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COMPARATIVE ANALYSIS OF ELECTRIC BIKE CHASSIS USING DIFFERENT MATERIALS

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Abstract

The future of automotive industry is to design and develop electrical vehicles to control the emissions released from gaseous fuels and not to release any harmful gases into atmosphere. A chassis is a core structure of an electric bike, supporting all the components and providing the necessary strength, stability, and comfort for the rider. The greater capability to absorb the vibrations generated in the vehicle and maintain the amplitude of frequency in the acceptable range. Hence, materials properties of the chassis frame plays a vital role to with stand the loads acting on it and produce lower deformations against various types of loads acting on it. The values of equivalent von Mises stress and total deformation for all the materials are observed, after performing static Analysis. The best material which is considered for fabrication.

Keywords: Two-wheeler chassis frame, Static analysis

1. INTRODUCTION

The automotive sector is widely recognized as a key driver of economic growth in any country. Technological advancements have significantly contributed to the evolution of this industry, enabling the development of innovative vehicle designs that meet stringent consumer demands. These demands include enhanced braking performance, improved safety features, cost efficiency, and attractive aesthetics. A current and prominent trend in the automotive industry is the transition toward the design and development of electric vehicles (EVs). The goal is to provide performance levels comparable to those of traditional petrol and diesel vehicles while addressing environmental concerns. As a result, many automotive companies are actively investing in the creation of zero-emission vehicles that align with global sustainability goals. Based on various research studies conducted in the field of electric bikes (E-bikes), it has been observed that the selection of materials plays a crucial role in withstanding the loads acting on the chassis. The behavior of a two-wheeler electric bike chassis is analyzed under static and impact loading conditions by varying the material properties of the frame.

2. LITERATURE REVIEW

Malikasab Bagawan, M. Vamsi Krishna Et.al.[1] in May 2023, works on Design and analysis of electric motorcycle chassis frame to design and create a lightweight chassis compared to conventional ones which was also sturdy, safe, and cost-effective.

Naresh Kumar Konada, Koka Naga Sai Suman [2] in March 2020, works on Analysis on two-wheeler chassis frame of E-bike subjected to static and impact loads-composite material with proper fabrication methodology can replace the metals used in E Bike technology and produce higher stiffness to weight ratio, lower deformation and with stand higher loads closer to metals.

Vignesh.M, Dr. Arumugam K, Vinoth's, Hariharan.S[3] in Jan 2019, Works on Design and Analysis of Frame of an Electric Bike-Superior and effective vehicle structure depending upon the various requirements. Different material can be substituted and analyzed for better efficiency, but still the material availability, machinability and cost play a major role in selection of different material.

P. Jeyapandiarajan, G. Kalaiarassan, J. Joel [4]in 2018, Works on Design and Analysis of Chassis for an Electric Motorcycle-To design the chassis for electric motorcycle analyzing different material for chassis used and Comparison of parameters by Analysis software ANSYS.

Ms. Priyanka Pandit Kore, Prof. H. D. Lagdive [5] in 2018, Works on Comparative Finite Element Analysis of different materials for Bike Chassis to reduce weight-In this work, different analysis techniques for automobile frame are studied under different loading conditions. The loading may be static or dynamic and studied analytical techniques available for automobile frame analysis.

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Problem Statements

- Excessive Weight: A heavier chassis reduces the bike's range by increasing energy consumption. It affects acceleration and handling, making the ride less agile.
- Stress Concentration: Certain areas of the chassis experience higher stress, leading to potential cracks or fatigue failure.
- Limited Durability: Continuous exposure to vibrations and road impacts can degrade the chassis over time. Material fatigue leads to reduced lifespan, requiring frequent maintenance or replacement.
- Material Selection: The right material choice enhances performance while maintaining safety standards.

Importance of selection of proper material for electric bike chassis

- Selecting the right material for an electric bike chassis is crucial for performance, durability, and safety.
- Strength and Durability: The chassis must withstand stress from road conditions, rider weight, and vibrations. High-strength materials enhance longevity.
- Weight Optimization: A lighter chassis improves battery efficiency and overall ride quality.
- Safety and Stability: The material affects the bike's ability to absorb shocks and impacts, ensuring a stable and secure ride.
- Corrosion Resistance: Exposure to moisture and environmental factors can degrade certain materials.
- Manufacturing Feasibility: Some materials are easier to mold and weld, impacting production costs and design flexibility.

Objectives

- To study the working of automobile chassis.
- To study the design procedure of chassis.
- To investigate the forces and loads acting on chassis.
- To prepare 3D CAD model of chassis.
- To perform finite element analysis of chassis on different material
- Comparative analysis of electric bike chassis using different materials.
- To optimize the chassis structure for weight reduction without compromising strength and safety.
- To evaluate the impact of different road and loading conditions on chassis performance.
- To recommend the most suitable material for electric bike chassis based on performance, cost, and sustainability criteria.

Methodology

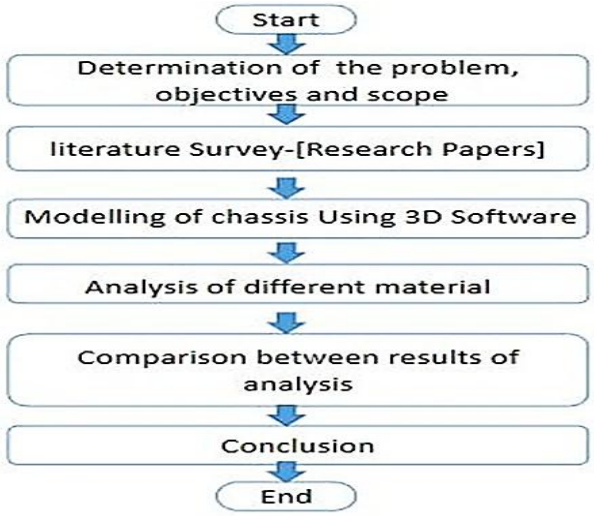

Figure 1 Diagram of Methodology

Chassis Structural Analysis

Once the basic parameters are determined, the chassis must undergo rigorous structural analysis to ensure that it can withstand all expected loads and conditions. FEA is commonly used in chassis design to simulate and analyze how forces, vibrations, and stresses affect the frame. The model is broken down into a mesh of smaller elements, each of which is analyzed individually to determine how the entire structure behaves under different load conditions. Following are the Key FEA Steps:

Model Creation: The 3D model of the chassis is created, often using CAD software like SolidWorks or CATIA.

Mesh Generation: The chassis model is subdivided into a mesh of small elements for easier analysis.

Boundary Conditions: Constraints are applied to simulate fixed points.

material selection-The material selection of an automobile plays a vital role for giving strength to the automobile. The load with standing capability primarily depends on the selection of materials.

Load Application: Loads are applied to the model based on real-world scenarios, such as rider weight, road bumps, braking forces, and wind resistance.

Analysis: The software calculates the stress, deformation, strain etc.

Material Properties

Table 1 Material Properties

Material	Density (kg/m3)	Youngs Modulus	Poisson Ratio	Yield Strength	Ultimate Tensile Strength
Aluminium Alloy	2780	73.080GPa	0.33	324.054MPa	468.843MPa
Stainless Steel	8000	193.00GPa	0.30	250.000MPa	540.00MPa
Mild Steel	7850	220.00GPa	0.275	207.00MPa	345.00MPa

Titanium Alloy	4510	102.81GPa	0.361	275.60MPa	344.50MPa
Carbon Steel	7850	200.00GPa	0.29	262.001MPa	551.581MPa
Grey Cast Iron	7395	81.496GPa	0.235	151.684MPa	179.263MPa
Structural Steel	7800	200.000GPa	0.26	248.211MPa	475.738MPa
Magnesium Alloy	1740	44.000GPa	0.35	115.000MPa	180.00MPa

Loading and boundary conditions applied on frame for performing static analysis

Table 2 Boundary Conditions

Boundary Condition	Parameters
Fixed Position	Front and Back Part of the Frame
Load applied on Frame	Total 1500N
Material of Frame	Aluminium Alloy, Stainless Steel, Mild Steel, Titanium Alloy, Carbon Steel Grey, Cast Iron, Carbon Fiber, Magnesium Alloy
Types of Meshing	Parabolic coarse fine mesh having 124201 nodes and 62445 elements.

3. STATIC ANALYSIS RESULTS OF MATERIAL

Aluminium Alloy

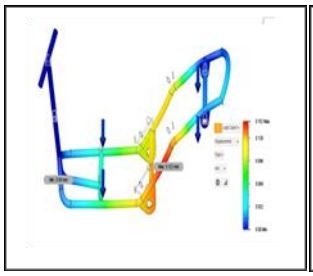

Figure 2 Total Displacement

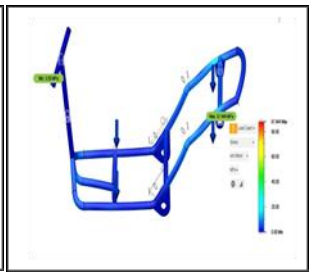

Figure 3 Equivalent Von Mises stress

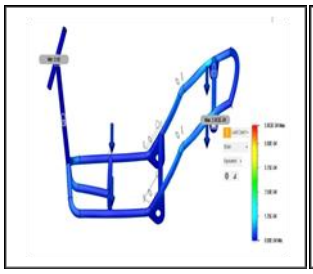

Figure 4 Equivalent Strain

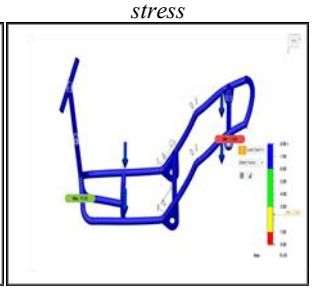

Figure 5 Factor of Safety

Stainless Steel

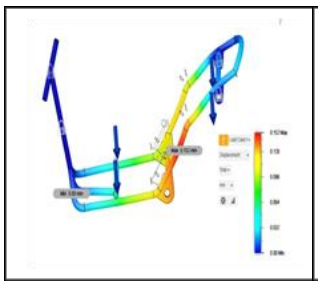

Figure 6 Total Displacement

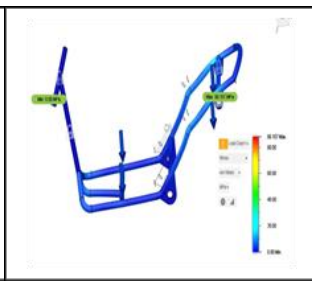

Figure 7 Equivalent Von Mises stress

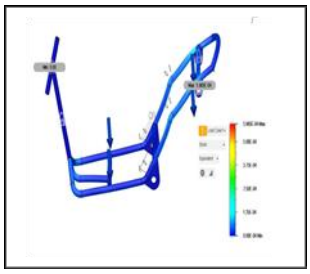

Figure 8 Equivalent Strain

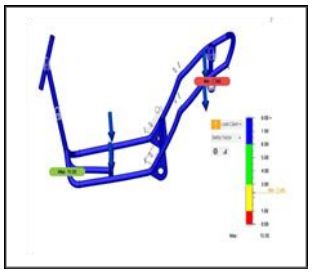

Figure 9 Factor of Safety

Mild Steel

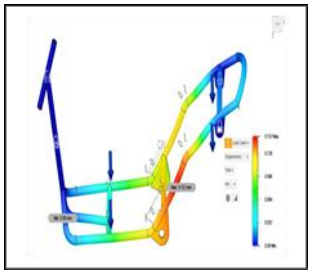

Figure 10. Total Displacement

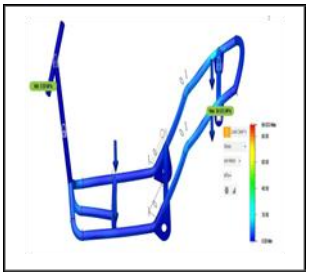

Figure 11 Equivalent Von Mises stress

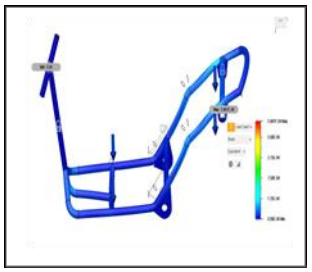

Figure 12 Equivalent Strain

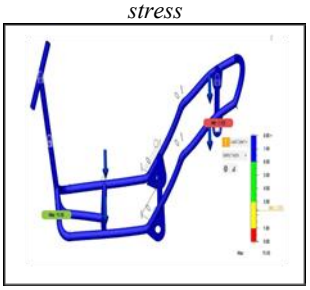

Figure 13. Factor of Safety

Titanium Alloy

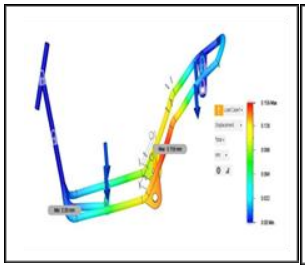

Figure 14 Total Displacement

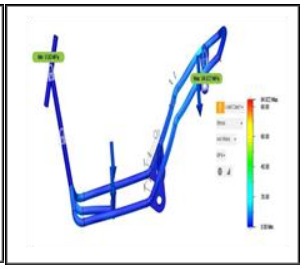

Figure 15 Equivalent Von Mises stress

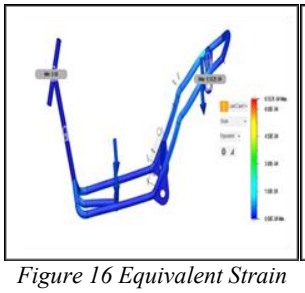

Figure 16 Equivalent Strain

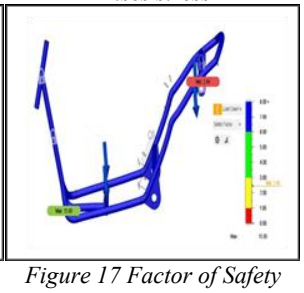

Figure 17 Factor of Safety

Carbon Steel

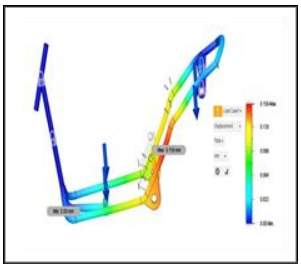

Figure 18 Total Displacement

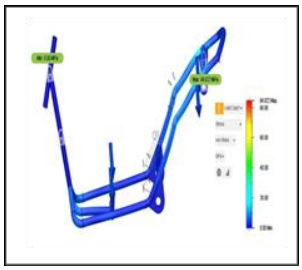

Figure 19 Equivalent Von Mises stress

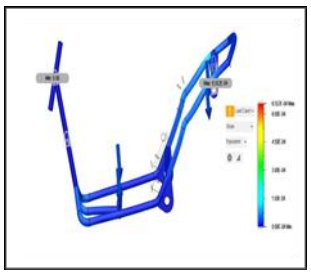

Figure 20 Equivalent Strain

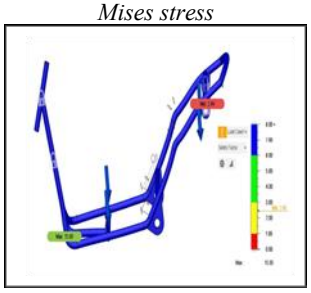

Figure 21 Factor of Safety

Grey Cast Iron

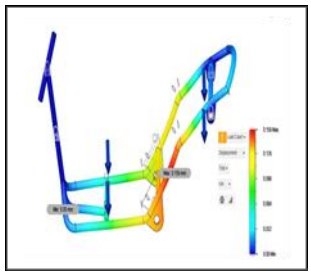

Figure 22 Total Displacement

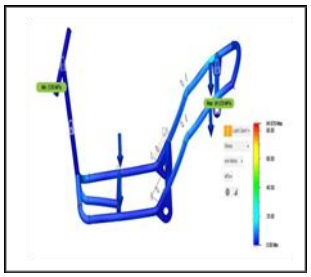

Figure 23 Equivalent Von Mises stress

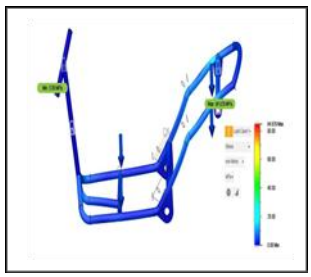

Figure 24 Equivalent Strain

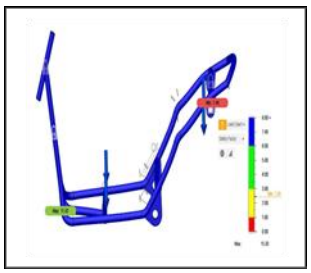

Figure 25 Factor of Safety

Structural Steel



Figure 26 Total Displacement

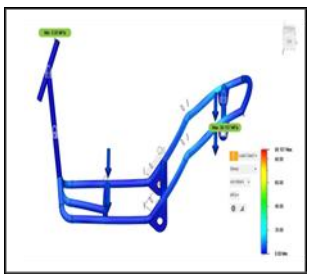

Figure 27 Equivalent Von Mises stress

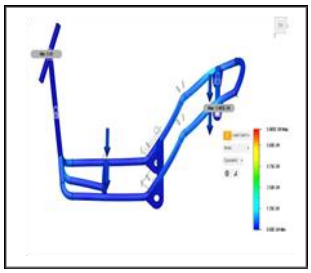

Figure 28 Equivalent Strain

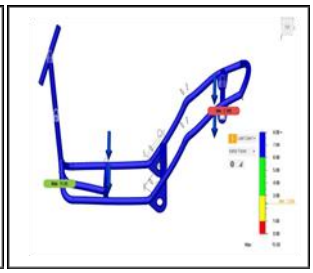

Figure 29 Factor of Safety

Magnesium Alloy

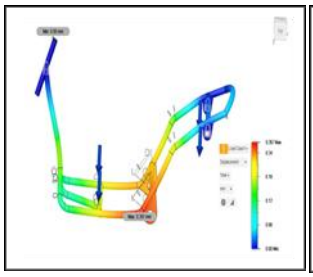

Figure 30 Total Displacement

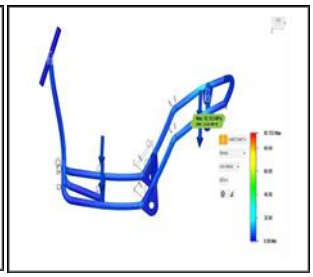

Figure 31 Equivalent Von Mises stress

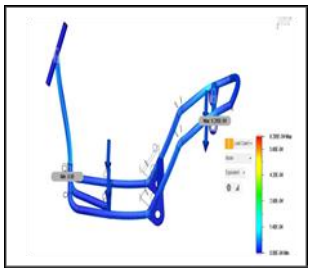

Figure 32 Equivalent Strain

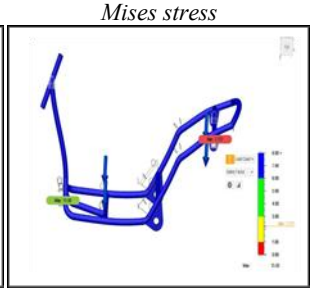

Figure 33 Factor of Safety.

4. VALUES OF PARAMETERS FOR ALL MATERIALS UNDER STATIC LOAD ANALYSIS

Table 3 Values of Parameters after analysis

Material	Total Displacement	Equivalent Von Mises stress	Equivalent Strain	Factor of Safety
Aluminium Alloy	0.152mm	87.994MPa	5.953E04	2.354
Stainless Steel	0.152mm	88.107MPa	5.965E04	2.349
Mild Steel	0152mm	88.633MPa	5.965E04	2.335
Titanium Alloy	0.159mm	84.822MPa	6.552E04	2.44
Carbon Steel	0.159mm	84.828MPa	6.553E04	2.44
Grey Cast Iron	0.159mm	84.829MPa	6.553E04	2.44
Structural Steel	0.152mm	88.107MPa	5.965E04	2.349
Magnesium Alloy	0.267mm	93.153MPa	6.285E04	2.222

5. COMPARATIVE ANALYSIS OF MATERIAL THROUGH GRAPHICAL REPRESENTATION

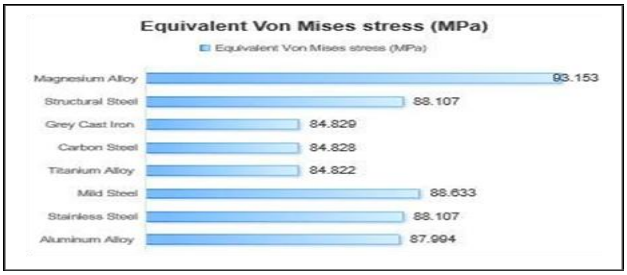

Figure 34 Graphical representation of Equivalent von Mises stress under static load for different materials

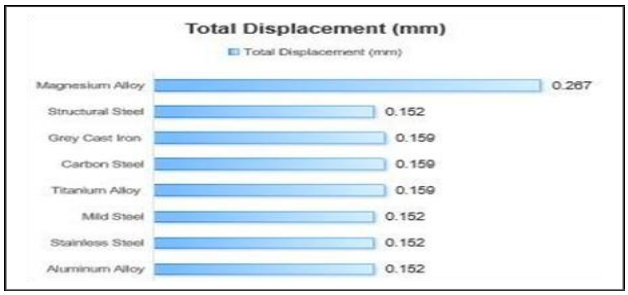

Figure 35 Graphical representation of Total displacement under static load for different materials

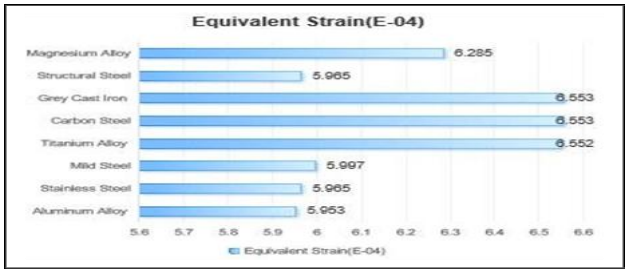

Figure 36 Graphical representation of Equivalent Strain under static load for different materials



Figure 37 Graphical representation of Factor of Safety under static load for different materials

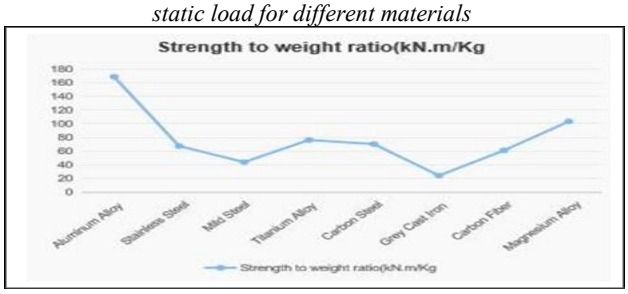

Figure 38 strength to weight ratio of materials

6. CONCLUSION

After performing static analysis on chassis frame by applying a load varying the materials of the bike Chassis, it was observed that: -

- Well-designed chassis Material will exhibit minimal displacement under typical operating conditions, ensuring stability and safety and in above analysis Aluminium Alloy exhibit minimum displacement.
- Higher equivalent strain in a bike chassis is generally not good because it indicates the material is being subjected to greater deformation and stress, potentially leading to failure and in analysis Aluminium Alloy exhibit lower equivalent strain.
- A higher factor of safety for a bike chassis is generally good, but it's a balance between safety and other factors like weight and cost. However, excessive safety factors can make the chassis heavier and more expensive, which might not be ideal for performance bikes or weight-sensitive applications. In analysis Titanium alloy, Carbon Steel, Grey Cast Iron have higher factor of safety but when compared with Aluminium alloy they are heavier. also, Titanium alloys more expansive than steel and aluminium.and minimum 2 factor of safety is recommended for electric bike chassis. so Aluminium and Steel material can fulfill above requirements.
- Higher equivalent stress in a bike chassis is not good. It indicates the frame is under a greater load, potentially leading to fatigue, cracking, and eventual failure. Lower equivalent stress occurs on Titanium alloy, Carbon Steel, Grey Cast Iron but same they are heavier as compared to other material.
- A higher strength to weight ratio is good for a Bike chassis. It means the chassis is strong and robust while also being lightweight, which leads to better performance and efficiency. Aluminum Alloy have higher strength to weight ratio. So as per Analysis of different material for Electric bike Chassis Aluminium Alloy exhibit minimum displacement, lower equivalent strain, recommended factor of safety, moderate equivalent stress and higher strength to weight ratio. so as per analysis Aluminium Alloy chassis is strong and robust while also being lightweight, which leads to better performance and efficiency.

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