Variable Acceleration Modelling in Electric Vehicles

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Abstract—Electric vehicles (EVs) are becoming one of the most important transportation technologies due to their high efficiency, low emissions, and advanced control systems. Unlike conventional vehicles, EVs experience continuously changing acceleration because of varying motor torque, road conditions, battery performance, traffic conditions, and driver behavior. Accurate modelling of variable acceleration is essential for improving vehicle performance, energy efficiency, ride comfort, and safety. This paper presents a detailed study of variable acceleration modelling in electric vehicles using Engineering Mechanics and vehicle dynamics principles. Mathematical models for traction force, rolling resistance, aerodynamic drag, and motor torque are analyzed. Simulation methods and computational tools used in EV acceleration analysis are also discussed. Results show that proper acceleration modelling significantly improves EV control, battery management, and driving efficiency.

Index Terms—Electric Vehicle, Variable Acceleration, Vehicle Dynamics, EV Modelling, Traction Force, Battery Performance

I. INTRODUCTION

Electric vehicles are replacing traditional internal combustion engine vehicles because they provide:

- Lower environmental pollution
- Higher energy efficiency
- Reduced fuel dependency
- Better torque response
- Smart electronic control systems

Unlike conventional vehicles, EVs produce instant torque, leading to rapid and continuously varying acceleration. Vehicle acceleration changes due to:

- Battery state of charge
- Road slope
- Aerodynamic drag
- Traffic conditions
- Driver input
- Vehicle load
- Motor control strategy

Understanding acceleration behavior is important for:

- Energy optimization
- Speed control
- Safety systems
- Autonomous driving
- Regenerative braking
- Motor sizing

This paper focuses on mathematical and computational modelling of variable acceleration in electric vehicles.

II. LITERATURE REVIEW

Researchers have developed different EV dynamic models ranging from simple longitudinal models to advanced multi body simulations. Modern EV studies combine electrical systems with mechanical vehicle dynamics.

Studies show that acceleration behavior strongly affects energy consumption, battery life, and passenger comfort. Advanced simulation tools such as MATLAB/Simulink and vehicle dynamics software are widely used for EV acceleration analysis.

Recent research also uses optimization and AI techniques to improve acceleration efficiency and reduce energy loss during transient motion.

III. OBJECTIVES OF THE STUDY

1. To study variable acceleration behavior in electric vehicles.
2. To develop mathematical acceleration models.
3. To analyze forces acting on EV motion.
4. To evaluate effects of acceleration on battery and energy consumption.

5. To improve vehicle performance and control strategies.

IV. THEORY OF VEHICLE ACCELERATION

The acceleration of an electric vehicle depends on the net tractive force acting on the vehicle.
According to Newton's second law:

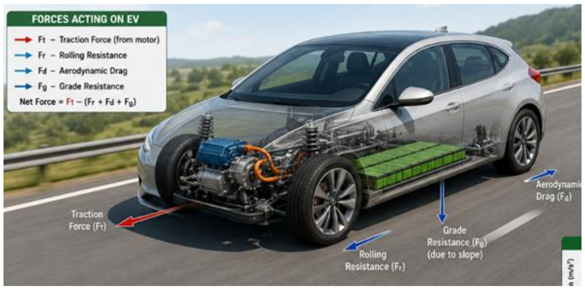
Fnet = ma

Where:
Fnet = Net force acting on vehicle
m = Vehicle mass
a = Acceleration

Net tractive force:

Ft- (Fr + Fd + Fg) = ma

Where:
Ft = Traction force
Fr = Rolling resistance
Fd = Aerodynamic drag force
Fg = Grade resistance force



Rolling resistance:

Fr = Cr mg

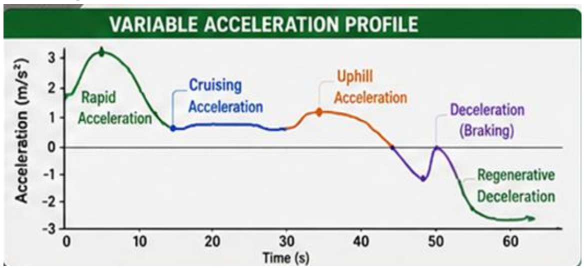
Aerodynamic drag:

Fd = $\frac{1}{2}$ ρ Cd Av²

Grade resistance:

Fg = mg sin θ

These forces continuously vary during EV operation, causing variable acceleration.



V. TYPES OF ACCELERATION IN EVS

5.1 Uniform Acceleration
Acceleration remains constant for a time interval.

5.2 Variable Acceleration
Acceleration changes with speed and load.

5.3 Positive Acceleration
Vehicle speed increases.

5.4 Negative Acceleration
Vehicle slows down or brakes.

5.5 Regenerative Deceleration
Motor acts as generator during braking.

VI. METHODOLOGY

Three EV operating conditions were analyzed:
1. Urban traffic driving
2. Highway acceleration
3. Uphill driving condition

Steps followed:
1. Develop vehicle dynamic equations
2. Determine traction and resistance forces
3. Simulate acceleration profiles
4. Analyze battery energy consumption
5. Compare acceleration under varying loads

Tools used:
- MATLAB
- Simulink
- ANSYS
- Python

VII. SAMPLE CALCULATION

Given:
- Vehicle mass = 1200 kg
- Traction force = 4000 N
- Rolling resistance = 300 N
- Drag force = 500 N
- Grade resistance = 200 N

Net force:
Fnet = 4000 - (300 + 500 + 200) = 3000 N

Acceleration:
$a = \frac{F_{net}}{m} = \frac{3000}{1200} = 2.5$ m/s²

Thus, vehicle acceleration is:
$a = 2.5$ m/s²

VIII. RESULTS AND ANALYSIS

Driving Condition	Acceleration Behavior	Energy Consumption
Urban Traffic	Highly Variable	Medium
Highway Driving	Smooth	Low
Uphill Driving	Reduced Acceleration	High
Heavy Load	Slow Response	Higher
Regenerative Braking	Negative Acceleration	Energy Recovery

Findings
1. Variable acceleration affects battery efficiency.
2. Aerodynamic drag increases at higher speeds.
3. Road slope significantly reduces acceleration.
4. Intelligent motor control improves performance.
5. Regenerative braking recovers energy during deceleration.

IX. APPLICATIONS

9.1 Autonomous Electric Vehicles
Speed and motion control systems.

9.2 Smart Transportation
Energy-efficient driving strategies.

9.3 EV Battery Management
Optimization of battery discharge rates.

9.4 Performance Testing
Acceleration and traction evaluation.

9.5 Regenerative Braking Systems
Energy recovery during deceleration.

X. DISCUSSION

Variable acceleration modelling is necessary because EV dynamics are influenced by both electrical and mechanical systems. Integrated EV models improve prediction of speed, torque, and energy behavior.

Benefits of proper acceleration modelling:
- Better energy efficiency
- Improved passenger comfort
- Safer driving control
- Enhanced battery life
- Reduced power losses

Challenges include:
- Real-time dynamic variations
- Battery performance changes
- Traffic unpredictability
- Road condition effects
- Complex nonlinear vehicle behavior

Advanced computational models help overcome these challenges.

XI. CONCLUSION

This study confirms that variable acceleration modelling is an important aspect of electric vehicle design and control. Proper analysis of traction forces, resistance forces, and motor behavior helps improve vehicle efficiency, battery management, and driving performance.
Future EV systems will increasingly depend on intelligent acceleration control and real-time dynamic modelling.

XII. RECOMMENDATIONS

1. Use advanced simulation tools for EV dynamics.
2. Develop AI-based acceleration prediction systems.
3. Improve regenerative braking control.
4. Optimize aerodynamic vehicle design.
5. Monitor battery performance continuously.

REFERENCES

[1] J. Y. Wong, *Theory of Ground Vehicles*. Wiley Publications.
[2] I. Husain, *Electric and Hybrid Vehicles: Design Fundamentals*. CRC Press.
[3] M. Ehsani, Y. Gao, and A. Emadi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*. CRC Press.

[4] C. C. Chan, “The State of the Art of Electric and Hybrid Vehicles.”
[5] R. Rajamani, *Vehicle Dynamics and Control*.
[6] T. D. Gillespie, *Fundamentals of Vehicle Dynamics*. SAE International.
[7] B. K. Bose, *Modern Power Electronics and AC Drives*. Prentice Hall.
[8] SAE Technical Papers on Electric Vehicle Dynamics and Acceleration Control.
[9] *IEEE Transactions on Vehicular Technology* – Research Articles on EV Modelling.
[10] *International Journal of Electric and Hybrid Vehicles (IJEHV).*
[11] *Journal of Automobile Engineering* – EV Dynamics.