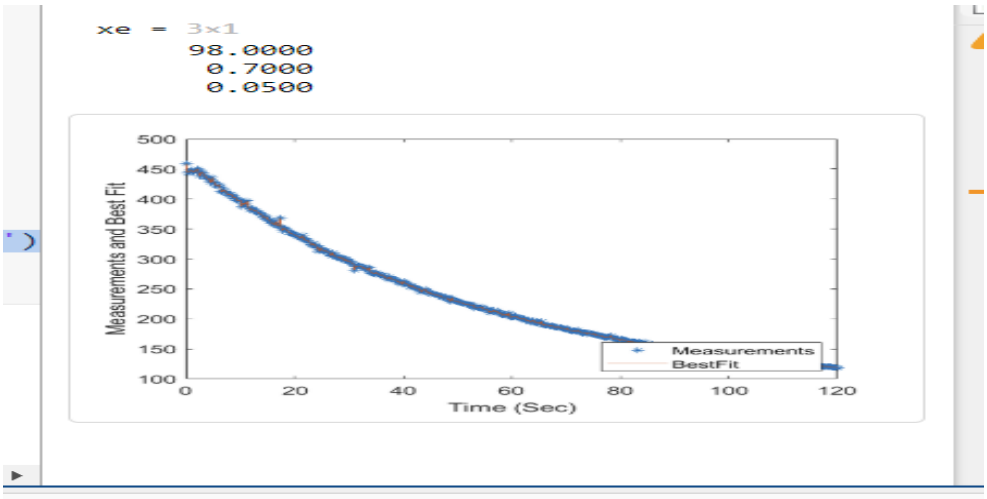


B)

% Generate Measurements

```
ym=98+0.700*(V)+0.0500*(V.*V);
% Form Basis Function Matrix
h=[Le V V.*V];
% Least Squares Estimate
 xe=inv(h'*h)*h'*ym
% % Estimated Outputy
 ye=xe(1)*1+xe(2)*V +xe(3)*(V.*V);
% % Plot Results
plot(T,ym,'*',T,ye)
set(gca,'fontsize',12)
legend('Measurements','BestFit','Location','SouthEast')
xlabel('Time (Sec)')
ylabel('Measurements and Best Fit')
```

Graph :



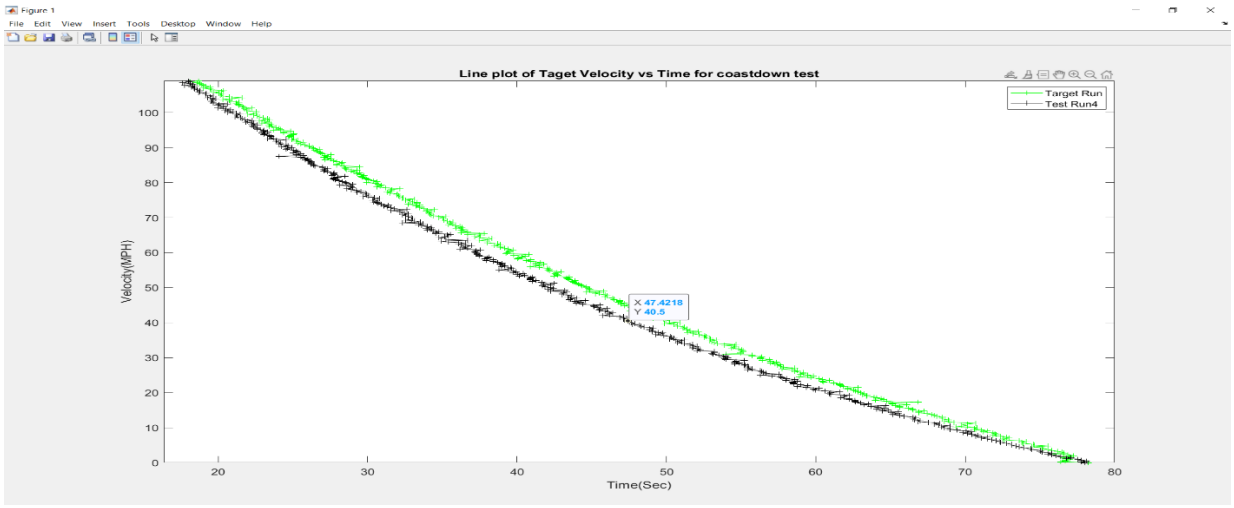
The ABC coefficients are A= 98.000, B=0.7000, C=0.500

3) Fit a curve to the target coastdown test to calculate the theoretical ABC coefficients. How do they compare to the best test run ABC coefficients on the chassis dyno.

Script:

```
lc
hold on
plot( V,T,'g+-','Markersize',1,'Linewidth',1);
plot( VT1,T,'r+-','Markersize',1,'Linewidth',1);
plot( VT2,T,'b+-','Markersize',1,'Linewidth',1);
plot( VT3,T,'y+-','Markersize',1,'Linewidth',1);
plot( VT4,T,'k+-','Markersize',1,'Linewidth',1);
hold off
title('Line plot of Velocity vs Time for coastdown test')
xlabel('Time(Sec)')
ylabel('Velocity(MPH)')
legend({'Target Run','Test Run1','Test Run2','Test Run3','Test Run4'},'Location','NorthEast');
set(gca,'fontsize',12)
```

Graph:



- Task-2:

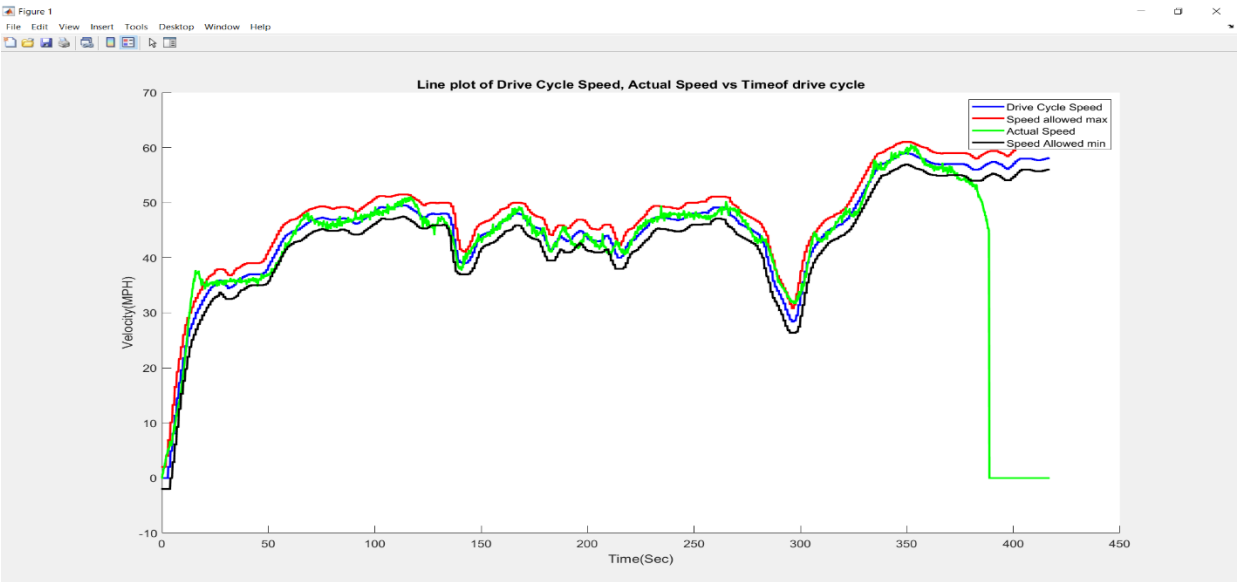
1) Calculate the root mean squared error for your test. What is the minimum root mean squared error for a 60 second window of the drive cycle? (This means you need to calculate the rms error for t= 1:60s, 2:61s, 3:62s, etc, and then select the minimum value).

Script:

```
clc
hold on
plot( T,DCS,'b+-','Markersize',2,'Linewidth',2);
```

```
plot( T,SMAX,'r+-','Markersize',2,'Linewidth',2);
plot( T,AS,'g+-','Markersize',2,'Linewidth',2);

plot( T,SMIN,'k+-','Markersize',2,'Linewidth',2);
hold off
title('Line plot of Drive Cycle Speed, Actual Speed vs Timeof drive cycle')
xlabel('Time(Sec)')
ylabel('Velocity(MPH)')
legend({'Drive Cycle Speed','Speed allowed max','Actual Speed','Speed Allowed min'},'Location','NorthEast');
set(gca,'fontsize',12)

%%
clc
Le = length(T1);
E1 = as1-DCS1;
E2 = as2-DCS2;
E3 = as3-DCS3;
E = as-DCS;

FMSE = (sqrt((sum(E)^2)/Le));


RMSE1 = (sqrt((sum(E1)^2)/ Le));
RMSE2 = (sqrt((sum(E2)^2)/ Le));
RMSE3 = (sqrt((sum(E3)^2)/ Le))
```

Graph:



- The root means square error for a 60 second window of drive cycle are

- R_1 = 82.0094
- R_2= 82.2440
- R_3= 82.2754