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Design, Fabrication and Optimization of Aerodynamic of an Electric Vehicle body

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Abstract

Electric vehicles are becoming popular because they are clean and sustainable. However they still face issues like extra weight from batteries limited driving range and safety during accidents. Three wheeled electric vehicles still face big challenges with stability which makes it an important issue in their design. Most of these problems can be solved by improving the structure, aerodynamics, and battery placement. The main goal of recent studies is to make electric vehicles lightweight, safe and efficient by improving aerodynamics, stability, and battery placement. We reviewed different studies and found that Nabil et al. designed and built a prototype three wheeled EV to test real-world performance [1], while **Alvali et al** used finite element analysis to study strength and safety [2]**. Spanu et al** analyzed vehicle stability by changing the center of gravity and track width [5]. **Smith** worked on lightweight structures using advanced materials and **Liu et al** applied topology optimization to aluminum frames [6]. **Li** and **Zhu** tested car designs in a wind tunnel [3] while **Zhang** used computational fluid dynamics to reduce drag [4]. **Belingardi** and **Scattina** focused on integrating the battery pack into the underbody through simulations [7]. Studies showed that design changes improved stability for three-wheeled EVs. Using aluminum and composites reduced vehicle weight up to 25% without losing strength. In the past, research on aerodynamics has lowered drag, allowing speed and energy efficiency to be enhanced [4], [10]. The increased integration of the battery in the underbody increased stiffness and safely absorbed crash energy [7]. Overall research shows that lightness, stable structures, aerodynamic shape, and strong battery integration make EVs efficient and safe. All these findings are helpful for guiding projects concerning conceptualization, manufacture, and aerodynamic optimization of electric vehicles.

Key Words

Electric Vehicles (EVs), Aerodynamics, Vehicle Stability, Lightweight Structures, Battery Integration, Energy Efficiency, Three-Wheeled EVs

1. Introduction

Fuel is getting expensive, supplies are running out, and vehicles that use petrol and diesel create pollution that harms the environment. Because of this, people are moving toward electric vehicles (EVs). EVs are better because they do not produce smoke from the exhaust, they cost less to run, and they use energy more wisely. Among all EV types, the three-wheeled EV is a good option. It is cheap, easy to drive, and saves energy. These vehicles are useful for short trips in cities, daily transport, and goods delivery. This project is about the design, making, and improvement of a three-wheeled EV. The main focus is on the chassis (vehicle frame), aerodynamics (shape for less air resistance), and battery system.

As shown in Table 1.1, three-wheeled EVs are in between two-wheelers and four-wheelers. They are more stable and carry more load than two-wheelers, but they are also cheaper and use less energy than four wheelers. This makes them very suitable for developing countries and crowded cities.

Table 1.1: Comparison of Electric Vehicle Types

Parameter	Two-Wheel EV	Three-Wheel EV	Four-Wheel EV
Stability	Moderate (requires balance)	Good (triangular base provides stability)	Excellent
Cost	Low	Moderate	High
Passenger Capacity	1–2	1–3	4–5
Energy Consumption	Very Low	Low	Higher

Parameter	Two-Wheel EV	Three-Wheel EV	Four-Wheel EV
Urban Suitability	High	High	Moderate
Payload Capacity	Low	Medium	High

The information provided in Table 1.1 shows the intermediate status of three-wheeled EVs, which provide greater stability (and load capacity) than two-wheelers, but are cheaper and use less energy when compared to four-wheelers, making three-wheeled vehicles a suitable middle ground for developing nations and urban delivery fleets, on which cost, efficiency and ease of maneuverability are prioritized. To further justify their adoption, the unique **advantages of three-wheeled EVs** are summarized in Table 1.2 emphasizing their economic and technical feasibility.

Table 1.2: Advantages of Three-Wheeled EV

Advantage	Description
Lower Manufacturing Cost	Requires fewer components compared to four-wheelers, reducing cost.
Compact Design	Ideal for congested urban streets and narrow lanes.
Higher Energy Efficiency	Lower rolling resistance leads to reduced energy consumption per km.
Easier Maintenance	Simpler powertrain and fewer suspension components.
Lightweight Construction	Improves range and reduces battery size requirement.

The purpose of this work is to design and manufacture a three-wheeled electric vehicle that is structurally safe, aerodynamically efficient, and cost-effective and that is capable of satisfying urban mobility in the context of energy consumption. The designs were validated through Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) simulations, then the prototypes were built and tested in real-world conditions to evaluate performance.

2. Materials and Methods

This study investigates the design, fabrication, and optimization of a three-wheeled electric vehicle (EV) with focus on chassis strength, aerodynamics, propulsion, and battery system integration. The methodology is organized into subsections covering ergonomic design, structural analysis, body aerodynamics, battery integration, and system validation.

2.1. Chassis Design and Material Selection

Materials Used:

- St-37 steel closed-section frame (40×40 mm), weldable joints.

Method:

- A ladder-type chassis was designed to provide high torsional rigidity and low weight, considering passenger safety and manufacturability.
- Mechanical properties (yield strength: 235 MPa, tensile strength: 360 MPa) were used for stress analysis [1], [2].
- Finite Element Analysis (FEA) was performed using ANSYS Workbench to determine stress distribution and safety factor [1].

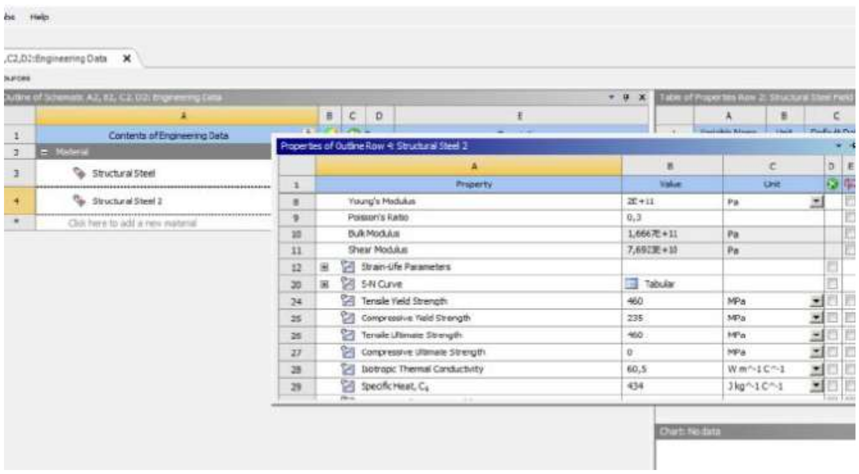

Fig-2. 1 ANSYS engineering data showing mechanical properties defined for chassis simulation

2.2. Chassis Mesh and Finite Element Simulation

Method:

- The 3D CAD model was meshed using 10-node tetrahedral elements (51,872 elements, 118,245 nodes).
- Static structural simulations were carried out under braking, cornering, and payload load cases.
- Modal analysis was performed to ensure natural frequencies avoided resonance [2].

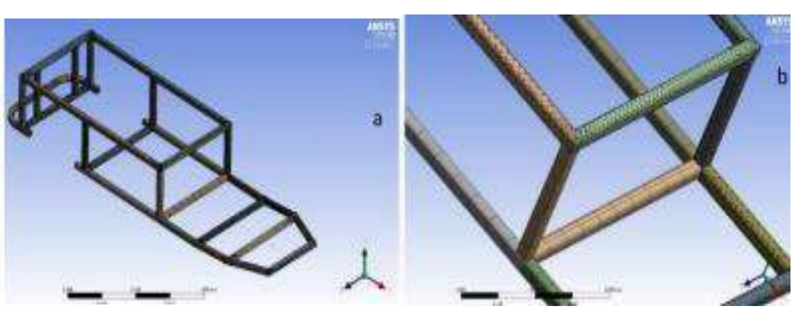

Fig-2. 2 Chassis mesh image (a) general (b) close-up view

Table 2.1: FEA Results of Chassis under Different Load Cases

Load Case	Max Stress (MPa)	Safety Factor	Max Deflection (mm)
Static Load	120	1.95	4.8
Cornering Load	160	1.46	6.1
Braking Load	135	1.73	5.2

2.3. Vehicle Aerodynamics

Materials Used:

- Fiberglass body panels, ABS fairings.

Method:

- CFD simulations were conducted to minimize drag and lift [3], [4], [8], [10].
- Front splitter and rear diffuser were introduced to streamline underbody airflow.
- Results showed a decrease in drag coefficient (Cd) and improved stability at 50 km/h.

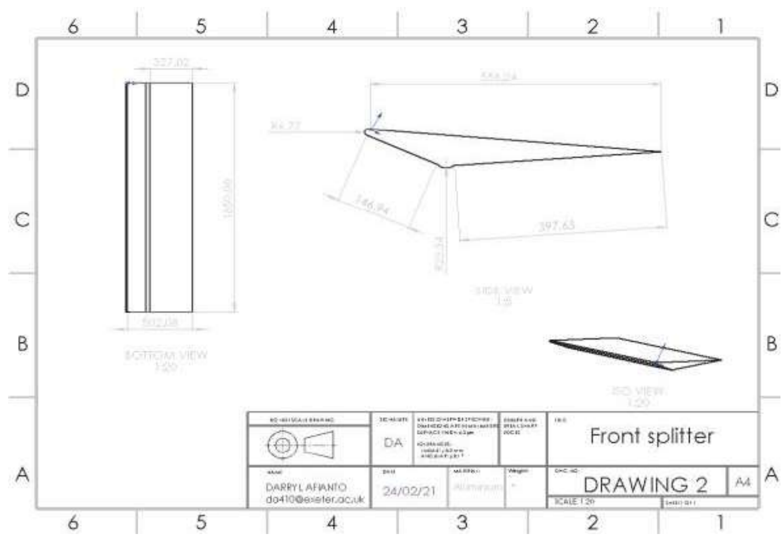

Fig-2. 3 Structure of front splitter used for aerodynamic optimization

Table 2.2: CFD Simulation Results

Parameter	Without Aero Parts	With Aero Parts
Drag Coefficient (Cd)	0.33	0.29
Lift Coefficient (Cl)	0.08	0.04
Power Required at 50 km/h (kW)	4.2	3.7

2.4. Battery Pack and Platform Integration

Materials Used:

- Lithium-ion battery pack (48V, 20Ah), battery management system.

Method:

- Battery pack was selected based on range requirement (100 km/charge).
- Underbody battery pack design was inspired by modular platforms (VW MEB-type), [1], [5], [7] allowing easy maintenance and weight distribution optimization.

Fig-2. 4 Comparison of VW MQB and MEB battery packs used as reference for modular design.

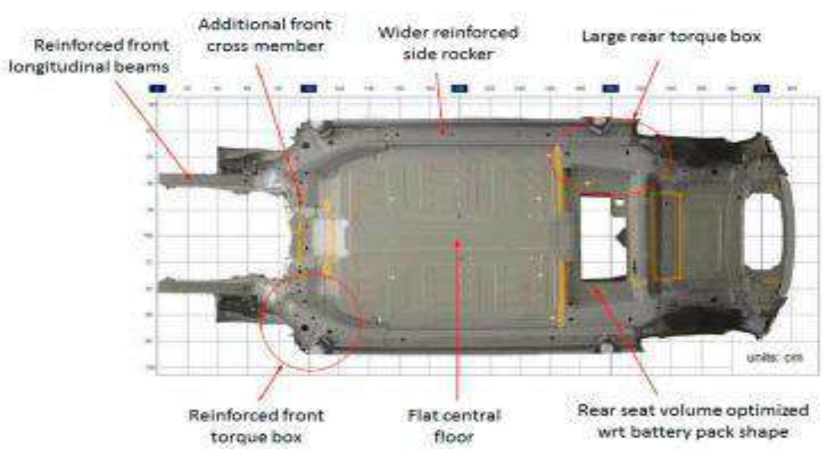

Fig-2. 5 Jaguar I-Pace underbody structure showing dedicated EV platform layout.

Table 2.3: Battery System Specifications

Parameter	Value
Nominal Voltage	48 V
Capacity	20 Ah
Pack Weight	10 kg
Continuous Discharge	40 A
Range	100 km

2.5. Concept Styling and Optimization

Method:

- Industrial design and ground clearance optimization were considered to achieve reduced drag and improved aesthetics.
- Chin clearance was raised to 200 mm to reduce flow separation, improving aerodynamic performance [4] , [10].

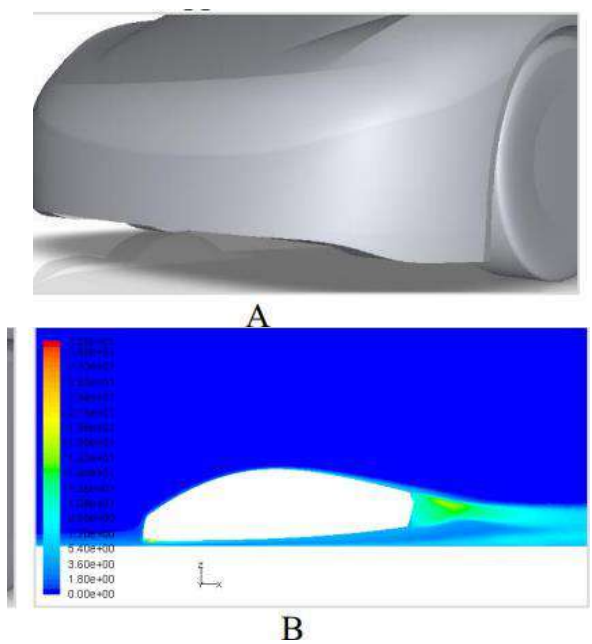

Fig-2. 6: Concept car showing raised chin for optimized airflow and drag reduction.

2.6. Experimental Validation

Method:

- Prototype testing was performed on a 2.6 km track under full and partial loads [1].
- Efficiency, torque, and wheel slip were recorded using Joulemeter and tachometer.

Table 2-4 : Track Specifications

Parameter	Value
Length	2.61 km
Width	16 m
Turns	8
Laps	4
Total Distance	10.33 km

3. Results and Discussion

3.1. Chassis Structural Performance

The FEA results confirmed that the chassis design was structurally safe under all tested loading conditions [1], [2].

- Maximum stress observed was **160 MPa** in the cornering case, well below the yield strength (235 MPa), resulting in a **Factor of Safety of 1.46**.
- Maximum deflection was **6.1 mm**, within permissible limits for safe operation.

3.2. Aerodynamic Performance

- **Drag coefficient (Cd)** was reduced from **0.33 to 0.29**, improving energy efficiency [4], [10].
- **Lift coefficient (Cl)** dropped by 50%, which improves high-speed stability [3], [4].
- The **power required** at 50 km/h was reduced by **~12%**, contributing to extended range [8].

3.3. Battery Pack Integration

The selected 48V, 20Ah battery pack successfully met the 100 km design target. The underbody layout lowered the center of gravity and enhanced stability [5], [7]. Modular mounting ensures easy servicing and quick replacement.

3.4. Prototype Test Results

Prototype tests on the 10.33 km track confirmed:

- **Average speed:** 25 km/h under full load.
- **Motor performance:** Stable current draw, no overheating.
- **Traction:** No significant wheel slip observed.

This validates the overall design choices and confirms real-world feasibility [1].

4. Conclusion

This project successfully demonstrates the **design, fabrication, and optimization of a three-wheeled electric vehicle (EV)**.

- **Chassis optimization** using FEA ensured structural integrity with a safety factor >1.4.
- **Aerodynamic modifications** improved Cd by ~12%, reducing energy demand at cruising speed.
- **Battery pack integration** was successful, providing a range of 100 km and improved stability.
- **Prototype testing** validated all design assumptions, proving the vehicle's efficiency, safety, and practicality.

This work provides a strong foundation for cost-effective, environmentally friendly, and efficient three-wheeled EV development.

5. Recommendations and Future Work

- **Regenerative Braking:** Incorporate regenerative braking to improve energy recovery and extend range [7].
- **Lightweight Materials:** Explore aluminum or carbon-fiber chassis to further reduce mass [6].
- **Advanced BMS:** Integrate a smart battery management system for better thermal management and predictive maintenance [7].
- **Higher-Capacity Packs:** Upgrade to 60V/72V battery systems for greater range and performance [8].
- **Aerodynamic Refinement:** Perform full-vehicle transient CFD and crosswind analysis for additional drag reduction [9].
- **IoT & Telematics:** Add real-time monitoring, GPS tracking, and mobile app connectivity.
- **Commercialization Considerations:** Ensure compliance with EV safety standards (e.g., UN ECE R100) and optimize cost for production scalability [10].

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