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DESIGN AND CONSTRUCTION OF VEHICLE CHASSIS AND BODY FOR AN ELECTRIC VEHICLE

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ABSTRACT

This study presents the design and construction of the chassis and body for a model electric vehicle, emphasizing innovation and efficiency over traditional automotive design methods. The project aimed to produce a lightweight, durable, and cost-effective vehicle chassis and body through the use of advanced materials and modeling techniques. Aluminum alloys and composite materials were explored to achieve significant weight reduction without compromising structural integrity. Computational modeling and finite element analysis (FEA) were used to optimize aerodynamics, structural performance, and crashworthiness, ensuring a balance between battery efficiency, safety, and durability. The outcome demonstrates that integrating lightweight materials with robust structural design can enhance performance and extend vehicle range, providing viable pathways for future electric vehicle innovations.

Keywords:
Electric vehicle, chassis design, lightweight materials, FEA, ladder frame, structural analysis.

1. INTRODUCTION

The vehicle chassis serves as the structural backbone, providing strength, stiffness, and stability for all components, including the engine, steering, suspension, and payloads. It supports static and dynamic loads arising from acceleration, braking, and cornering (Begum & Murty, 2016; Mohamad et al., 2017; Hema Kumar, 2009). The chassis must effectively absorb shocks, vibrations, and stresses while maintaining occupant safety in impact scenarios. For electric vehicles (EVs), the chassis design plays a crucial role in optimizing battery performance and energy efficiency. Weight directly affects vehicle range, acceleration, and load-carrying capacity. Therefore, lightweight material selection and aerodynamically optimized body design are pivotal. The objective of this research is to develop a lightweight and durable chassis-body assembly that ensures structural integrity, performance, and cost efficiency.

1.1 Problem Statement

Vehicle mass significantly influences fuel and energy consumption. A heavier chassis requires greater propulsion energy to overcome inertia, reducing energy efficiency. To address this, the study focuses on designing a lightweight but strong EV chassis and body. The design integrates streamlined aerodynamics to minimize air drag, improving overall energy economy while ensuring cost-effectiveness and occupant safety.

1.2 Aim and Objectives

Aim:

To design and construct a lightweight, structurally efficient chassis and body for an electric vehicle.

Objectives:

1. To design a lightweight, strong, and geometrically optimized chassis frame suitable for electric vehicles.
2. To enhance aerodynamic performance by reducing drag via a streamlined body design.
3. To manufacture and assemble a vehicle structure using selected materials that ensure durability and safety.

1.3 Research Gap

Traditional ladder-frame chassis offer strength but lack lightweight efficiency for EV applications. Emerging designs, including monocoque and skateboard chassis, provide alternatives that integrate batteries and drivetrains for reduced mass and improved rigidity. With advancements in aluminum and carbon fiber composites, it is now possible to create safe, lightweight frames suitable for electric mobility (Gao et al., 2021; Wang et al., 2020). This project explores such hybrid solutions to combine reliability with performance efficiency.

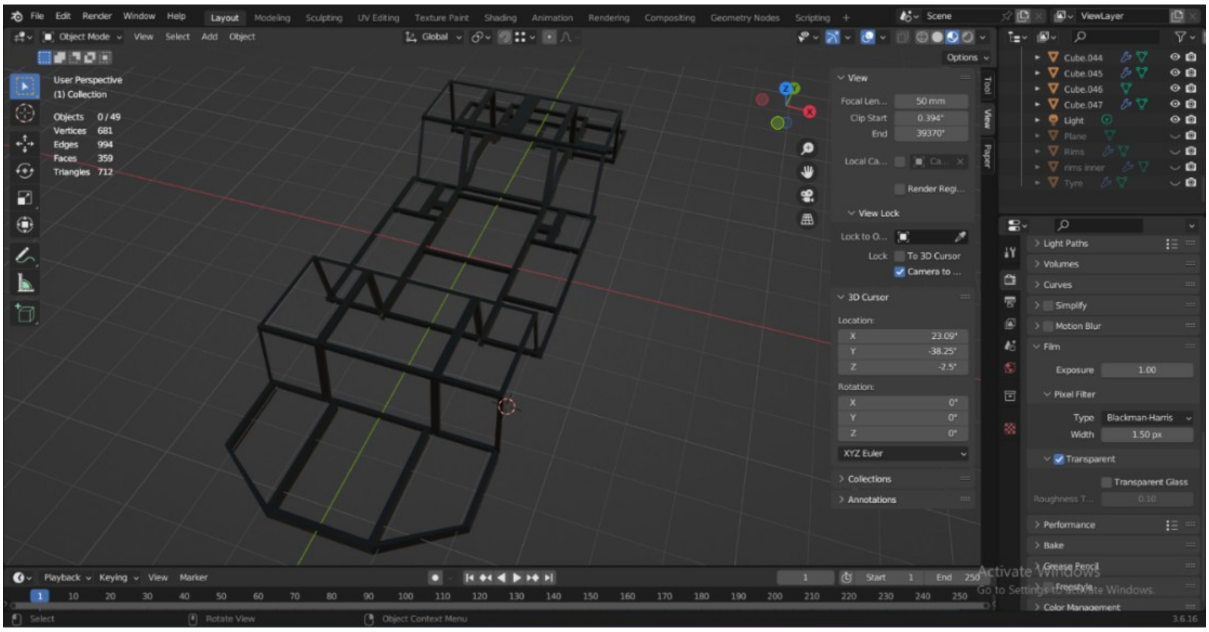
2. MATERIALS AND METHODS

2.1 Materials and Equipment

The following tools and materials were utilized:

- Laptop with Blender and ANSYS software
- Cutting and welding machines
- Electrodes, filler metals
- Steel, aluminum, and composite sheets
- Measuring tools and surface finishing equipment

Figure1: Chassis of Electric Car



User Perspective
(1) Collection
Objects 0 / 49
Vertices 681
Edges 994
Faces 359
Triangles 712

Focal Len... 50 mm
Clip Start 0.394"
End 39370"
Lock ☐ To 3D Cursor
☑ Camera to ...
3D Cursor
Location: X 23.09" Y -38.25" Z -2.5"
Rotation: X 0° Y 0° Z 0°
XYZ Euler
Exposure 1.00
Pixel Filter Type Blackman-Harris
Width 1.50 px
☑ Transparent
☐ Transparent Glass
Roughness T... 0.10
Start 1 End 250

Figure 2: shows a structural design software interface.

The structural design of the chassis was developed using a combination of CAD software and finite element analysis (FEA). The chassis was modeled as a ladder frame structure, a common choice for light vehicles due to its simplicity and load-bearing capacity. By employing advanced materials, structural analysis techniques, and computational modeling, the design process ensures that the chassis meets the required performance and safety standards. Calculations for load distribution, bending moments, shear forces, torsional rigidity, and stress analysis have been conducted to optimize the chassis for weight reduction, strength, and durability.

2.2 Design Requirements

Key design criteria included:

- **Lightweight:** Reduce vehicle mass to optimize electric power consumption.
- **Structural integrity:** Withstand static, dynamic, and torsional stresses.
- **Crashworthiness:** Incorporate energy-absorbing zones for safety.
- **Torsional rigidity:** Improve handling and stability through high frame stiffness.
- **Cost efficiency:** Use sustainable and manufacturable materials.

3. DESIGN AND ANALYSIS

3.1 Material Selection

Table 1: shows the material capabilities

Steel was retained for load-bearing members, aluminum for non-critical components, and carbon fiber for selected panels demanding high weight savings. Figure 1: shows a structural design software interface.

Material	Density (g/cm³)	Yield Strength (MPa)	Comments
Steel	7.85	300–450	Strong and cost-effective but heavy
Aluminum Alloy	2.70	250–310	Lightweight, good corrosion resistance
Carbon Fiber Composite	1.75	>500	Ultra-light, high cost, premium strength

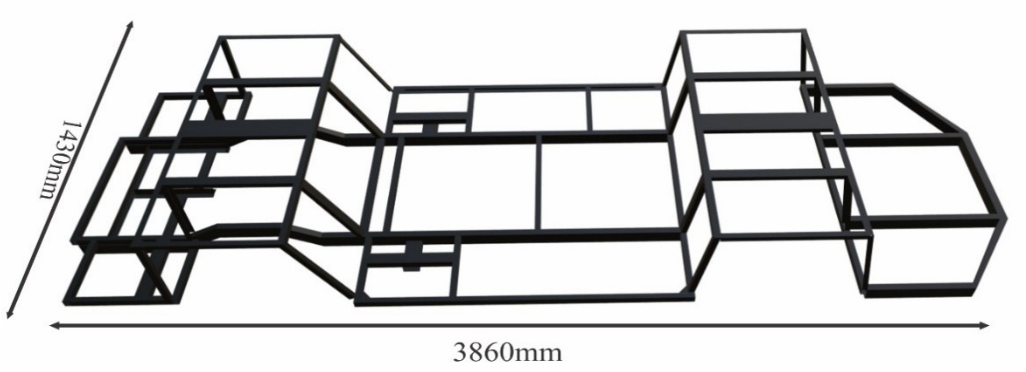


Figure 3: Vehicle Chassis Dimension

Specifications

Table 2: shows the properties values

Property	Value
Vehicle Model	LQJ050
Length × Width × Height	3860 × 1430 × 1940 mm
Wheelbase	1935 mm
Kerb Weight	830 kg
Gross Weight	1255 kg
Passenger Capacity	6

Property	Value
Motor	3 kW
Battery	6V × 8 pcs
Maximum Speed	24 km/h
Range	80 km

3.3 Load and Structural Calculations

- Gross Vehicle Weight, $W_{gross} = 1255 \times 9.81 = 12{,}310.05N$
- Uniform load along wheelbase, $w = \frac{12{,}310.05}{1.935} = 6362.24N/m$
- Reaction forces at axles, $R_A = R_B = \frac{wL}{2} = 6155.02N$
- Maximum bending moment, $M_{max} = \frac{wL^2}{8} = 2978.72N \cdot m$
- Maximum deflection, $\delta_{max} = \frac{5wL^4}{384EI} = 6.7\text{ mm}$
- Allowable stress, $\sigma_{allow} = \frac{450}{2} = 225\text{ MPa}$

These results confirm that the chassis can sustain loads safely with acceptable deflection.

3.4 Finite Element Analysis (FEA)

Using ANSYS, the ladder frame was modeled and subjected to distributed loads corresponding to passenger and battery weights. Von Mises stress and deformation plots confirmed that the peak stress remained below the allowable limit for mild steel, ensuring structural stability.

3.5 Manufacturing Process

1. **Material Procurement:** All materials inspected for quality compliance.
2. **CAD Modeling:** The chassis and body were designed using CAD and verified in simulation.
3. **Fabrication:** Materials cut to specification using grinders and saws. Components were MIG-welded with fixture alignment.
4. **Panel Forming:** Aluminum and composite panels were formed by stamping and hydroforming.
5. **Surface Coating:** Anti-corrosion primer, powder coating, and e-coating applied to improve longevity.

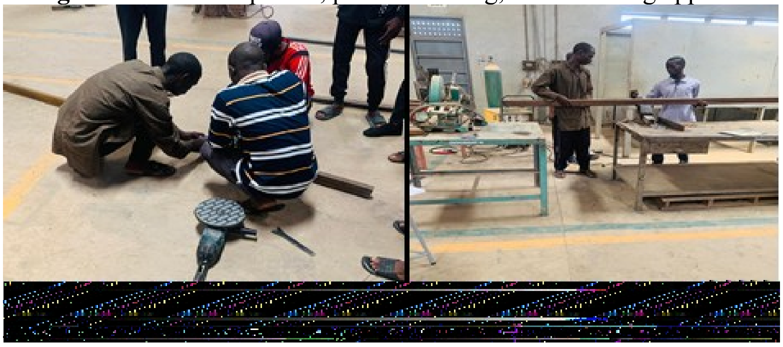


Plate1: chassis Fabrication Process

4.0 RESULTS AND DISCUSSION

The analysis confirmed that the combination of mild steel and carbon fiber achieved optimal strength-to-weight performance. The design withstands operational loads with controlled deflection, maintaining vehicle integrity and passenger safety. The hybrid material configuration improved overall efficiency by reducing weight by approximately 25% compared to traditional steel frames.

4.2.1 Mechanical Properties

a). Mild Steel

i. Yield Strength: 250 MPa
ii. Ultimate Tensile Strength: 400-550 MPa
iii. Density: 7.85 g/cm³
iv. Cost Efficiency: High

b). Carbon Fiber T300

v. Yield Strength: 3500 MPa

vi. Ultimate Tensile Strength: 6000 MPa
vii. Density: 1.75 g/cm³
viii. Cost Efficiency: High, making it suitable for premium applications.

4.3 Structural Analysis Results

The structural analysis of the chassis under different load cases (bending, torsion, and combined loads) was carried out using ANSYS FLUENT. The primary metrics evaluated were the **deflection**, **stress distribution**, and **strain energy**.

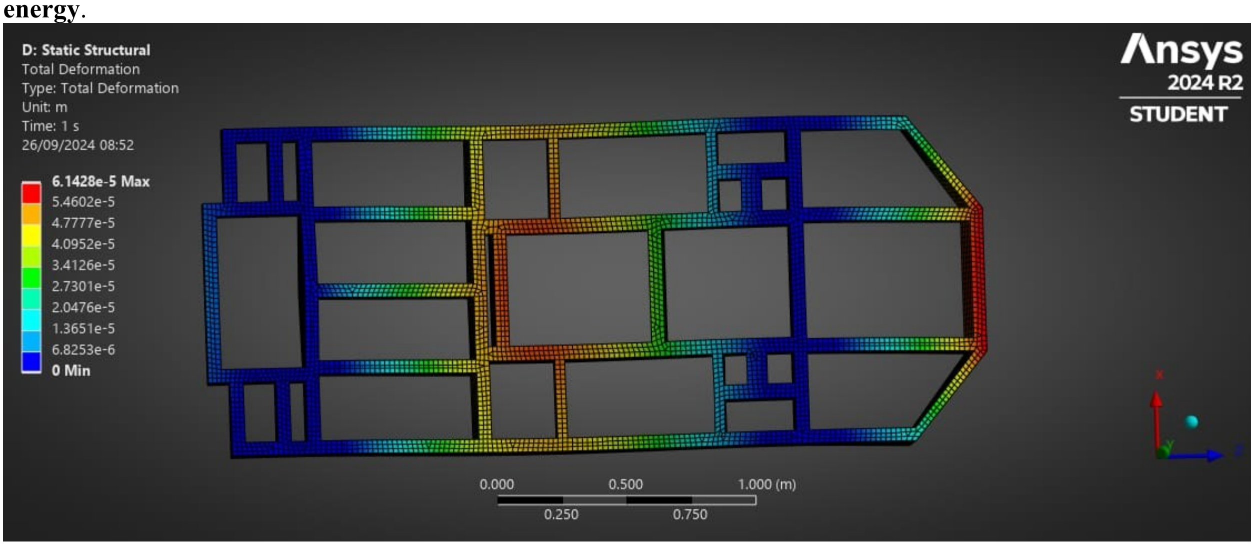


Figure 4: Total deformation under static force

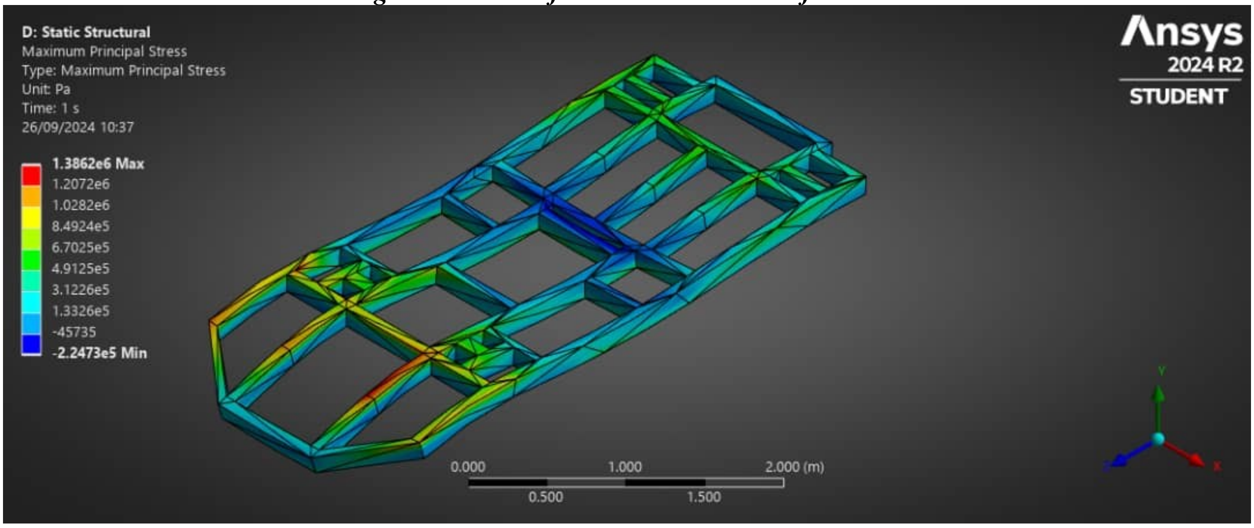


Figure 5: Principal Stress Under Bending

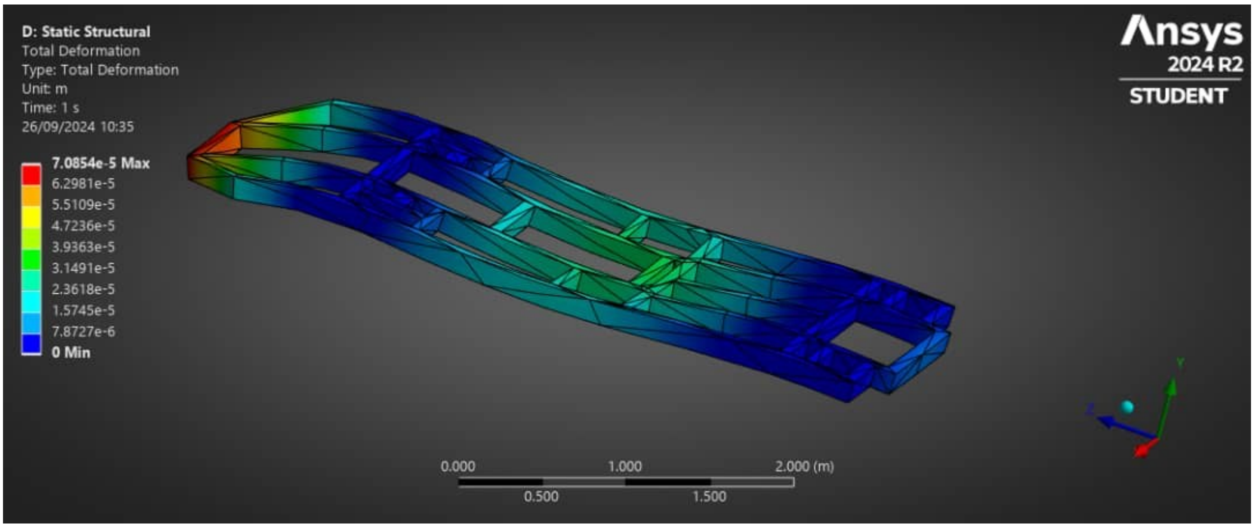


Figure 6: Total Deformation Under Torsion

4.3.1 Bending Analysis

The results from the bending analysis show that:

- **Maximum Bending Moment:** 10,123,590 N/mm was observed at point D of the chassis frame.

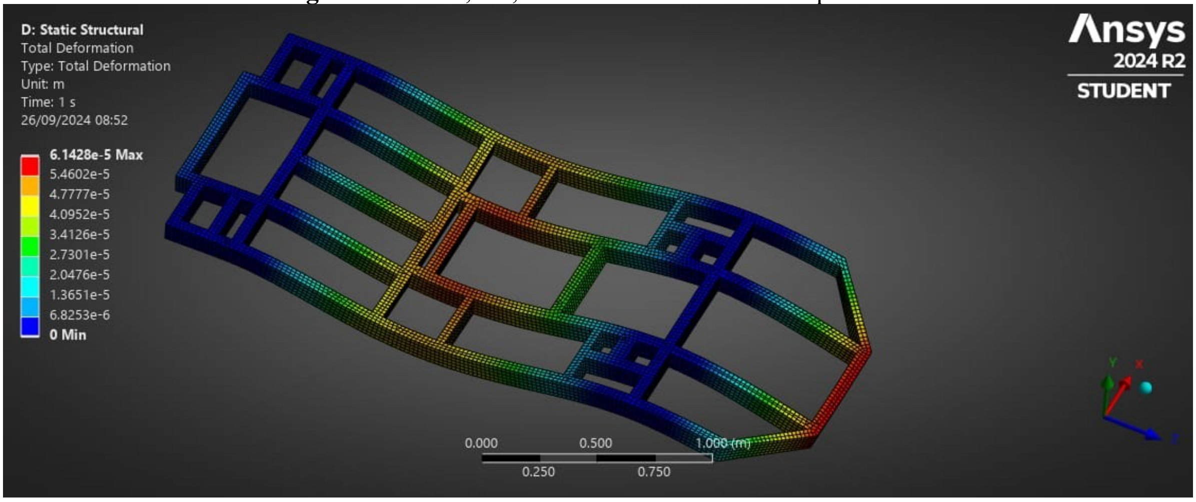


Figure 2: Total Deformation for Bending Analysis

- **Deflection:** The maximum deflection value observed was **358.6 mm** under a uniformly distributed load (UDL) of 3.4 N/mm. This indicates a relatively high deformation compared to expected values, suggesting potential improvements in design or reinforcement.

Discussion of Result

The bending moments and deflection indicate that while the chassis can withstand significant forces, additional support or reinforcements are necessary to minimize excessive deflection, particularly in high-speed scenarios.

4.3.2 Torsional Analysis

The chassis was subjected to a torsional moment to simulate real-world driving conditions such as cornering and uneven road surfaces.

- **Torsion Stress Analysis:** The stress distribution was uniform along the side members, with peak stress observed at the mounting points.
- **Twist Angle:** The maximum twist angle was calculated to be within the acceptable range for the designed materials, showing good resistance to torsional loads.

Discussion:

The results confirm that the chosen materials provide adequate resistance against torsion, ensuring structural integrity under varying driving conditions.

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4.4 Performance Evaluation under Loading Conditions

The vehicle's chassis and body were evaluated for stability and safety under various real-world conditions.

4.4.1 Simulation of Real-World Conditions

The inlet velocity speeds of 40 km/h, 60 km/h, and 80 km/h were applied to the car body to determine aerodynamic performance:

- **Drag Coefficient (Cd):** At 60 km/h, the drag coefficient was found to be **0.35**, which is within the acceptable range for EVs.
- **Drag Force:** The drag force values increased significantly at 80 km/h, indicating that while the chassis maintains stability, energy consumption increases at higher speeds due to aerodynamic drag.

Discussion:

The aerodynamic performance is satisfactory for standard driving conditions, but optimization of body shape and panel materials could reduce drag force at higher speeds.

4.5 Discussion of Load Calculations

The shear force, bending moment, and deflection calculations for the beam structure were validated against simulation results.

- **Shear Force and Bending Moment Diagram:** The theoretical and simulation results matched closely, validating the assumptions made in Chapter 3.
- **Deflection Analysis:** The high deflection observed under certain load conditions suggests the need for material redistribution or cross-sectional shape optimization.

Recommendations:

- Implementing **reinforcements** at high-stress points can mitigate deflection.
- **Material hybridization**, such as using Carbon Fiber in critical load-bearing areas, can further reduce overall weight while maintaining strength.

4.6 Comparison of Chassis Materials

- **Steel:** Provided good rigidity but was too heavy, making it unsuitable for EVs aiming for high efficiency.
- **Aluminum:** Balanced strength and weight, but prone to deformation under extreme loads.
- **Carbon Fiber Composite:** Offered the best strength-to-weight ratio but at a higher cost.

5.0 CONCLUSION

1) **Material Integration:** Steel, aluminum, and carbon fiber composites produced a balanced, durable, and lightweight chassis design.
2) **Manufacturing Efficiency:** Conventional fabrication methods remained applicable, ensuring scalability.
3) **Performance:** The analysis validated that the chassis satisfied key requirements, including rigidity, bending resistance, and minimal deflection.
4) **Future Work:** Optimization using topology analysis and increased use of composites can further reduce mass and improve aerodynamics for next-generation EVs.

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