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Design and Analysis of an EV Skateboard Chassis with Integrated Battery System

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Abstract

This project work presents a comprehensive study on the design and analysis of a skateboard-type electric vehicle chassis with battery integration system. It highlights the key design considerations, including weight distribution, structural integrity, and performance under various loading conditions. The primary objective is to ensure a high factor of safety by optimizing the chassis for strength. Additionally, the battery integration is evaluated with a focus on structural stability and frequency behavior. The analysis includes determining the natural frequencies of the chassis to prevent resonance and ensure reliable operation.

Keywords: BEV Chassis, FEA, Composite Materials etc.

1. Introduction

The skateboard electric vehicle (EV) chassis is an advanced and modular platform that plays a vital role in modern electric mobility. Unlike conventional vehicle chassis, it integrates batteries, motors, and control systems into a compact skateboard-like structure, improving space utilization, efficiency, and performance. The design focuses on key factors such as structural strength, weight optimization, aerodynamics, and safety. Battery enclosures are essential for protecting battery cells from impacts, moisture, and thermal hazards. In this project, the EV skateboard chassis is modeled using SolidWorks and analyzed through finite element analysis in ANSYS to evaluate stress distribution and optimize weight. The study highlights the advantages of skateboard chassis design, including modularity, improved load distribution, and suitability for future electric vehicle applications.

1.1 Purpose of the study

The purpose of this study is to investigate the structural integration of the vehicle underbody and battery pack in Battery Electric Vehicles (BEVs) to improve performance, efficiency, and lightweight design. The research focuses on dedicated BEV skateboard platforms and analyzes important design parameters affecting structural stiffness, Noise, Vibration, and Harshness (NVH), and overall weight optimization.

The project is divided into two parts: the first involves benchmarking and comparison of modern BEV platforms, such as the Jaguar I-PACE, to identify major design trends and integration techniques between the chassis and battery pack. The second part uses Finite Element Analysis (FEA) and Design of Experiments (DOE) to develop and analyze a simplified platform model. The study aims to establish validated design guidelines that improve static stiffness, structural performance, and integration efficiency while minimizing vehicle weight for future BEV platforms.

Figure 1: EV integration and battery pack

2. Literature Review

The literature review highlights the growing importance of lightweight, high-strength, and structurally efficient chassis systems for electric vehicles (EVs). Researchers have extensively investigated advanced materials such as carbon fiber, glass fiber composites, Kevlar, aluminum alloys, magnesium alloys, and advanced high-strength steels to improve chassis stiffness, crashworthiness, durability, and weight reduction. Most studies employed Finite Element Analysis (FEA) to evaluate stress distribution, deformation, vibration, fatigue behavior, and structural safety under different loading conditions.

Several researchers concluded that composite materials such as S-glass/epoxy, carbon epoxy, E-glass epoxy, and Kevlar provide significant weight reduction compared to conventional steel while maintaining acceptable structural performance. Studies reported weight reductions of up to 70–75% using composite chassis structures, which directly improves vehicle efficiency, fuel economy, and dynamic performance. Carbon fiber and graphene-based materials demonstrated excellent stiffness and deformation control, whereas aluminum alloys showed good structural rigidity with lower weight. However, high manufacturing cost, repair complexity, and limited experimental validation remain major challenges for large-scale implementation of advanced composites.

Research on chassis optimization also emphasized the importance of structural geometry, reinforcement strategies, and material hybridization. Double C-section chassis, reinforced frames, and optimized joint regions showed improved stress distribution and reduced deformation. Several studies highlighted that joints and connection regions are the most critical areas for stress concentration and require special reinforcement for enhanced durability and crash resistance.

The review further indicates that most existing studies focus mainly on static structural analysis, while fewer investigations address fatigue, crashworthiness, torsional rigidity, NVH (Noise, Vibration, and Harshness), and real-world dynamic loading conditions. Additionally, there is limited research on composite chassis applications specifically for two-wheelers and dedicated EV skateboard platforms.

Overall, the literature confirms that lightweight composite and hybrid chassis structures have strong potential for future EV applications due to their superior strength-to-weight ratio, corrosion resistance, and energy efficiency. However, further research involving experimental validation, dynamic analysis, crash testing, cost optimization, and multi-material integration is necessary to develop reliable, safe, and commercially viable electric vehicle chassis systems.

2.1 Problem Statement

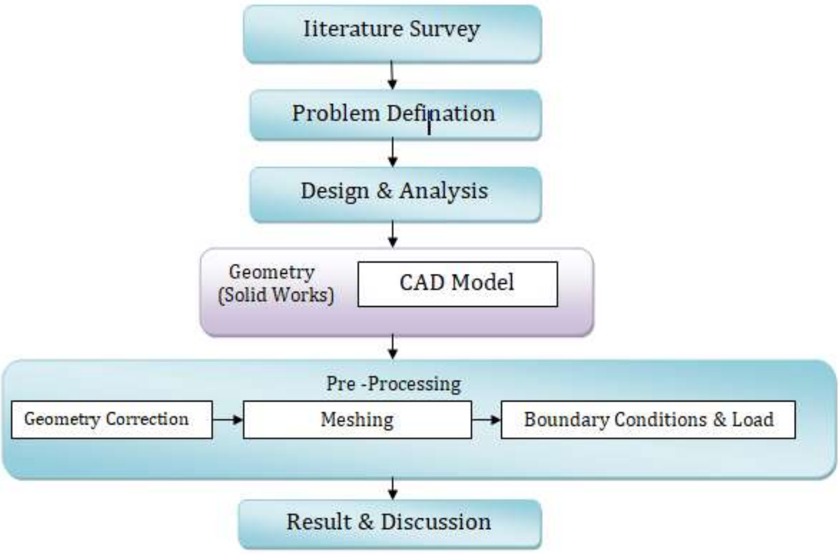
The increasing adoption of battery-electric vehicles (BEVs) requires chassis designs that safely accommodate high-capacity battery packs while minimizing vehicle mass, preserving structural integrity, and meeting crash and thermal-management requirements. Current EV chassis solutions often treat batteries as add-on components, resulting in suboptimal packaging, increased mass, compromised crash performance, and inefficient thermal paths. This research aims to design and analyze an integrated EV chassis that houses the battery as a structural member—optimizing stiffness-to-weight, crashworthiness, thermal management, and manufacturability—using finite element analysis and multi-objective optimization.

2.2 Objectives

1. To design a skateboard-type electric vehicle chassis with an integrated battery system.
2. To analyze weight distribution and structural integrity of the chassis under various static and dynamic loading conditions.
3. To ensure a high factor of safety by optimizing the chassis structure for strength, stiffness, and durability.
4. To compare the result of chassis with different composite materials.

3. Methodology

Figure 2: Flow Chart



4. Selection of Material

Material selection plays a vital role in EV chassis design because the chassis must provide high strength, rigidity, crash safety, and lightweight performance while supporting heavy battery packs. In this study, a hybrid CFRP composite material is selected due to its excellent strength-to-weight ratio, high torsional stiffness, and superior crash energy absorption. Carbon fiber provides high structural rigidity, while glass fiber improves impact resistance and reduces manufacturing cost. The hybrid composite offers an efficient balance between safety, structural performance, thermal stability, manufacturability, and weight reduction, making it highly suitable for integrated electric vehicle chassis applications.

1. Aluminum Alloy

Aluminium is a lightweight, nonferrous material with excellent corrosion resistance and a high strength-to-weight ratio, making it suitable for electric vehicle chassis applications. Although it is generally weaker than steel, its mechanical properties can be significantly improved through alloying and heat treatment. In this project, Aluminium Alloy 6063-T6 is selected due to its good mechanical strength, toughness, corrosion resistance, workability, and surface finish. It is one of the most widely used and cost-effective heat-treatable aluminium alloys from the 6000 series. The material also offers good weldability and manufacturability, making it suitable for structural components such as EV chassis and vehicle frames where lightweight construction and durability are important.

2. Steel

Structural steel is widely used in engineering applications due to its excellent corrosion resistance, strength, and durability. Its corrosion resistance is mainly provided by chromium content, which forms a protective oxide layer on the surface. In this study, Grade 317 structural steel is considered because it contains higher chromium, nickel, and molybdenum content than conventional grades, providing improved strength and corrosion resistance. The material also offers good weldability, toughness, and suitability for various manufacturing processes such as stamping, drawing, and hot working. However, it has relatively low machinability due to work hardening characteristics. Owing to its high structural strength and corrosion resistance, 317 structural steel is suitable for chassis and structural automotive applications.

3. Carbon Fiber

Carbon Fiber Composite material is selected for the skateboard chassis due to its high strength-to-weight ratio, excellent stiffness, corrosion resistance, and superior durability. Compared to conventional materials, carbon fiber composites provide significant weight reduction while maintaining high structural strength and rigidity. These properties improve the overall performance, stability, and load-carrying capacity of the skateboard chassis. Therefore, Carbon Fiber Composite is considered one of the most suitable materials for lightweight and high-performance skateboard chassis applications.

4. Glass Fiber

Glass Fiber Reinforced Polymer (GFRP) is selected for the skateboard chassis because of its lightweight nature, good mechanical strength, corrosion resistance, and cost-effectiveness. Compared to conventional metals, GFRP provides reduced weight while maintaining sufficient stiffness and structural performance. It also offers good impact resistance, vibration damping, durability, and ease of manufacturing. Due to these advantages, GFRP improves the stability, performance, and service life of the skateboard chassis, making it a suitable material for lightweight and durable EV chassis applications.

Table 1-Material Properties

Material	**Aluminum Alloy**	**Steel**	**CFRP**	**GFRP**
Modulus of Elasticity (GPa)	69.5	210	200	90
Poisson's Ratio	0.3	0.3	0.1	0.3
Modulus of Rigidity (GPa)	24	70	33	56
Density (Kg/m3)	2710	7830	1600	2000

This table indicates the properties of composite materials such as CFRP (carbon fiber reinforced plastic), GFRP (glass fiber reinforced plastic), Aluminum Alloy and conventional steel. As per these properties the values are assigned for the analysis in the Ansys software.

5. Design and Modelling of BEV Chassis

The CAD model of the battery electric vehicle (BEV) chassis was developed using SolidWorks after finalizing the structural dimensions. The chassis was designed using parametric modeling techniques, allowing easy modification of dimensions through an external file for future design improvements. Simple rectangular section profiles were used to maintain a simplified structural layout while ensuring effective analysis.

To support the Design of Experiments (DOE) and Finite Element Method (FEM) analysis, the chassis was modeled as a surface model instead of a solid model. This approach simplified meshing, reduced geometry cleanup, and improved simulation efficiency. Rails and cross-members were modeled using external surfaces so that thickness modifications would not affect the overall external dimensions of the chassis.

Figure 3: CAD Model of BEV Chassis

6. Analysis of BEV Chassis

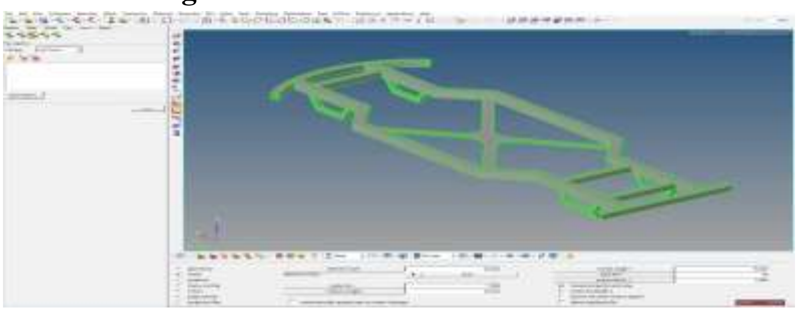
1. Finite Element Method (FEM)

Finite Element Method (FEM) is a numerical and approximate analysis technique used to simulate the behavior of physical components and structures under different loading conditions. In FEM, the geometry of a part is divided into small standard-shaped elements, and mathematical equations are applied to calculate parameters such as stress, deformation, temperature, and pressure. The behavior of all individual elements is combined to predict the overall response of the complete structure. FEM enables efficient and accurate analysis by performing calculations at selected points and interpolating the results over the entire surface or volume of the model.

2. Mesh generation

Mesh generation is an important step in Finite Element Modeling (FEM), where the geometry is divided into small quadrilateral surface elements for analysis. These elements form interconnected nodes and links that help calculate stress, displacement, and structural behavior under applied loads. The mesh elements are assigned material properties and wall thickness values, making accurate property assignment essential for obtaining reliable simulation and analysis results.

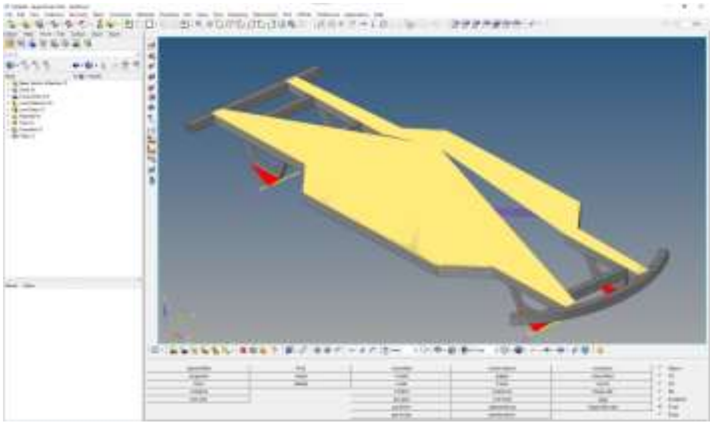
Figure 4: Meshed Models of Chassis



6.1 Loads/Boundary Conditions

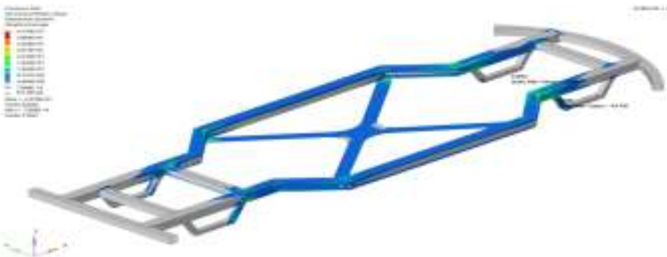
Typical boundary conditions include fixing the suspension mounting points or wheel locations to restrict unnecessary movement of the chassis. Loads are applied to represent the weight of the battery pack, passengers, motor, and other vehicle components. Additional forces such as vertical loads, torsional loads, braking forces, and impact loads may also be applied to study the structural response of the chassis. These loading conditions help identify critical stress regions, evaluate load-carrying capacity, and optimize the chassis design for strength, safety, and lightweight performance.

Figure 5: Boundary Conditions for Chassis



6.2 Results & Discussion

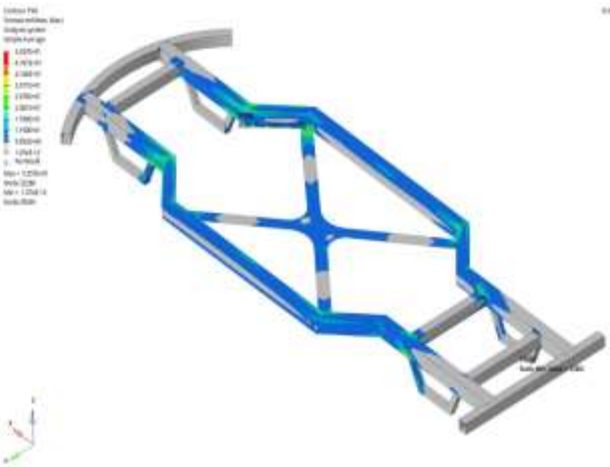
1. Results for Alluminum Alloy



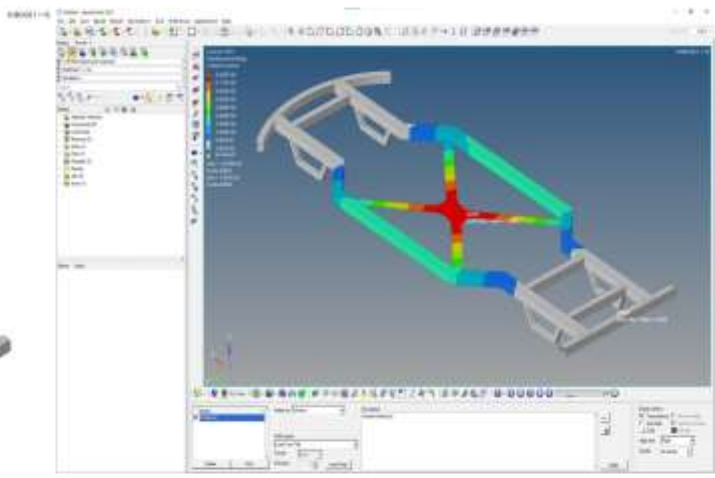
Stress analysis of conventional steel

Deformation of conventional steel

2. Results for Steel

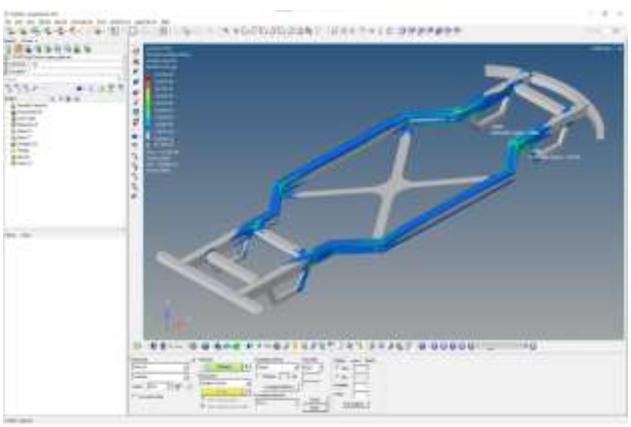


Stress analysis of steel

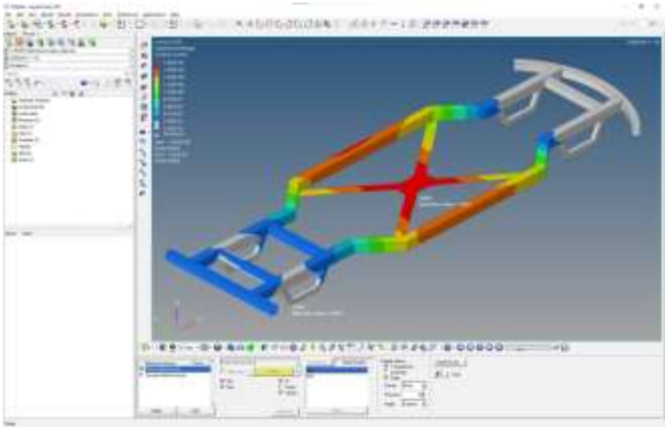


Deformation of steel

3. Results for Carbon Fiber

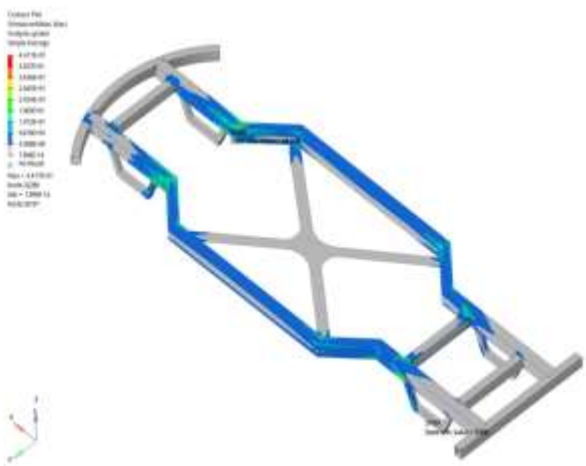


Stress analysis of Carbon Fiber

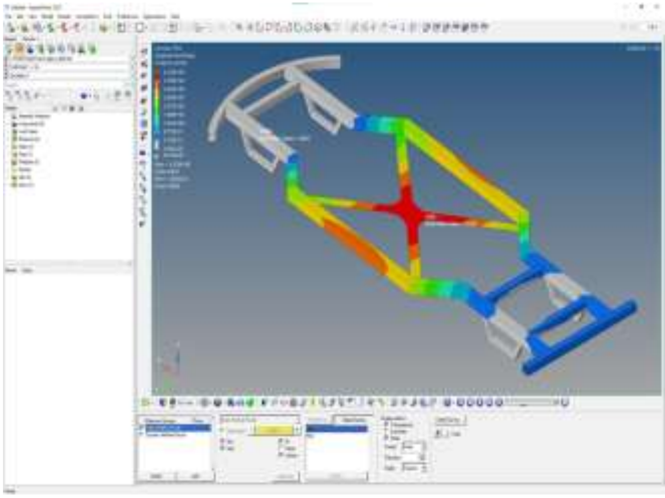


Deformation of Carbon Fiber

4. Results for Glass Fiber



Stress analysis of Glass Fiber



Deformation of Glass Fiber

7. Results and Discussion

Among all the materials analyzed, Carbon Fiber exhibits a comparatively low total deformation value of 1.842 mm, which indicates higher stiffness and better structural rigidity under loading conditions. Although Structural Steel shows the highest equivalent stress value of 53.566 MPa, it also produces the maximum deformation of 4.629 mm and increases the overall weight of the chassis. Aluminum and Glass Fiber provide moderate stress values, but their deformation is higher compared to Carbon Fiber.

Carbon Fiber composite offers an excellent strength-to-weight ratio, lightweight characteristics, high stiffness, and superior durability, which are essential requirements for EV skateboard chassis applications. The reduced deformation improves vehicle stability, handling performance, and structural safety while also minimizing the overall weight of the electric vehicle, thereby improving battery efficiency and driving range.

Therefore, based on the obtained analysis results, Carbon Fiber is recommended as the best material for manufacturing the EV skateboard chassis.

7. 1 Obtained Result

After assigning load to chassis and fixing the support, stress analysis is performed in ANSYS workbench and the following results were observed in chassis analysis.

Table 2- Obtained Result

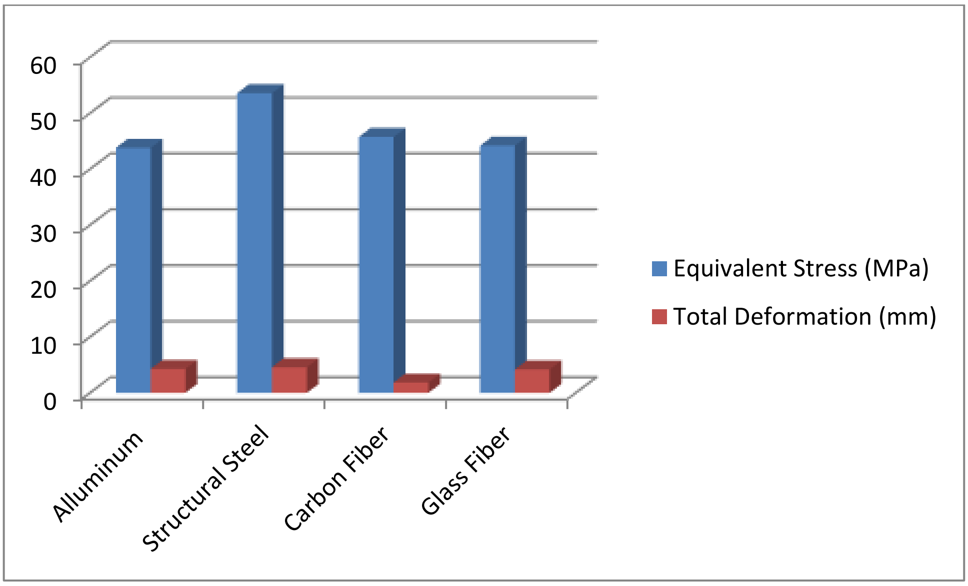
Material	Equivalent Stress (MPa)		Total Deformation (mm)	
Values	**Max**	**Min**	**Max**	**Min**
Alluminum	43.791	0	4.347	0.073
Structural Steel	53.566	0	4.629	0.018
Carbon Fiber	45.731	0	1.842	0.016
Glass Fiber	44.174	0	4.235	0.047

The comparative analysis of different chassis materials shows significant variations in stress distribution and deformation behavior. Structural steel exhibits the highest equivalent stress value of 53.566 MPa and the highest total deformation of 4.629 mm, indicating greater structural loading and displacement under the applied conditions. Aluminum shows comparatively lower stress (43.791 MPa) with moderate deformation of 4.347 mm due to its lightweight nature and good strength-to-weight ratio.

Among all the materials, carbon fiber demonstrates the best structural performance with very low total deformation of 1.842 mm while maintaining acceptable stress levels of 45.731 MPa. This indicates its superior stiffness, high strength-to-weight ratio, and better resistance to deformation. Glass fiber also provides lower stress values (44.174 MPa) with deformation slightly lower than aluminum and steel, making it a suitable lightweight alternative.

Overall, the results indicate that composite materials, especially carbon fiber, provide improved structural performance and reduced deformation compared to conventional metallic materials. Therefore, carbon fiber can be considered the most effective material for lightweight and high-strength electric vehicle skateboard chassis applications.

Graph 1- Stress & deformation Comparison



Conclusion

This project work investigated the structural performance of an EV skateboard chassis using four materials: Aluminum Alloy, Structural Steel, Carbon Fiber Composite, and Glass Fiber Composite. Finite Element Analysis (FEA) was conducted to evaluate equivalent stress and total deformation under loading conditions.

The results showed that all materials could safely withstand the applied loads; however, their deformation behavior varied significantly. Structural Steel exhibited the highest stress and deformation, while Aluminum Alloy and Glass Fiber showed moderate performance. Among all materials, Carbon Fiber Composite demonstrated the best structural performance with the lowest deformation of 1.842 mm, indicating superior stiffness and stability.

Due to its high strength-to-weight ratio, lightweight nature, corrosion resistance, and durability, Carbon Fiber Composite was identified as the most suitable material for the EV skateboard chassis. Its use can reduce vehicle weight, improve structural efficiency, and enhance the overall performance and driving range of electric vehicles.

Future scope

The present work can be extended further to improve the performance, safety, and practicality of EV skateboard chassis design. Future research may focus on dynamic and crash analysis to evaluate the chassis behavior under real-world operating and impact conditions. Fatigue and durability studies can also be performed to investigate the long-term structural performance of the chassis under repeated loading cycles.

Advanced optimization techniques may be applied to further reduce the chassis weight while maintaining structural strength and stiffness. Hybrid composite materials combining carbon fiber with glass fiber or other advanced materials can be explored to achieve a balance between performance and manufacturing cost. Experimental validation through prototype fabrication and physical testing can also be conducted to verify the Finite Element Analysis (FEA) results.

Further studies may include thermal analysis of the integrated battery pack and chassis system, vibration and NVH (Noise, Vibration, and Harshness) analysis, and topology optimization for improved structural efficiency. In addition, future work can investigate sustainable and recyclable composite materials to support environmentally friendly electric vehicle development. These improvements can help develop safer, lighter, and more energy-efficient EV skateboard chassis systems for next-generation electric mobility applications.

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