Evaluate Traction Forces and Torque for Electric Vehicle Using MATLAB Simulink Program.

Shrinit Lambodari[1], Mayur Bidwe[2], Raj Gaikwad[3]

[1] K. K. Wagh Institute of Engineering Education and Research, Maharashtra, India.
[2] Maratha Vidya Prasarak Samaj's Karmaveer Adv. Baburao Ganpatrao Thakare, College of Engineering, Nashik.
[3]College of Engineering, Pune.

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Abstract - *With the advancement of technology, the vehicle industry has taken a turn with the advent of Electric Vehicles. Electric vehicles benefit humanity by providing a sustainable means of transportation that does not harm the environment. Simulations are carried out using a combination of MATLAB scripts and Simulink modules. The car's speed and distance travelled correlate to genuine electric vehicle operating cycles and torque changes. The aerodynamics drag, linear acceleration, and rolling resistance forces are all simulated by this model. The impact of variables including battery voltage and energy capacity, motor rated torque and power, and transmission gear ratio on vehicle performance and energy consumption has been investigated.*

Key Words: Driving cycle, Mathematical Modelling, Simulink, MATLAB, Motor, Resistive Force and SOC etc.

1. INTRODUCTION

Electric vehicles are made up of several models that are linked together to allow the vehicle to function. When developing an electric car, several factors must be fixed first, such as tire radius, engine type, battery type, and vehicle size. These variables are utilized to calculate numerous aspects such as resistances presented, torque provided by tires, and battery charge and discharge rates. The vehicle's design has a significant impact on the vehicle's efficiency. If the vehicle is more aerodynamically engineered, it will have to overcome less resistance when driving, which will lessen the strain on the motor, allowing it to run more efficiently and provide a longer range. The environment and terrain in which we will utilize Electric Vehicles is an especially important element, because different terrains have varied environmental conditions, and the Electric Vehicle should be constructed in such a way that it adapts to the terrain in order to improve the vehicle's performance. The Motor and the Battery are the two most important components of an electric vehicle. The type of motor to use is determined by the environment in which the vehicle will be driven, as well as the amount of range for which the vehicle must be designed. Varying motors produce different torques. The battery that is chosen is determined by the amount of range that the vehicle requires. Because there is a steady flow of charge between the motor and the battery, the motor and the battery must sync efficiently. As the world progresses in the development of alternative energy sources, the Regenerative System is added into the model to support the Battery model for vehicle operation. When the car is braking, the tires do not come to a complete stop right away because there is still rotating kinetic energy in them. At this point, the rotating kinetic energy, which is a type of mechanical energy, is turned into electrical energy by the regenerative system's generators, and the created electrical energy is stored in the battery.

2. VEHICLE FORCES

2.1 Rolling Resistance Force (Frr)

The friction between the tires and the driving surface causes the rolling resistance force. At a stop, the rolling resistance force is zero. When the vehicle begins to move, the rolling resistance force acts in the opposite direction of motion, and it may be calculated by multiplying the rolling resistance coefficient Cr by the normal force between the vehicle and the road. On a level surface, the normal force is equal to the vehicle mass m multiplied by the standard gravity g.The normal force is equal to the weight m.g multiplied by the cosine of the inclination angle in the case of a sloping road. It's important to note that rolling resistance is unaffected by vehicle speed and always acts in the opposite direction of travel. The coefficient Cr should be low to keep frictional losses to a minimum. For contemporary automobiles, it's usually between 0.01 and 0.02.

$$F_{rr} = C_{rr} Mg$$

2.2 Gradient Force(Fgrad)

The gradient force is the force that operates on a vehicle when it is going uphill or downhill. The longitudinal component of gravitational force, namely the gradient force, is responsible for the gradient force. where theta is the road's inclination angle. The cosine component of gravity adds to the normal force and the related rolling resistance force, as previously stated. When driving downhill, the gradient force and angle theta are negative, but when driving uphill, they are positive. Road gradients are usually stated as a percentage in terms of tangent theta, with a value of plus or minus ten.

$$F_g = mg \sin \theta_g$$

2.3 Aerodynamic drag force (Faero)

The aerodynamic drag force opposes vehicle motion as air is forced to flow around the moving vehicle as the vehicle speed increases. It is equal to the product of the aerodynamic drag coefficient Cd, the vehicle's front area Af, the air density, and the square of the vehicle speed v, divided by two. It's vital to remember that while aerodynamic drag is independent of vehicle mass, it's strongly influenced by vehicle speed. That is why, at speeds of 70 to 80 km/h, the aerodynamic drag force is greater than the rolling resistance force in an automobile. Second, a modern car's drag coefficient is normally between 0.25 and 0.35. SUVs, with their boxy designs, have coefficients ranging from 0.35 to 0.45, while two-wheelers have coefficients ranging from 0.2 to 0.3.

$F_{aero} = 0.5 \cdot Cd \cdot A \cdot \rho air \cdot (V - Vwind)$

2.4 Acceleration Force (Faccel)

The Force Required to Accelerate the Vehicle is equal to the vehicle's mass m and the required acceleration a.

2.5 Traction Force (F)

The net force generated by the vehicle's powertrain to overcome resistive forces such as Aerodynamic Drag, Rolling Resistance, and Gradient Force, as well as the force required to accelerate the vehicle, is known as traction. We only consider forces in the forward and reverse directions because they have an impact on the powertrain. For the sake of simplicity, the forces in other directions are ignored. Second, the vehicle's forces are believed to be acting at a single location. The forces are spread throughout the vehicle in actuality.

$$F = F_{accel} + F_{aero} + F_{rr} + F_g$$

2.6 Wheel Torque

Torque required at the wheel is calculated by multiplying the tire radius by the traction force required to drive the vehicle.Tw denotes the wheel torque in Nm, F the required traction force in 'N,' and r the tire radius in'm'. The Final Drive Ratio FDR and gear efficiency g are used to compute the torque Tmotor and speed required at the motor.

$$T_{motor} = \frac{T_{wheel}}{G.R \times \eta_g}$$

3.VEHICLE

3.1 Vehicle Specification

Table -1: Vehicle Specification

Parameter	Data	Unit
Power (Continuous)	3.3	kw
Power (peak)	6	kw
Max Torque	26	Nm
Acceleration (0-40)	3.3	s
Top Speed	80	Km/h
Gradeability	20	deg
Motor Type	PMSM	
Range (True)	85	Km
Range (IDC)	116	Km
Battery(installed)	2.9	kWh
Usable Capacity	2.6	kWh
Type	Li-Ion 21700	
Transmission Type	Belt	
Transmission Ratio	7.8:1	
Kerb Weight	108	Kg
Wheelbase	1278	mm
Shaft Moment of Inertia	Not Known	
Wheel size	12	inches
	304.8	mm
Tire Size	90/90-12	18.38 inch (466.8mm)
Rolling radius	234mm	

3.2 Drive Cycle

Drive Cycle is a dataset of the vehicle speed collected at every instant of time, which can be used to determine the vehicle parameters, torque ratings, power ratings, emissions and fuel consumption.

Table -2: Vehicle Specification

Rural Road	Motorway 150
Duration, s	1082
Distance, km	17.275
Average speed (trip), km/h	57.5
Maximum speed, km/h	111.1

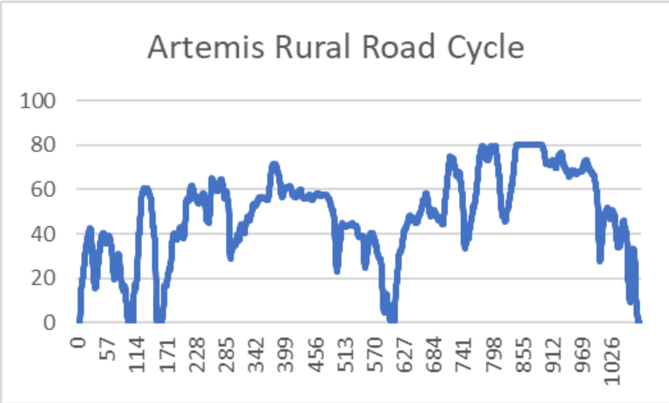

Chart -1: Drive Cycle

3.3 MATLAB Model

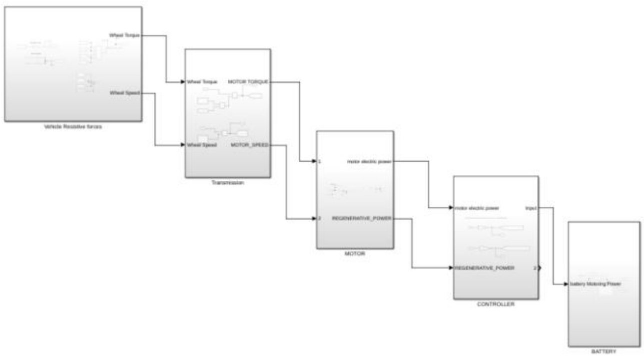

Fig -1: Simulink Block

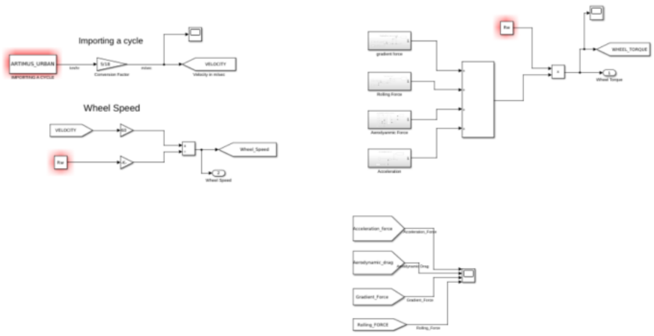

Fig -2: Forces and Torque Block Diagram

4. RESULTS

4.1 MATLAB Result

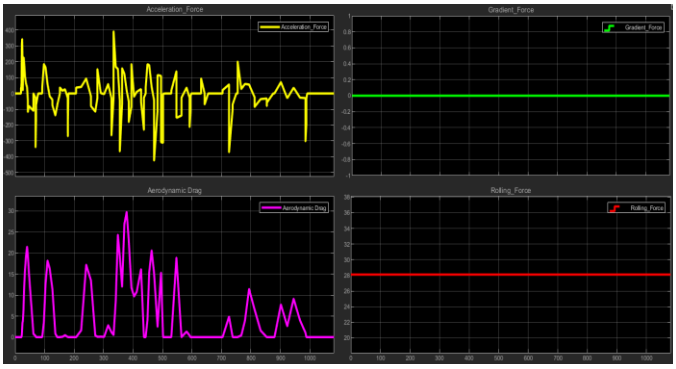

Fig -3: Forces Result

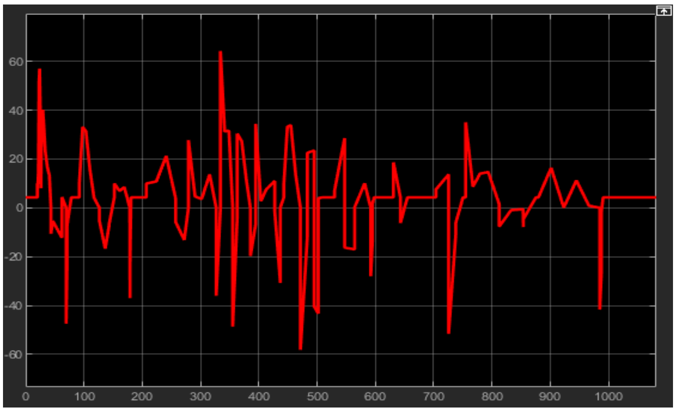

Fig -4: Wheel Torque Result

4.2 Battery Specification

Sr No	Parameter	Value	Units
1	i. Motor Controller Efficiency	85	%
2	ii. Battery Capacity	2900	Wh
3	iii. Battery Voltage	48	V
4	iv. Artemis Rural drive cycle distance	14.561	Km

Chart -2: Battery Specification

Energy= Voltage x Capacity
Voltage: 48V
Energy: 2.9kWh
Usable Capacity: 2600W(VA)h/48V
= 54 Ah
N(Series) = 48/3.65

= 13.15
= 14
N(Parallel) = Total Capacity/ Cell Capacity
= 54/4
= 14

5. CONCLUSION

We calculate forces by MATLAB code and Simulink Model.

From further plots we get the Wheel torque for motor and hence we select the motor required for particular motor.

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