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Research Article

Factor of Safety Analysis on the Automotive Chassis using Finite Element Method under Various Loading Conditions

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ABSTRACT

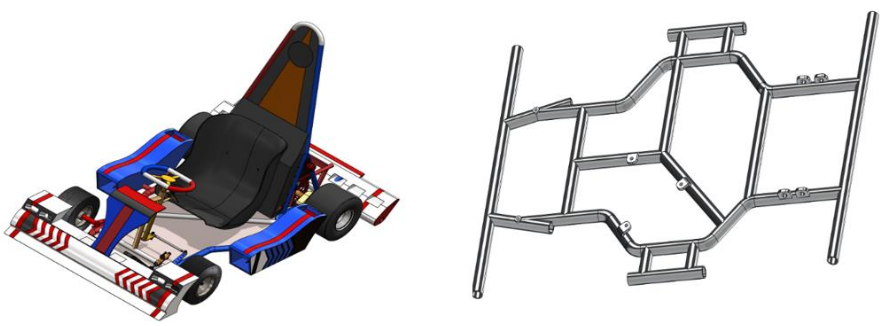
In this project, a Factor of Safety analysis was conducted on an automotive chassis using the Finite Element Method (FEM) under diverse loading conditions. Various materials, including titanium alloy, magnesium alloy, structural steel, boron, and aluminum alloy, were scrutinized. The objectives encompassed determining the for each material, assessing FOS under different loading scenarios and analyzing stress, strain, and deformation patterns. This comprehensive investigation yields insights into material suitability and structural integrity, offering valuable data for optimizing chassis design and ensuring safety across a spectrum of real-world usage scenarios.

Key words : Factor of safety , Elastic strain , Total Deformation , Shear Stress

1 INTRODUCTION

The chassis, often referred to as the vehicle's frame, serves as the fundamental support structure for all vehicles, comparable to a living organism's skeleton In essence, a chassis is the load-bearing framework that structurally sustains an object during its construction and operation. As go-karting has evolved, technological advancements and engineering innovations have played crucial roles in enhancing performance and safety. Among the critical components influencing a go-kart's performance, the chassis stands as the backbone of the vehicle. Typically constructed from lightweight materials such as tubular steel or aluminum, the chassis strikes a delicate balance between rigidity and flexibility. Chassis designs can vary considerably, with configurations tailored to specific racing disciplines. This research project delves into the intricate realm of go-kart chassis design, exploring key concepts, methodologies, and considerations that influence the construction of an effective, high-performance chassis and also conducted by [12]. By discretizing the chassis into finite elements and defining material properties, this analysis assesses stress distribution, deformation, and potential weak points. Its primary objective is to ensure chassis integrity within safety and performance limits while optimizing weight distribution. Ultimately, a well-structured chassis is essential for achieving competitive excellence in the world of go-karting.

Figure 1 Computed-Aided Design of Chassis



Literature review

- In response to the growing need for compact and easily transportable vehicles, the study by Raghuvanshi, at el [1]focuses on the design and development of a foldable GO KART named "ASHVA." This innovative vehicle features a foldable midsection with a robust joint connecting the front and rear chassis, ensuring both portability and structural strength. The research encompasses comprehensive design, strength analysis using ANSYS software, and subsequent development, promising a practical solution for compact urban mobility.
- Agarwal and Mathembu (2022), [2] compared metal matrix composite materials, Al GA 7-230 and Al6092/Sic/17.5p MMC, with conventional ST52E steel. The results demonstrated a substantial reduction in chassis mass, with values of 62.564 Kg and 71.502 Kg for MMC materials compared to 214 kg for structural steel, indicating significant weight-saving potential.
- Duchet et al. (2019) [3] aimed to enhance the fatigue strength of Gaz Metal Arc Welds in lightweight chassis applications using Advanced High Strength Steels. They investigated post-treatment methods and demonstrated weight-saving potential through quantifiable improvements in fatigue resistance.
- Conle et al. (1991)[4] focused on analysing the fatigue life of automobile chassis components by integrating automotive load history data and advanced computational methods. This research highlights the potential of vehicle dynamics modelling, finite-element analysis, and fatigue assessment for automotive component design, while emphasizing the need for further refinements in the durability process before practical engineering application.
- The focus was on enhancing the suspension attachment zone of FST Lisboa's formula student monocoque chassis. The research explored two reinforcement methods, inserts and chamfers, with variations in their geometry parameters. A finite element model was employed for comparative analysis, both independently and within a suspension quarter-car assembly. The most effective geometries were selected, leading to laminate layup optimization. To validate the numerical model, physical specimens were fabricated, and pull-out tests were conducted. The findings revealed that inserts outperformed chamfers, aligning well with theoretical predictions. These results were subsequently applied in the design and construction of the team's new monocoque prototype (2019)[5]. Mao and Wu (2022) [6]introduced a proactive dynamic chassis control method, integrating fuzzy logic and machine vision for road condition recognition. A camera captures road irregularities, and a neural network aids in pattern recognition. The method effectively reduces vertical acceleration, enhancing ride comfort. Li FWang LWu Y (2021) [7] explored Pseudo-resonance issues were identified, primarily due to stiffness mutations. The study employed 273 ground motions, analysed four types, and recommended composite seismic isolation technology when displacement limits were exceeded. The research highlights challenges in reducing lateral-torsional coupling effects in large chassis structures during long-period ground motions. In 2017, Kumar Dama and Kumar Malyala Suresh Babu, [8] explored Additive Manufacturing (AM) in the automotive industry. They emphasized AM's flexibility over traditional manufacturing, focusing on prototype fabrication of an automotive Flex Body Space-Frame Structure using CAD modelling and finite element analysis in Hyper Works 13.0. Their work showcased joining dissimilar materials to achieve weight reduction while meeting safety regulations. The automotive industry is transitioning [9] toward electric propulsion and carbon fiber composite chassis, signalling the future of automotive engineering. Universities worldwide are preparing engineering students through initiatives like Formula Student Electric, a competition featuring student-built electric racing cars. In 1972, [10] Anderson D Mills B, comparing results with experiments. Examined the first nine natural resonances up to 100 Hz, employing different computing techniques for efficient cost-effective analysis. Demonstrated that simple idealizations can yield accurate results for relatively simple structures. Numerical analysis of a Formula Student race car's [11] space frame chassis was conducted using CATIA and SOLIDWORKS software. The innovative chassis design aimed to strengthen the open cockpit section and pass various load tests, ensuring driver safety. Triangulations and load paths were strategically employed to enhance chassis stiffness and compliance with FSAE rules. Mohammed et al. 2018[12] Using CAD software and ANSYS, the team conducted static, modal, transient, and fatigue analyses to assess chassis performance, with a notable exploration of vibration transfer path analysis. In the design and analysis of "Eco"[13] car chassis for fuel-efficient racing, a lightweight steel space frame was chosen. Finite Element Analysis (FEA) confirmed the chassis' ability to safely withstand loads, including engine, driver weight, and dynamic forces, with minimal deflection. (ORV) chassis materials, including durability and fatigue properties. It aims to optimize roll cage safety through material selection, design, and manufacturability considerations. Among the materials studied, AISI 4130 stands out for its high tensile strength. ANSYS models were employed to evaluate chassis performance under front, side, and rear impact loads as per SAE standards (2021) [14] . This study optimizes [15]CAD-based chassis design adheres to SAE standards for safety and ergonomics. Finite Element analysis assesses materials (AISI 1020) and 1.4 mm thickness as ideal, considering safety, cost, and weight. Srivastava, Reddy, and Teja (2021) investigated the effects of [16] on vibration characteristics and structural behaviour. Using modal analysis and FEA software, they assessed natural frequencies and impact performance. Design 1 demonstrated superior vibration characteristics and safety, offering valuable insights for both student projects and industry applications.

2 Problem Description

2.1 Structural analysis

For the intended analysis, varying pressure is applied vertically on the chassis, ranging from 3000Pa to 7000Pa and the stress , strain , total deformation , factor of safety (x, y & z directions) is recorded

Table 1 Property Table of different Materials used for the Study.

Types of properties	Aluminum alloy	Boran	Magnesium alloy	Structural steel	Titanium alloy
Density(kg/m3)	2770	2460	1800	7850	4620
Compressive ultimate strength (Pa)	0	0	0	0	0
Compressive yield strength (Pa)	2.8E+08	4.00E+5	1.93E+08	2.5E+08	9.3E+08
Tensile yield strength (Pa)	2.8E+08	2.00E+5	1.93E+08	2.5E+08	9.3E+08
Tensile ultimate strength (Pa)	3.1E+08	2.00E+5	2.55E+08	4.6E+08	1.07E+09
Young's modulus (Pa)	7.1E+10	4.00E+11	4.5E+10	2E+11	9.6E+10
Poisson's Ratio	0.33	0.13	0.35	0.3	0.36
Bulk Modulus (Pa)	6.9608E+10	3.596e+11	5E+10	1.6667E+10	1.1429E+11
Shear modulus (Pa)	2.6692E+10	3.474e+11	1.6667E+10	7.6923E10	3.5294E+10

2.2 Research Methodology

- **CAD Model** : CAD models are indispensable in my go-kart chassis analysis project. They facilitate precise design visualization, structural stress simulations, weight distribution evaluation, and effective communication of complex concepts, crucial for optimizing chassis performance and safety.
- **Analysing**: For our capstone project, we utilized ANSYS software to comprehensively analyze the go-kart chassis. ANSYS facilitated a detailed assessment of structural integrity, performance under varying conditions, and design optimization, enabling data-driven recommendations for enhanced safety and efficiency.
- **Identifing the behaviour of Model**: We employed ANSYS software to assess the go-kart chassis model, enhancing design precision and meeting safety and performance criteria.

Types of Analysis Performed on Go-Kart Chassis:

1. Equivalent Stress
2. Shear Stress
3. Strain Energy
4. Maximum Principle Stress
5. Total Deformation

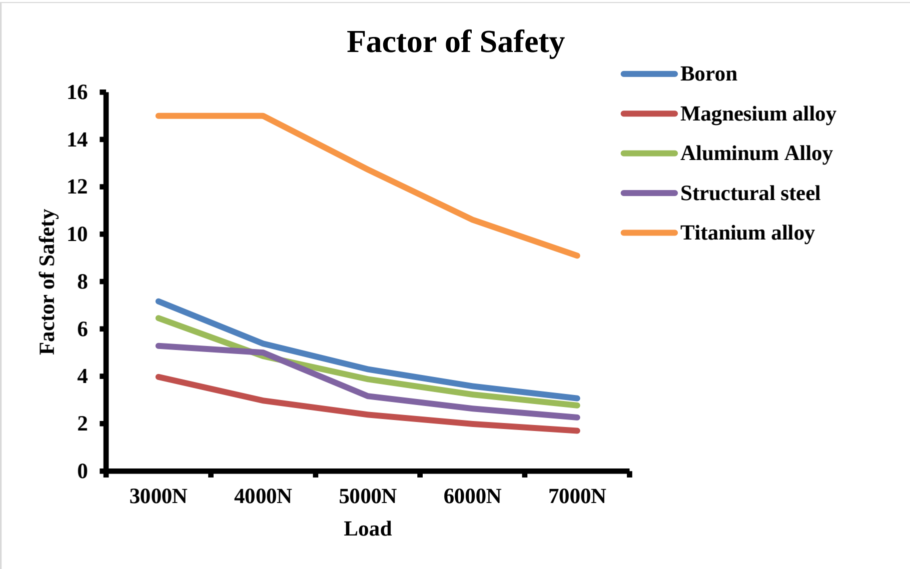


Figure 2 Factor of safety

3 Results & Discussions

Factor of safety: The results of the Factor of Safety analysis reveal that Titanium Alloy demonstrates the highest margin of safety, indicating its suitability for use in the automotive chassis. On the other hand, Magnesium Alloy exhibits a lower safety margin, suggesting that it may not be the optimal choice for critical chassis components.

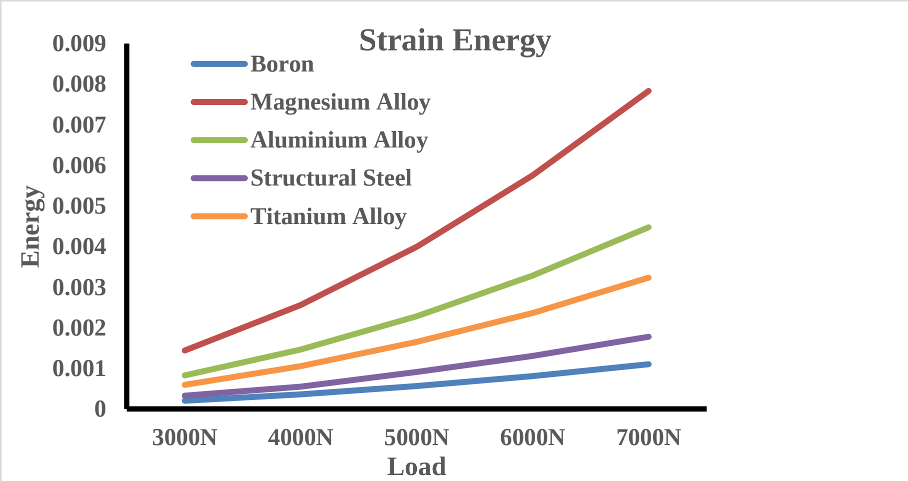


Figure 3 Strain Energy

Strain Energy: Among these materials, the magnesium alloy exhibited the highest strain values, signifying its vulnerability to deformation under the applied loads. In contrast, boron displayed the lowest strain levels, indicating its superior resistance to structural deformation.

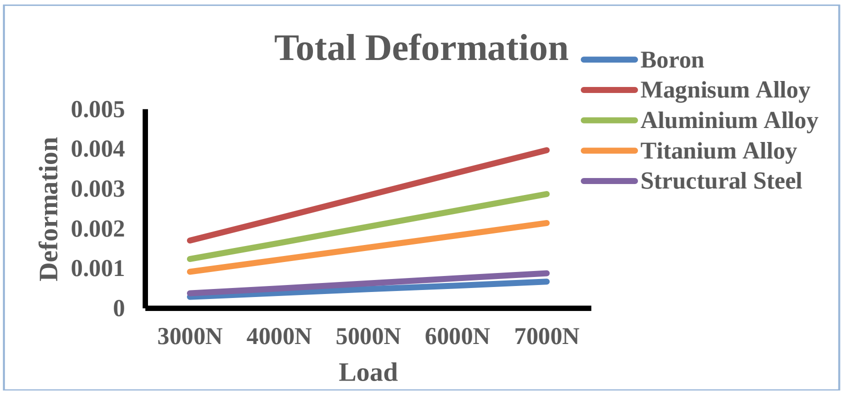


Figure 4 Total Deformation

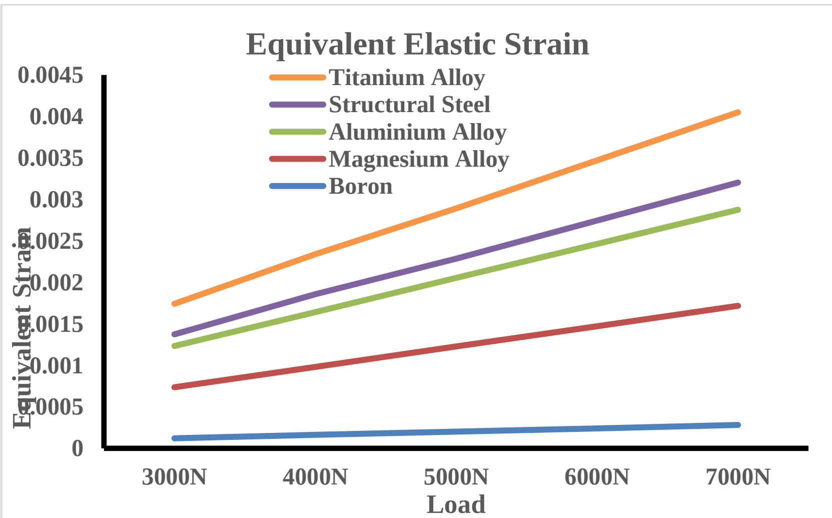


Figure 5 Maximum Principal Elastic Strain

Total Deformation: Among these materials, magnesium alloy exhibited the highest total deformation, signifying a greater degree of structural flex under the applied loads. On the contrary, boron displayed the least total deformation, indicating its superior resistance to deformation and deflection. These findings provide valuable insights into the material properties and structural behavior of these substances, offering guidance for informed material selection in chassis design and engineering to achieve optimal performance and safety standards.

Maximum Principal Elastic Strain: It is found to vary significantly among these materials, with magnesium alloy exhibiting the highest value, while boron displayed the lowest. This outcome highlights the material-dependent behaviour of the chassis under load conditions and underscores the critical role of material selection in influencing the structural response and overall performance of the chassis. Such insights can prove invaluable in optimizing chassis designs for enhanced safety and performance in various automotive applications.

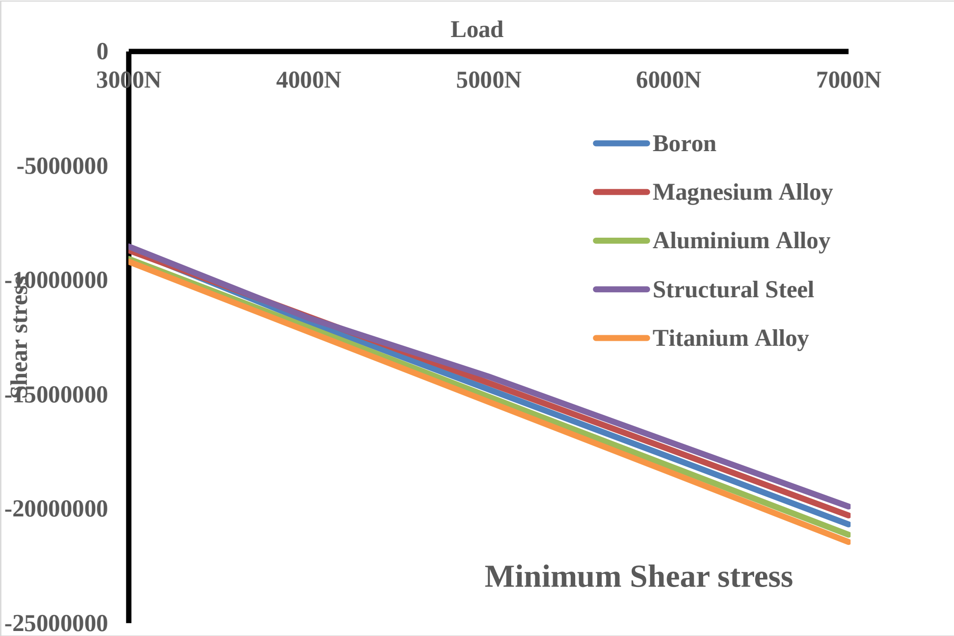


Figure 6 Minimum Shear stress

Minimum Shear Stress: The notable conclusion drawn from the study is that structural steel exhibits the highest minimum shear stress among the materials considered, signifying its robust resistance to shearing forces. In contrast, titanium alloy demonstrated the lowest minimum shear stress, indicating its superior ability to withstand such stresses. This finding provides valuable insights into material selection for chassis design, highlighting structural steel's suitability for applications where shear resistance is paramount and titanium alloy's advantage in weight-sensitive scenarios requiring enhanced shear stress performance.

4Conculsion

In this study, a comprehensive safety analysis of automotive chassis under various loading conditions was conducted using Finite Element Method. The objectives were to determine the Factor of Safety for distinct materials (titanium, magnesium alloy, boron, aluminium alloy, and structural steel) and assess their performance under different loading scenarios.
The findings reveal that Titanium demonstrate superior Factor of Safety, indicating their suitability for chassis construction. Moreover, the study highlights the critical importance of material selection in ensuring the structural integrity and safety of the automotive chassis.
Additionally, the analysis elucidates the response of different materials to stress, strain, and deformation, providing valuable insights for optimizing chassis design. These results serve as a foundation for enhancing both the performance and safety aspects of automotive chassis, contributing to advancements in vehicle engineering and safety standards.

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