Topology Optimization of Electric Vehicle Chassis Design using CATIA 3D Experience

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ABSTRACT

The rapid growth of electric vehicles (EVs) has created a need for lightweight, high-performance chassis designs that enhance efficiency, safety, and durability. This study focuses on the design and optimization of an EV chassis using CATIA analysis to improve structural integrity while minimizing weight. The research involves modeling the chassis framework, conducting finite element analysis (FEA)for stress distribution ,and optimizing the design for better load-bearing capacity and crashworthiness. The proposed methodology ensures an optimal balance between strength and weight, contributing to improved vehicle performance and energy efficiency. The findings of this study can serve as a foundation for future advancements in EV chassis development, aligning with the growing demand for sustainable and high- performance electric mobility solutions.

Keywords : Electric vehicles ,Topology optimization, FEA and CATIA analysis.

INTRODUCTION

The transportation landscape is under go in gas significant shift towards sustainable solutions. Electric vehicles (EVs) are playing a pivotal role in this transition, offering cleaner and more efficient alternatives to traditional gasoline-powered options. Within the EV segment, electric all-terrain vehicles (EATVs) are gaining traction due to their ability to navigate diverse terrains with minimal environmental impact. Conventional chassis designs for all-terrain vehicles (ATVs) prioritize strength over weight, a strategy well-suited for combustion engines but detrimental to EATV performance. The increased weight translates to reduced efficiency and limited range ,two key limitations for ATVs. To address this challenge, this study focuses on the development of a novel, lightweight tubular chassis specifically tailored for EATVs .The Indian market for all-terrain vehicles(ATVs)is currently dominated by traditional petrol-powered models ,with a element for both vehicle capability and driver protection.[1].Race car chassis design is a balancing act. It needs to be stiff to fight twisting forces in corners for precise handling ,but also light weight for better acceleration and agility .This is achieved through special materials and simulations, with the goal of a responsive car that stick to the track.[2]The granular approach provides an accurate understanding of the model's overall behavior under various conditions. [3] This paper investigates chassis safety through several tests: frontal crash, rear impact, side collision, rollover, bumps, and torsion. These simulate real-world stresses to ensure the chassis protects occupants in all crash scenarios. [4] The roll cage prioritizes occupant safety in crashes, especially rollovers, through its high-strength ,impact-absorbing design .While offering secondary mounting and stiffness benefits, its core function is protecting the occupant's life. [5] The BAJA SAE India rulebook dictates the CAD model's construction, employing a three-tiered member system. Primary members, built for maximum strength, form the core of the chassis. Secondary members offer additional support, while tertiary members focus on nonstructural functions like mounting components. This ensures a safe, strong, and lightweight chassis that adheres to competition regulations. [6] Reducing weight while maintaining strength is a top priority. It leads to performance improvements (handling, prosthetics) and environmental benefits (less material). Advanced materials and manufacturing are making this lighter, stronger future a reality.[7] For in creased range and efficiency, a high strength-to weight ratio is key .Engineers consider not just the material properties but also availability and manufacturability to find the optimal balance for safety, efficiency, and cost effectiveness. High-strength steel alloys are an affordable option. [8] However, the integration of a powerful electric motor and battery pack presents unique design challenge s .The weight distribution needs careful consideration to maintain optimal handling, while the chassis must possess the structural integrity to withstand the high torque generated by the vehicle.

Objectives of the Project

Primary Objectives:

Markets size estimated at USD 470.55 millionin2023[Next· Minimize Weigh t:OptimizetheEVchassisdesigntoreduceMove Strategy Consulting]. However, a nascent electric ATV weight while maintaining structural integrity and performance. Segment beginning to take shape, present in intriguing2.Maximize Stiffness: Improve the stiffness of the EV chassis to Possibilities for the future. While electrical Vs currently hold a small portion of the overall ATV market, industry analysts predict significant growth for the electric segment. Enhance handling, stability, and safety. Optimize Material Usage :Reduce material waste and optimize material distribution to minimize production costs.

According to Next Move Strategy Consulting ,then tire3.Improve Crash worthiness:Enhance the crash worthiness of the EV Indian ATV and UTV market, including both electric and petrol, is expected to reach USD 929.98 million by 2030, indicating Compound Annual Growth Rate(CAGR)of9.4% from 2024 to 2030 [Next Move Strategy Consulting]. This growth suggests apathetical increase in electric ATV adoption. chassis to meet regulatory requirements and ensure occupant safety. Reduce Production Costs: Minimize production costs by optimizing the design for manufacture ability and reducing material usage.

Secondary objective

Alongside the rise of the overall market

1.ImproveNVH(Noise, Vibration ,and Harshness)Performance:

Optimize the EV chassis design to reduce NV Hand improve

The BAJA SAE vehicle's chassis, or roll cage, is the core structure. It supports all components, prioritizing both strength and light weight design for optimal performance. Functioning a s a safety cage during rollovers ,the chassis is a crucial. overall vehicle refinement. Enhance Durability: Improve the durability of the EV chassis to extend its lifespan and reduce maintenance cost

1.Literature Review and Requirement Analysis

- Study existing EV chassis designs and their structural performance.
- Identify key design parameters ,material selection, and performance criteria.
- Define weight ,strength ,and safety requirements based on industry standards.
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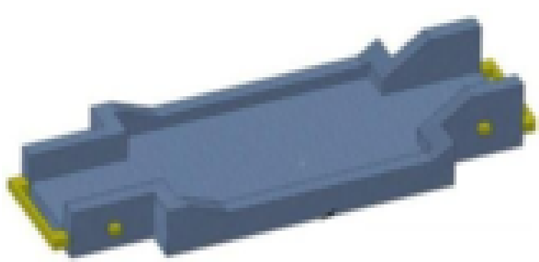
2.Conceptual Design and CAD Modeling

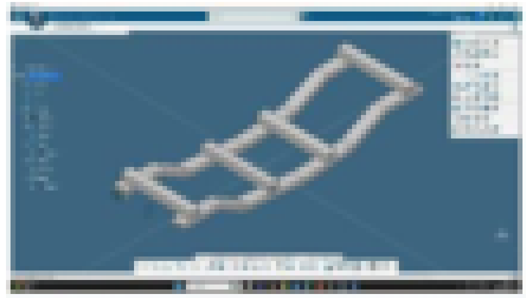
- Developaninitial3DCADmodelofthechassis using CATIA V5**.**
- Consider vehicle dimensions, weight distribution, and structural framework**.**
- Incorporate material properties such as aluminum alloys or high-strength steel for lightweight and durability.



3. Finite Element Analysis (FEA) in CATIA

- Apply static and dynamic loads to simulate real- world conditions.

- Perform stress ,strain ,and deformation analysis to assess structural integrity.
- Identify weak point sand area requiring reinforcement.

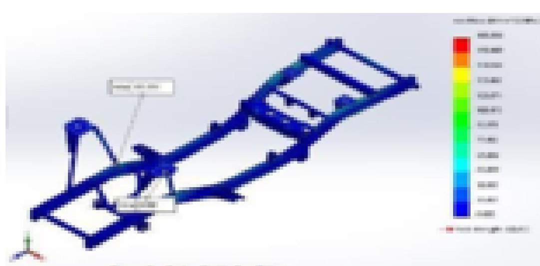


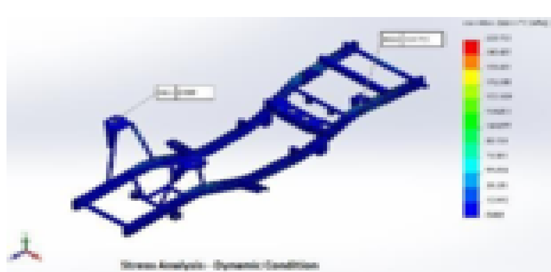
4.TopologybOptimization

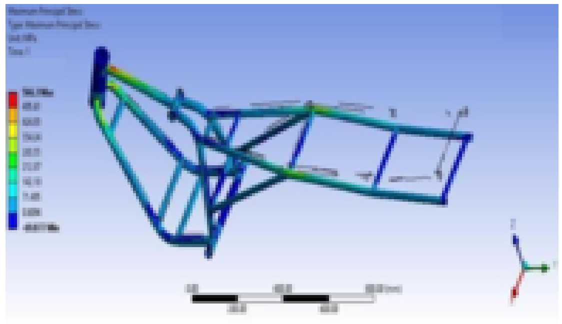
- We CATIA and FEA tool s to optimize material distribution for weight reduction.
- Implement design modifications while ensuring structural strength and performance.
- Improve the crash worthiness and load-bearing capacity of the chassis

5.vadidation and simulation testing

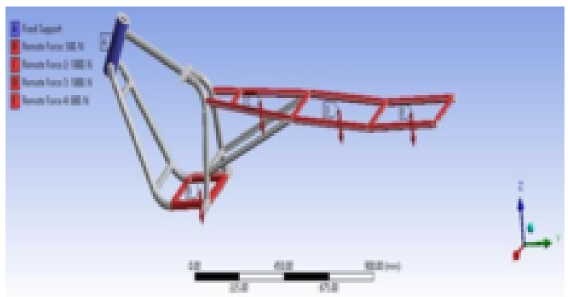
- Conduct impact and crash wortthiness tests to evaluate safety standards.
- Perform modal analysis to check vibration.
- Compare optimized chassis performance with the intial design.







Max principle stress



Loading Conditions

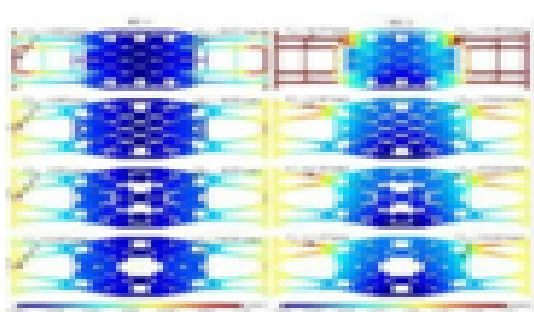
6. Prototype Development and Manufacturing Feasibility

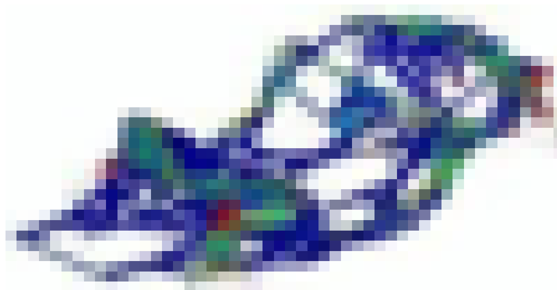
- Assess the manufacturability of the optimized design.
- Consider cost-effective materials and production methods such as welding ,casting ,or 3Dprinting**.**

This methodology ensures a high-performance, lightweight, and cost-effective EV chassis design using CATIA analysis**,** aligning with industry trends toward sustainability and efficiency**.**

RESULTS AND DISCUSSIONS

Topology is the mathematical study of shapes, spaces, and their properties under continuous transformations such as stretching, bending ,and twisting ,without breaking or tearing. It focuses on the fundamental spatial relationships between objects rather than their specific geometric measurements.

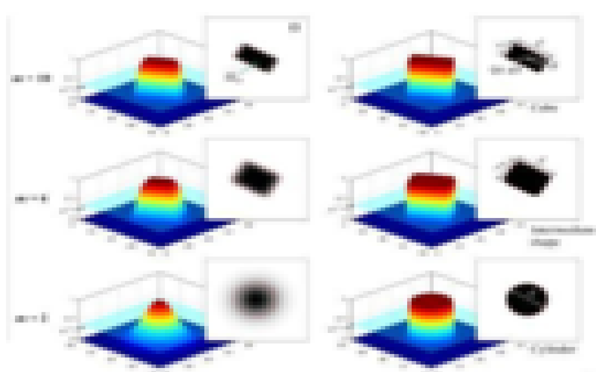


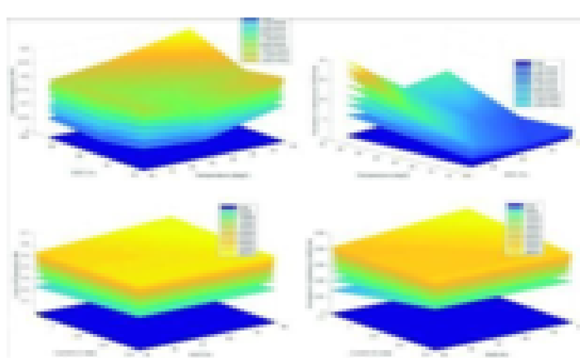


Topology Optimization

Topology optimization is a computational design process used to determine the most efficient material layout with in a given design space while satisfying performance constraints. It helps create lightweight, high-strength, and structurally efficient components by removing unnecessary material while maintaining functionality.

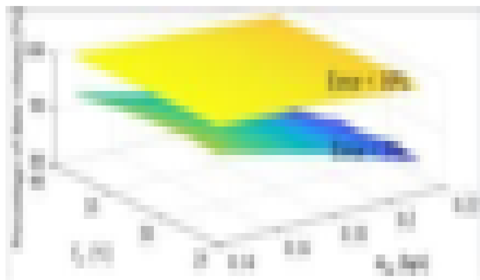
1. Material Distribution: Determines the optimal placement of material within a design space to achieve the best structural performance.
2. Objective Function: Optimizes parameters such as weight reduction ,stiffness maximization ,or stress minimization.
3. Constraints :Includes manufacturing constraints ,load- bearing capacity, and safety factors.
4. Iterative Process :Use s simulation techniques like Finite Element Analysis(FEA)tore fine the design iteratively.

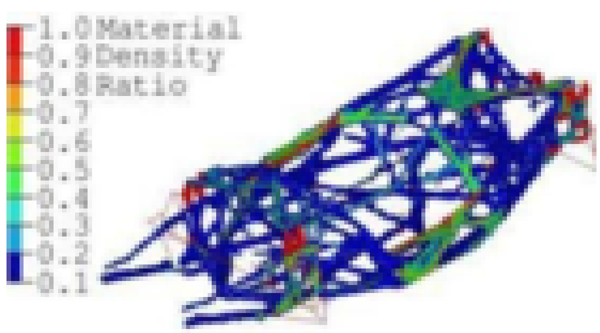




Applications of Topology Optimization:

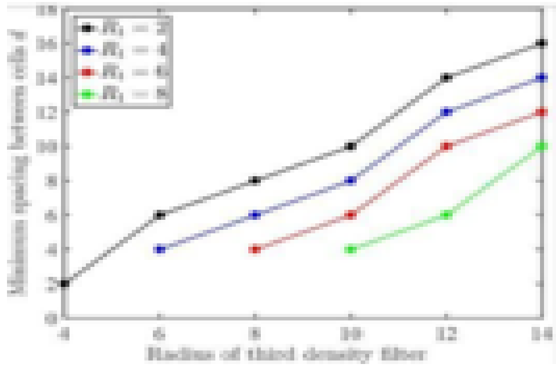
- Automotive Industry: Lightweight chassis, optimized suspension components, and crash-resistant structures.
- Aerospace Engineering :Reduced-weight aircraft structures with high strength-to-weight ratios.
- Civil Engineering :Efficient bridge and building structures for enhanced durability.
- Biomedical Engineering: Custom implants and prosthetics with optimized material usage.





Benefits o f Topology Optimization:

- Reduces material waste and manufacturing costs
- Improves structural strength and durability
- Enhances energy efficiency In auto motive and aerospace applications
- Supports sustainability by minimizing resource usage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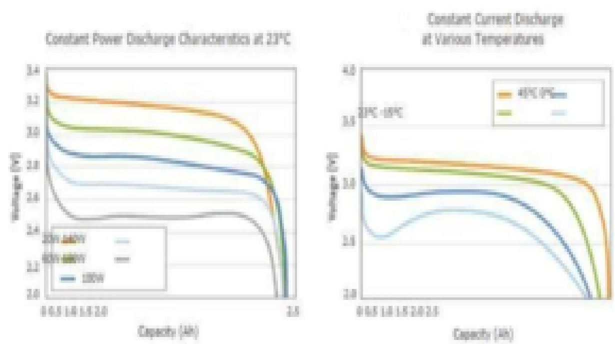
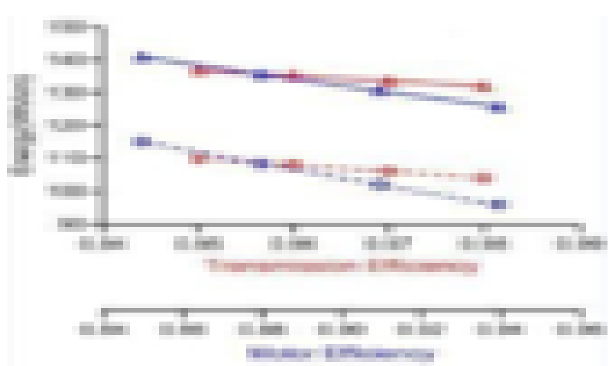
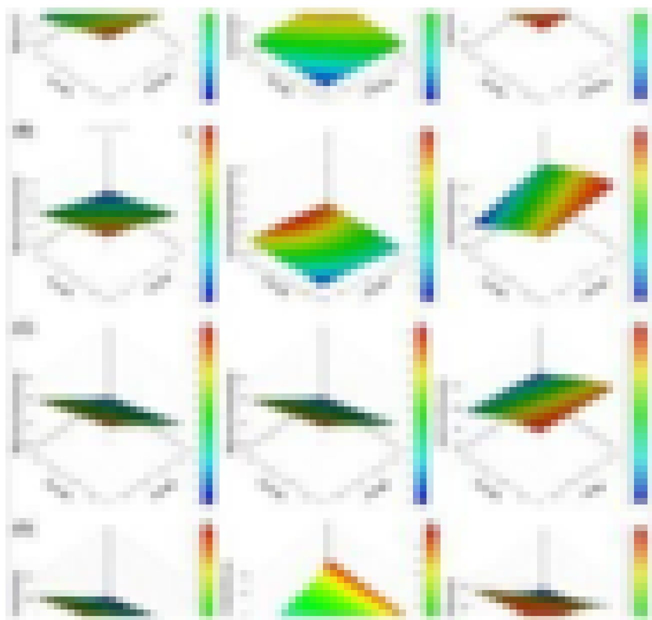

Constant Power Discharge Characteristics at 23°C
Constant Current Discharge
at Various Temperatures
Capacity (Ah)
Capacity (Ah)

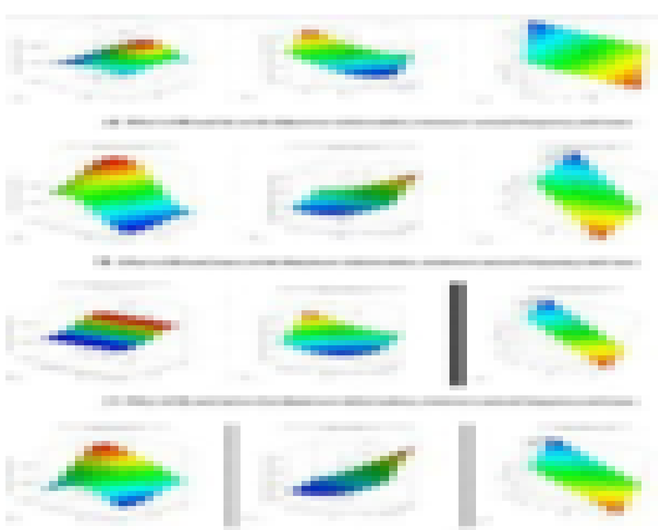

Transmission Efficiency
Motor Efficiency

Software for Topology Optimization:

- CATIA ,ANSYS, Abacus , Solid Works ,Altair OptiStruct , COMSOL Multi physics

In Electric Vehicle (EV) chassis design, topology optimization is crucial for reducing weight while maintaining high crashworthiness, load-bearing capacity, and durability, leading to improved energy efficiency and vehicle performance. Topology optimization is a mathematical method that finds the most efficient material distribution within a defined space, optimizing design by removing material based on constraints and loads, aiming to maximize performance and minimize cost.





CONCLUSION

The study successfully demonstrates the design and optimization of an Electric Vehicle (EV) chassis using CATIA analysis, ensuring a balance between lightweight construction, structural integrity, and performance efficiency. Through finite element analysis (FEA),the optimized chassis exhibits enhanced load-bearing capacity, improved crashworthiness, and reduced weight, leading to better energy efficiency and vehicle safety. The findings contribute to the development of sustainable, high-performance EV chassis designs, providing a foundation for future innovations in electric mobility and automotive engineering. This research highlights the potential of advanced simulation tools in optimizing vehicle components, paving the way for more efficient, cost-effective, and environmentally friendly electric vehicles.

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