Modelling the Acceleration of a Small Electric Car (GM EV1 battery electric car) using MATLAB

PROJECT REPORT 1

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ABSTRACT

This report presents the development of a dynamic simulation model using MATLAB to analyse the acceleration performance of the GM EV1 battery electric car, a small electric vehicle The electric motor was modelled using mathematical equations to represent its velocity-time characteristics. In Electrical vehicles, acceleration is one of the important parameters. Acceleration depends upon the speed of the motor and torque The simulation model also took into account vehicle dynamics, such as weight distribution, rolling resistance, and aerodynamic drag. Various acceleration scenarios were simulated, and the results were analysed to gain insights into GM EV1's acceleration performance.

The GM EV1 battery electric car was a groundbreaking vehicle that paved the way for the modern electric vehicle industry. Understanding its performance characteristics, such as acceleration, is crucial for optimizing its design and predicting its behaviour on the road. In this report, we present a dynamic simulation model developed using MATLAB to analyse the acceleration performance of the GM EV1.

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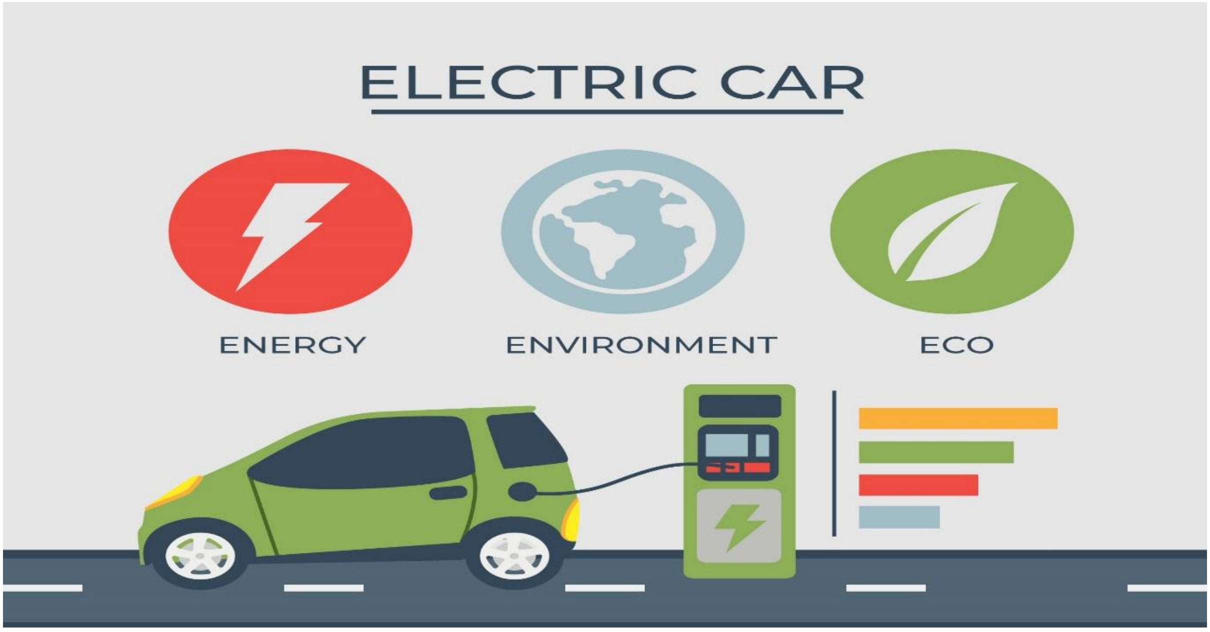
INTRODUCTION TO ELECTRICAL VEHICLE

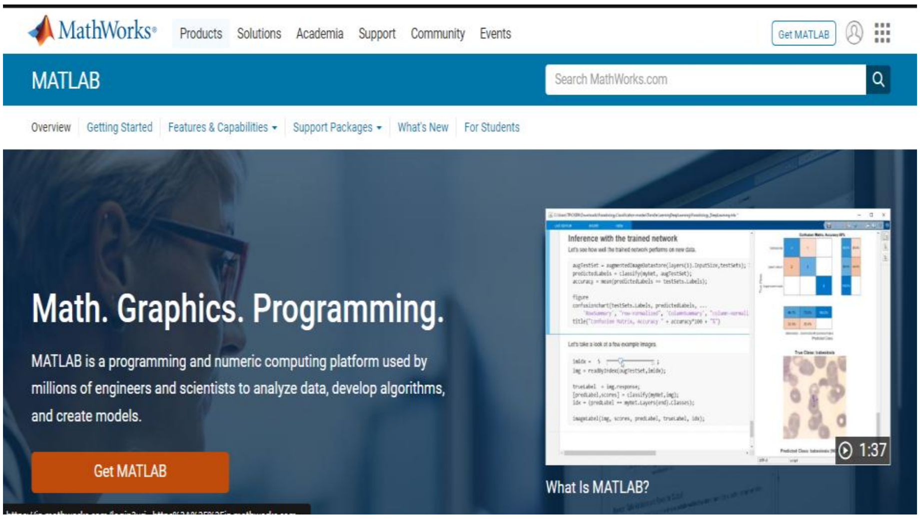
Electric vehicles (EVs) are revolutionizing the automotive industry by offering a sustainable and environmentally friendly alternative to traditional internal combustion engines (ICE) vehicles. Unlike conventional vehicles that rely on fossil fuels, EVs are powered by electricity, stored in rechargeable batteries, and use electric motors for propulsion. The adoption of EVs has gained significant momentum in recent years due to several factors. Firstly, concerns over climate change and the need to reduce greenhouse gas emissions have driven the demand for cleaner transportation options. EVs produce zero tailpipe emissions, resulting in lower carbon footprints compared to gasoline or diesel-powered vehicles. This makes EVs a key solution for achieving sustainable and greener transportation. Secondly, advancements in battery technology have significantly improved the range and performance of EVs. Lithium-ion batteries, commonly used in EVs, have become more efficient, providing longer driving ranges and quicker charging times. This has alleviated a range of anxiety concerns and increased the practicality and appeal of EVs for everyday use.

Furthermore, government incentives, subsidies, and regulations aimed at promoting clean transportation have also played a crucial role in the growth of the EV market. Many countries and regions around the world have implemented policies to encourage the adoption of EVs, such as tax credits, rebates, and investments in charging infrastructure. These measures have made EVs more affordable and accessible to a wider range of consumers. In addition to their environmental benefits, EVs offer other advantages. Electric motors provide instant torque, delivering swift acceleration and a smooth driving experience. Moreover, EVs have lower operating costs compared to conventional vehicles, as electricity is generally cheaper than gasoline or diesel fuel, and the maintenance requirements are typically less complex. Despite the progress made in the EV industry, challenges remain. The limited availability of charging infrastructure, longer charging times compared to refuelling with gasoline, and the higher upfront costs of EVs are some factors that continue to impact widespread adoption. However, ongoing technological advancements and the commitment of governments, automakers, and other stakeholders are expected to address these challenges and further accelerate the transition towards electric mobility. In conclusion, electric vehicles represent a transformative solution for sustainable transportation, addressing concerns about climate change and air pollution. With improving battery technology, expanding charging infrastructure, and supportive policies, EVs are becoming increasingly viable and appealing options for consumers worldwide. The electrification of the automotive industry is set to shape the future of transportation, creating cleaner, greener, and more efficient mobility systems.

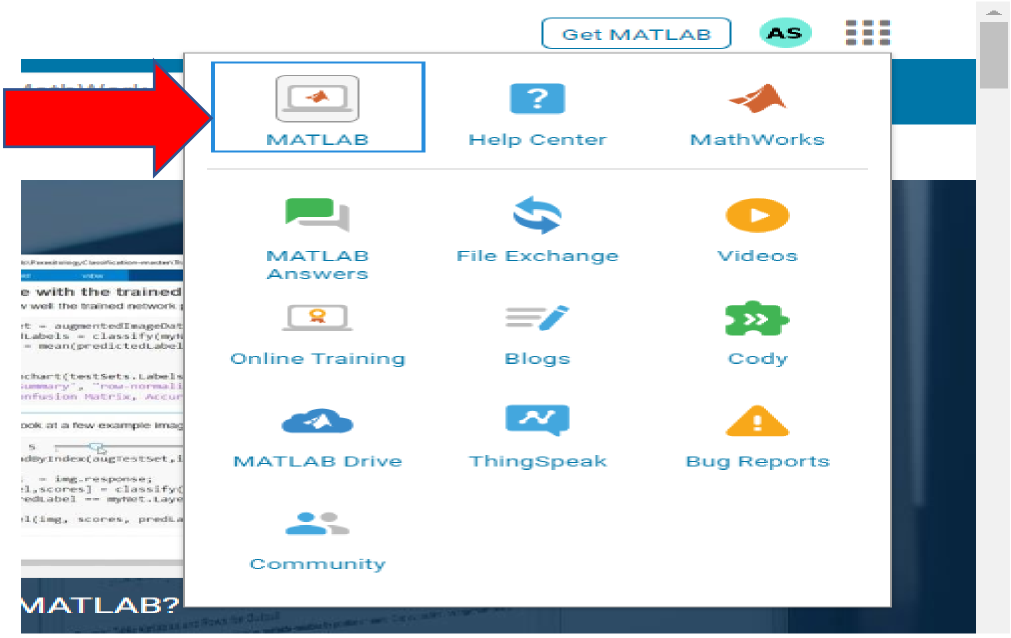


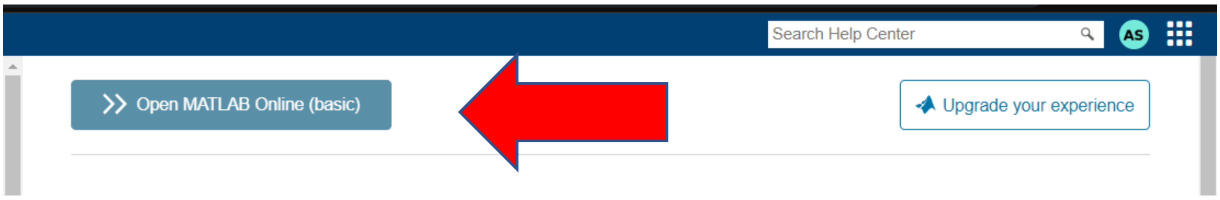
INTRODUCTION TO MATLAB

MATLAB (Matrix Laboratory) is a powerful and widely used software tool that combines numerical computing, visualization, and programming capabilities. It provides an interactive environment for algorithm development, data analysis, and modeling. Originally developed by MathWorks in the 1980s, MATLAB has become an indispensable tool for engineers, scientists, researchers, and educators in various fields. One of the key strengths of MATLAB is its ability to perform complex mathematical and computational tasks efficiently. It supports a wide range of mathematical operations, including matrix manipulations, linear algebra, numerical optimization, statistical analysis, and signal processing. MATLAB's extensive library of built-in functions and toolboxes further expands its capabilities, enabling users to tackle diverse computational problems with ease. MATLAB's user-friendly interface, consisting of a command-line interface (CLI) and a graphical user interface (GUI), allows users to interact with the software intuitively. The CLI provides a command prompt where users can enter commands, perform calculations, and execute scripts and functions. The GUI, on the other hand, offers a visual environment for creating and editing scripts, designing user interfaces, and visualizing data through plots, graphs, and other graphical representations. In addition to numerical computations, MATLAB also supports symbolic computing, which allows the manipulation of mathematical expressions and equations symbolically. This feature is particularly useful in mathematical modelling, solving differential equations, and performing symbolic mathematics, providing a powerful tool for theoretical analysis and mathematical exploration. Here is a MATLAB website where we can use a trial version or a licensed or an online MATLAB

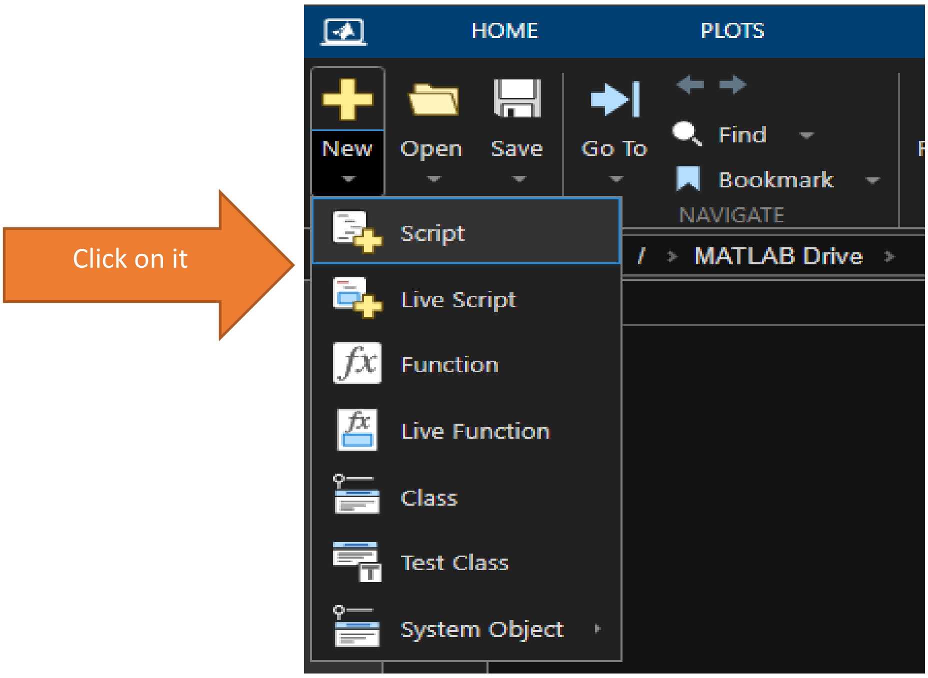


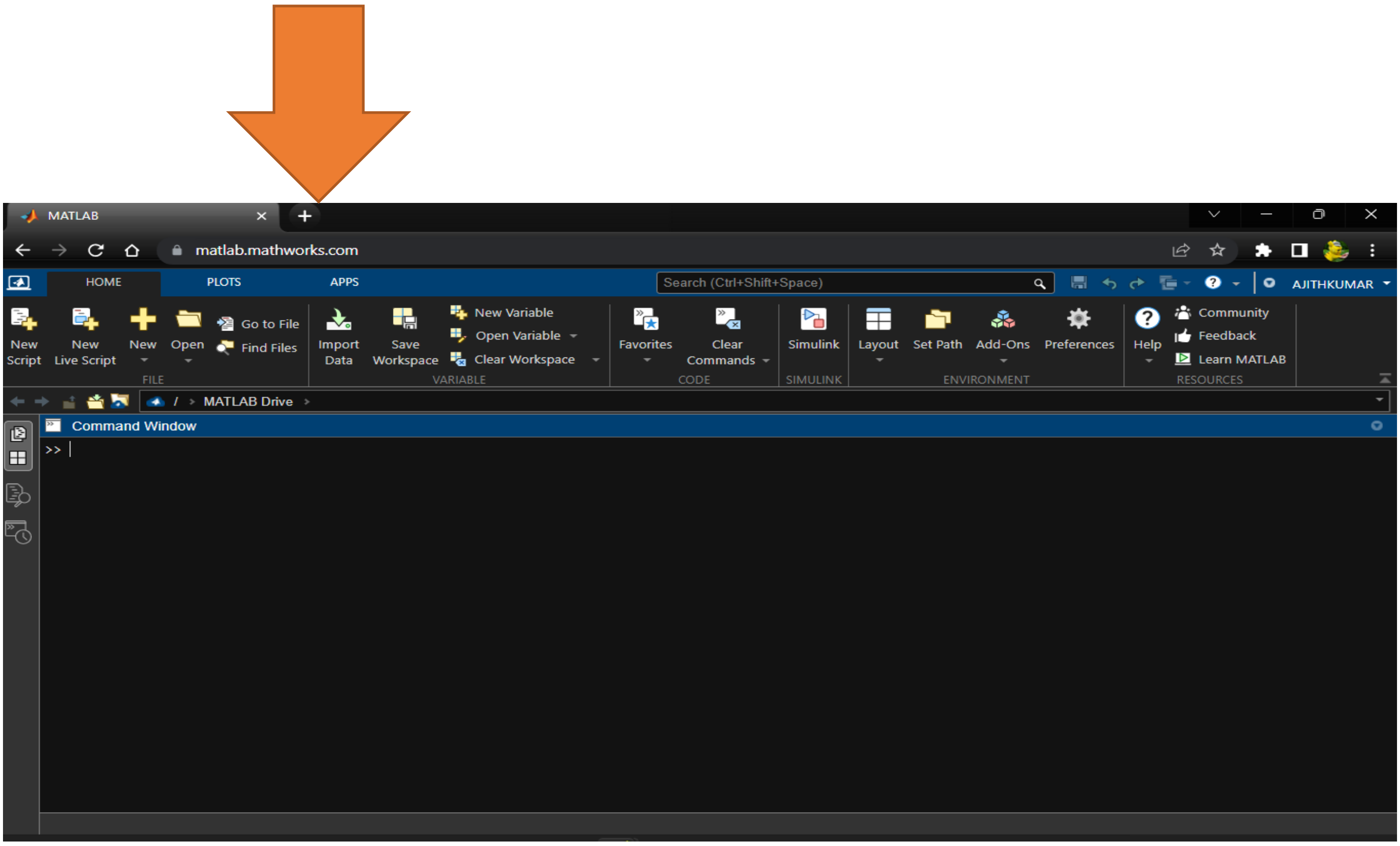
.MATLAB's versatility extends to programming capabilities, as it supports scripting and the development of custom functions and algorithms. Users can write MATLAB code to automate tasks, implement complex algorithms, and create custom solutions tailored to specific requirements. MATLAB's high-level programming language, with its intuitive syntax and extensive documentation, makes it accessible to both novice and experienced programmers. Another advantage of MATLAB is its extensive ecosystem and community support. The MATLAB File Exchange provides a vast repository of user-contributed scripts, functions, and toolboxes that users can download and integrate into their projects. The
The MATLAB community is active and vibrant, with forums, blogs, and online resources readily available for seeking assistance, sharing knowledge, and exploring new techniques and applications. Overall, MATLAB offers a comprehensive and versatile environment for numerical computing, data analysis, and algorithm development. Its user-friendly interface, powerful mathematical capabilities, and extensive ecosystem make it an indispensable tool for professionals and researchers across various disciplines. Whether it's simulating physical systems, analyzing data, or developing sophisticated algorithms, MATLAB provides the tools and flexibility to tackle complex computational tasks efficiently and effectively.





then click online MATLAB and next it goes to a new window where you can find the command window, the console window. Create a new script through a new ion in the window





MATHEMATICAL EQUATION FOR ACCELERATION FROM TORQUE

If the velocity of the vehicle is changing, then clearly a force will need to be applied in addition to the forces This force will provide the linear acceleration of the vehicle, and is given by the well-known equation derived from Newton's third law,

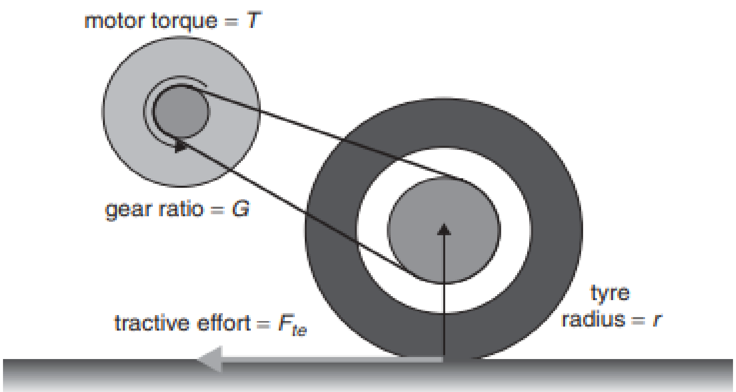
$$Fla = ma$$

However, for a more accurate picture of the force needed to accelerate the vehicle, we should also consider the force needed to make the rotating parts turn faster. In other words, we need to consider rotational acceleration as well as linear acceleration. The main issue here is the electric motor – not necessarily because of its particularly high moment of inertia, but because of the higher angular speeds.

, clearly, the axle torque equals Fte*r, where r is the radius of the tyre and Fte is the tractive effort delivered by the powertrain. If G is the gear ratio of the system connecting the motor to the axle and T is the motor torque, then we can say that

$$T = Fte*r/ G$$

$$Fte = G *T/r$$



The total tractive effort is the sum of all these forces

$$Fte = Frr + Fad + Fhc + Fla + F\omega a$$

where:

- Frr is the rolling resistance force,
- Fad is the aerodynamic drag
- Fhc is the hill climbing force
- Fla is the force required to give linear acceleration
- Fωa the force required to give angular acceleration to the rotating motor,

We should note that Fla and Fωa will be negative if the vehicle is slowing down and that Fhc will be negative if it is going downhill.

And equation becomes

$$Fte = \mu rr*m*g + 0.625ACd\ v2 + ma + I*(\ G2/\ \eta gr2)*\ a$$

Sub $a = dv/dt$

$$\frac{G}{r}T = \mu_{rr}mg + 0.625AC_d v^2 + \left(m + I\frac{G^2}{\eta_g r^2}\right)\frac{dv}{dt}$$

In the initial acceleration phase, when $T = Tmax$,

$$\frac{G}{r}T_{\max} = \mu_{rr}mg + 0.625AC_d v^2 + \left(m + I\frac{G^2}{\eta_g r^2}\right)\frac{dv}{dt}$$

SPECIFICATION:

Ultra-low drag coefficient (Cd)	0.19
Very low coefficient rolling resistance(μrr)	0.0048
Motor	Use a variable frequency Induction motor
Maximum Speed	1200rpm at maximum speed
Mass of car (m)	1560kg
Gear ratio(G)	11
Tyre radius (r)	0.3m
Forntal area(A)	1.8m*m

MOTOR TORQUE :

- T_{max}=140Nm
- ωc =733 rad/s

for motor T =T max until v=19.8m/s (71.3Km/hr)

Above 19.8 m/s, the Motor operates at constant power as102KW…

- T = 102000 /37 * v
- T= 2756/v

The efficiency of the single–speed drive coupling between the motor and axle is estimated at 95%, so ng =0.95.

The values of the torque T will be reduced by a factor of 0.95.

This slightly lower figure is because there is a final drive and a higher ratio gearbox.

Now substitute a value in the equation……..

For a first-phase motor torque is a constant…

$$0.95 \times 37 \times 140 = 72.4 + 0.214v^2 + 1560 * dv/dt$$

So..

$$dv/dt = 3.11 - 0.000137v^2$$

Once the speed has reached 19.8 m s−1 the velocity is given by the differential Equation

$$0.95 \times 37 \times 2756/ v = 72.4 + 0.214v^2 + 1560* dv /dt$$

So….

$$dv/dt = 62.1 /v - 0.046 - 0.000137v^2$$

ACCELERATION EQUATION :

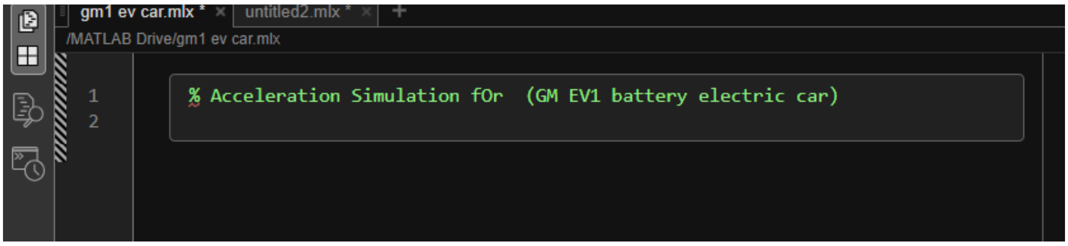
$$V(n+1) = v(n)+ \delta t (3.11 - 0.000137v^2 (n))\text{………}$$

$$v_{n+1} = v_n + \delta t \left(\frac{62.1}{v_n} - 0.046 - 0.000137 v_n^2 \right)$$

Then make MATLAB script by above discussed mathematical calculation…..

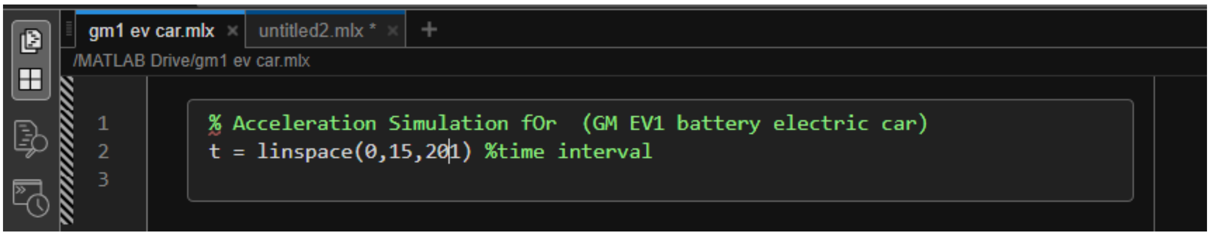
MATLAB CODE

- Go to the new script window and save a file name as the project title.



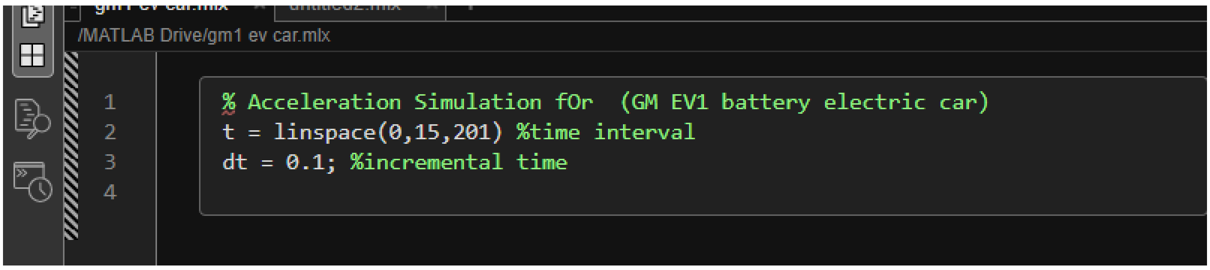
```
% Acceleration Simulation fOr  (GM EV1 battery electric car)
```

- For user and other understanding purposes write the command line by a symbol % which should be in a proper manner with respect to a code line explanation.



```
% Acceleration Simulation fOr  (GM EV1 battery electric car)
t = linspace(0,15,201) %time interval
```

- Then make time steps interval 0 to 15s, in an 0.1s steps



```
% Acceleration Simulation fOr  (GM EV1 battery electric car)
t = linspace(0,15,201) %time interval
dt = 0.1; %incremental time
```

- then make 201 readings of velocity and storing in an array

```
% Acceleration Simulation fOr  (GM EV1 battery electric car)
t = linspace(0,15,201) %time interval
dt = 0.1; %incremental time
v= zeros(1,201)% 150interval in arrays
```

- For an iteration a looping from a range of 1 to 100 or 200 to velocity equation with respect to a readings

- Where torque constant at this point 19.8m/s

```
for n = 1:100
    if v(n)<19.8
        v(n+1) = v(n)+dt*(3.11-(0.000137*v(n)^2))
```

- At this point iteration will continue when reaching above a point19.8m/s taken into an else statement and must end a loop with the end statement as an end;

```
    else
        v(n+1) = v(n)+dt*((62.1/v(n))-0.046-(0.000317*v(n)^2));
    end;
end;
```

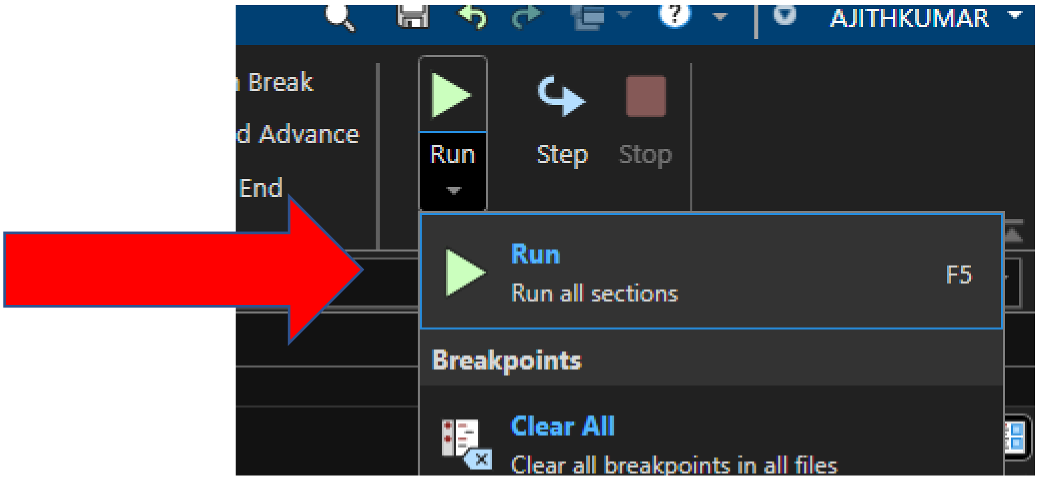
- Then convert a velocity from m/s to Kmphr which is multiplied by a 3.6 as (18/5)

```
v = v.*3.6; % converstion m/s to km/hr
plot(t,v);
axis([0 30 0 50]);
```

- Then plot an point by polt(t,v) with an x and y axis values

```
xlabel('TIME/SECONDS');
ylabel('VELOCITY/KMPH');
```

- Make an label with xLabel () and yLable() and give label name inside an parentheses with in a(‘’) and for analyses run an code



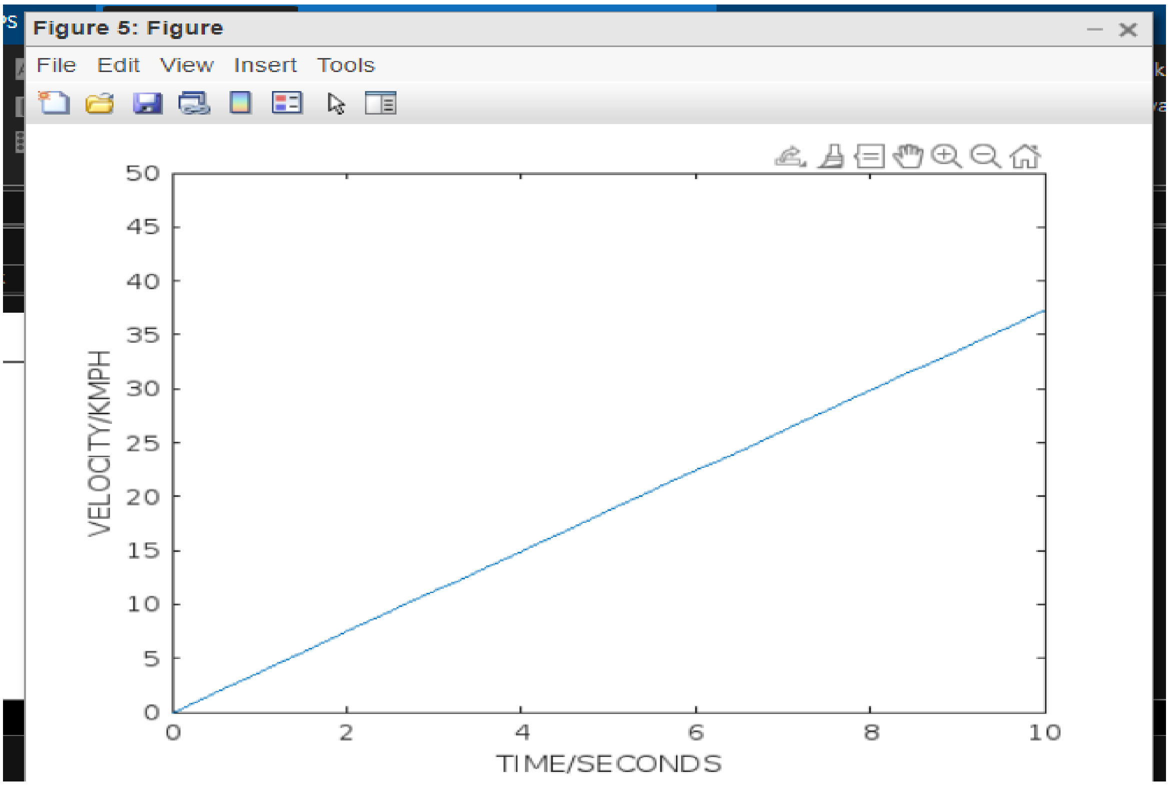
- Complete Matlab code for acceleration analyses

```
% Acceleration Simulation fOr  (GM EV1 battery electric car)
t = linspace(0,30,101) %time interval
dt = 0.1; %incremental time
v= zeros(1,101)% 150interval in arrays

for n = 1:100
    if v(n)<19.8
        v(n+1) = v(n)+dt*(3.11-(0.000137*v(n)^2))
    else
        v(n+1) = v(n)+dt*((62.1/v(n))-0.046-(0.000317*v(n)^2));
    end;
end;
v = v.*3.6; % converstion m/s to km/hr
plot(t,v);
axis([0 10 0 50]);
xlabel('TIME/SECONDS');
ylabel('VELOCITY/KMPH');
```

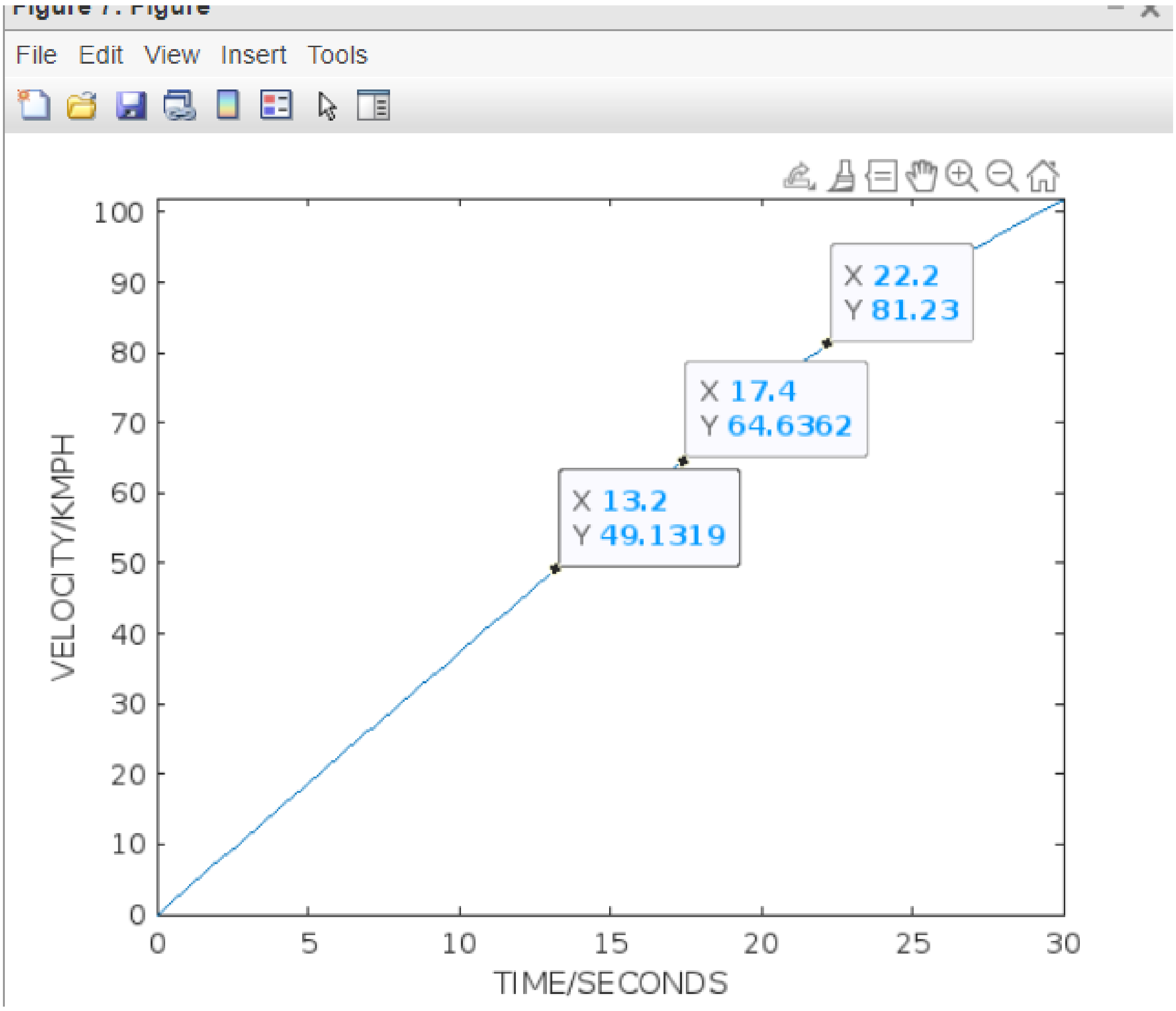
RESULT

It is well known that the range of electric vehicles is a major problem. In the main, this is because it is so hard to store electrical energy efficiently. In any case, this problem is certainly a critical issue in the design of any electric vehicle. Two types of calculations or tests can be performed about the range of a vehicle.



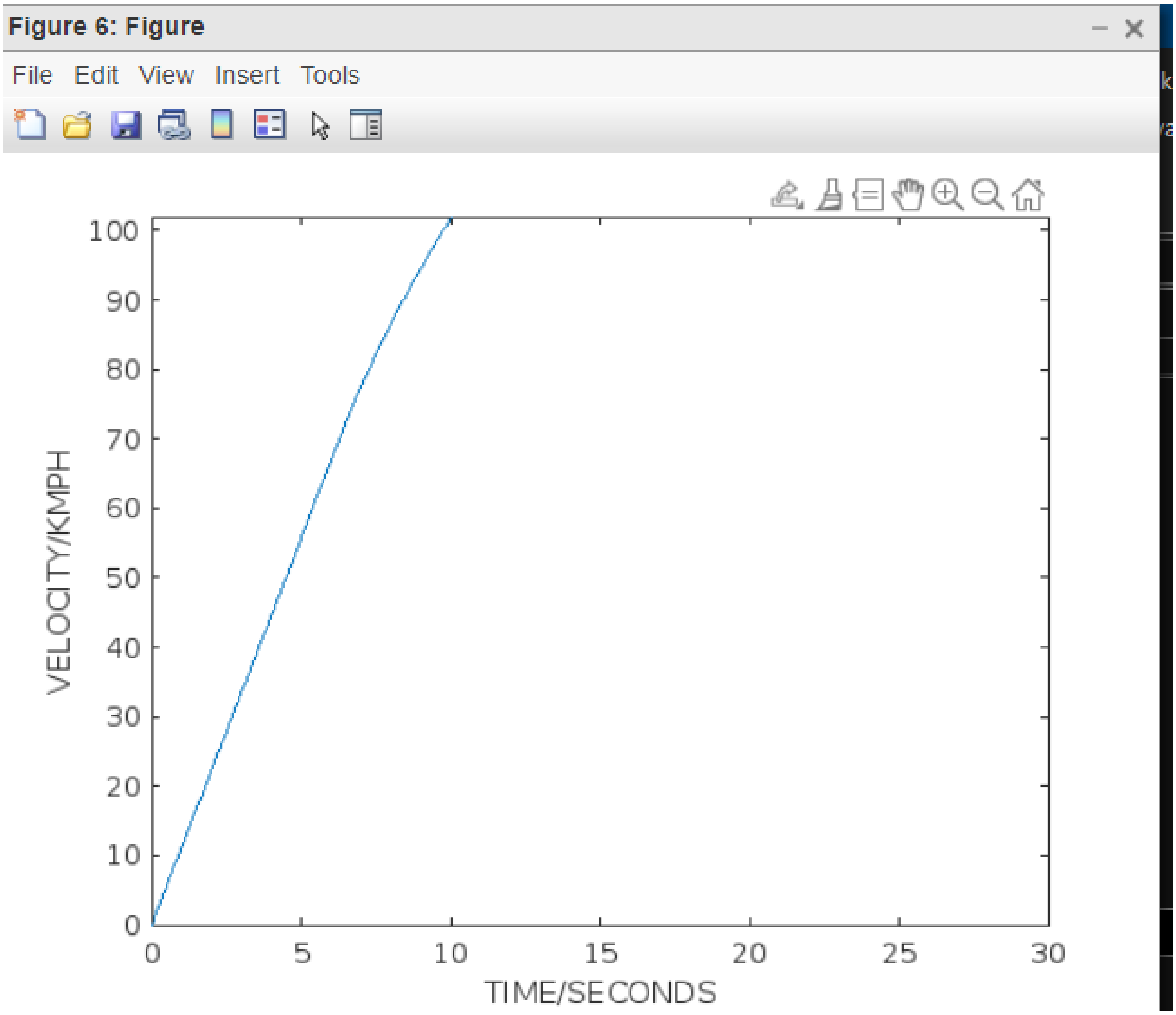
- **A graph of velocity against time for a GM EV1 at full power. This performance graph, obtained from a simple mathematical model, gives very good agreement with published real performance data**

- Where for different cases of distance and velocity can determine a derivation of velocity into the acceleration of a vehicles



- For 81.23m/s need a 22.2 and other cases are shown in figure

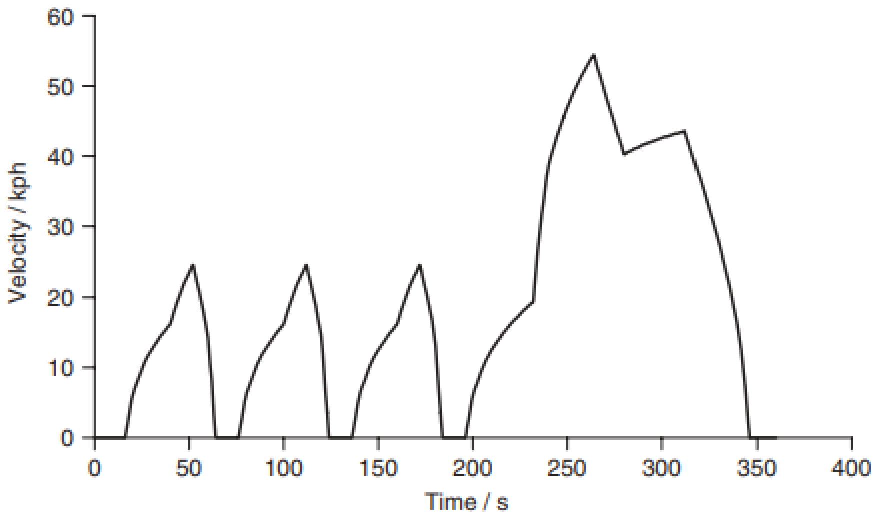
- By changing the time steps and mass of vehicles and other specifications can make different case result. According to that, we can make proper specific energy vehicles



The first, and much the simplest, is the constant velocity simulation. Of course, no vehicle is driven at a constant velocity, especially not on level ground, and in still air, which are almost universal further simplifications for these tests. However, at least the rules for the test are unambiguous, even if the simulation is unrealistic. It can be argued that they do at least give useful comparative figures. The second type of test – more useful and complex – is where the vehicle is driven, in reality, or simulation, through a profile of ever-changing speeds. These test cycles have been developed with some care, and there are (unfortunately) a large number of them. The cycles are intended to correspond to realistic driving patterns in different conditions. During these tests, the vehicle speed is almost constantly changing, and thus the performance of all the other parts of the system is also highly variable, which makes the computations more complex. However, modern computer programs make even these more complex situations reasonably straightforward. These driving cycles (or schedules) have primarily been developed to provide realistic and practical tests for the emissions of vehicles. One of the most well-known of the early cycles was one based on actual traffic flows in Los Angeles and is known as the LA-4 cycle. This was then developed into the Federal Urban Driving Schedule or FUDS. This is a cycle lasting 1500 seconds, and for each second there is a different speed, There is also a simplified version of this cycle known as SFUDS, which has the advantage that it only lasts 360 seconds, and so has only 360 data points. This has the same average speed, the same proportion of time stationery, the same maximum acceleration and braking, and gives very similar results when used for simulating vehicle range.

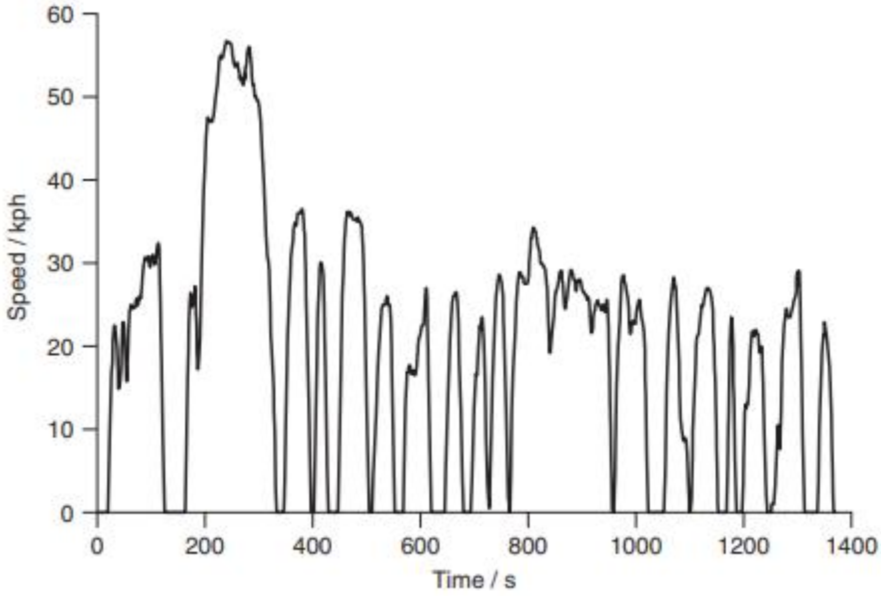
For reference graph …

- The Federal Urban Driving Schedule, as used for emission testing by the United



States Environmental Protection Agency

- Graph of speed against time for the Simplified Federal Urban Driving Schedule



CONCLUSION

In this project, we successfully developed a dynamic simulation model using MATLAB to analyse the acceleration performance of the GM EV1 battery electric car, a small electric vehicle. The simulation model incorporated various factors that influence acceleration, including motor characteristics, vehicle weight, gearbox ratio, tyre radius and efficiency. By gathering accurate data on the GM EV1's motor specifications, weight distribution, and drivetrain efficiency, we parameterized the simulation model to ensure the fidelity of the results. The electric motor was accurately modelled using mathematical equations to represent its velocity-time characteristics, allowing us to simulate the torque produced at different speeds and predict the vehicle's acceleration performance. By considering vehicle dynamics, such as weight distribution, rolling resistance, and aerodynamic drag, we created a realistic simulation that mimicked real-world driving conditions. Through various simulated acceleration scenarios, we obtained valuable insights into the GM EV1's performance. We analysed parameters such as acceleration time and maximum speed attained. The simulation results provided a comprehensive understanding of the vehicle's acceleration capabilities and identified potential areas for improvement. To validate the accuracy of our simulation model, we compared the simulation results with real-world data obtained from performance tests conducted on the GM EV1. The comparison demonstrated a close match between the simulated and actual acceleration performance, confirming the reliability of our model. Overall, the developed MATLAB simulation model proved to be a valuable tool for analysing and understanding the acceleration performance of the GM EV1 electric vehicle. The model can be further utilized to optimize the design of electric vehicles, improve energy efficiency, and enhance overall acceleration performance. As the electric vehicle industry continues to evolve, such simulation models will play a crucial role in designing and developing next-generation electric vehicles. The insights gained from modelling the acceleration performance of the GM EV1 can contribute to the ongoing advancements in electric vehicle technology and support the transition towards a more sustainable and efficient transportation system.