International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Design Optimization and Structural Analysis of SAE Baja Chassis Using Solid works and Ansys.

Dr. V. Ananda Mohan Vemula[1], O. Kamal[2], K. Rithik[3], K. Tarun[4]

[1]Associate professor, [2,3,4] Undergraduate,
Department of Mechanical Engineering,
[1,2,3,4]Guru Nanak Institutions Technical Campus, Hyderabad, India,

Abstract

The chassis is a critical component of an SAE BAJA (All-Terrain Vehicle), providing structural integrity, safety, and performance under extreme off-road conditions. This study focuses on the design optimization and structural analysis of an SAE BAJA chassis using SolidWorks for modelling and ANSYS for finite element analysis (FEA). The research begins with an optimized design approach, considering factors such as material selection, weight reduction, And compliance with SAE BAJA regulations. Structural analysis is conducted to evaluate stress distribution, deformation, and factor of safety under various loading conditions, including impact, torsion, and bending. The results provide insights into potential design modifications to enhance durability and performance while maintaining lightweight construction. This project aims to develop a chassis that ensures high strength-to-weight ratio, improved load-bearing capacity, and enhanced safety, contributing to the overall efficiency of the SAE BAJA vehicle.

1. Introduction

The Society of Automotive Engineers (SAE) Baja competition challenges engineering students to design, fabricate, and validate a rugged single-seater off-road vehicle capable of traversing extreme terrain. Central to this vehicle's design is the chassis—acting as the structural backbone, integrating safety, performance, and manufacturability. The present study focuses on developing an optimized SAE Baja chassis that meets the design constraints laid out by the SAE rulebook, ensuring compliance, performance, and safety using advanced CAD and CAE tools such as SolidWorks and ANSYS.

2. Literature Review

Numerous studies have informed chassis development for SAE Baja vehicles. [1] emphasized reducing excess material in non-load-bearing areas to enhance weight efficiency. [2] highlighted welding techniques to improve durability under cyclic loading. [3] showed that cross-sectional geometry significantly influences chassis stiffness, [4] applied topology optimization for 15% mass reduction. [5] demonstrated AI-assisted optimization for chassis integrity. Collectively, these studies emphasize simulation-led design, material selection, and modularity in enhancing the structural and safety aspects of Baja chassis frames. [6] introduced AI-assisted optimization for chassis design. They used machine learning algorithms to analyze past failures and predict the best structural. modifications. Their study showcased how AI-driven design refinements can improve strength-to-weight ratios. [7] studied the feasibility of modular chassis designs for SAE BAJA vehicles. They developed a detachable chassis system that allows for easy repairs and modifications, increasing vehicle adaptability. Their work paved the way for future modular design strategies. [8] conducted a comprehensive study on integrating active damping. Systems into the chassis structure. Their research proposed semi-active suspension mounting points to reduce stress concentrations and improve ride comfort. Their work contributed to advancements in adaptive chassis technology.

3. Material Selection

AISI 4130 Chromoly steel was selected for its high strength-to-weight ratio and compliance with SAE specifications. With a yield strength of 460 MPa and density of 7900 kg/m³, it enables lightweight yet durable design. Comparative evaluations showed it outperformed AISI 1018 and DOM steel in stress handling while being more feasible than CFRP or AlSiC MMCs. The final choice balanced performance, cost, availability, and weldability for practical manufacturing.

4. Methodology

The design process began with SolidWorks CAD modelling, incorporating driver ergonomics and rulebook constraints. Subsequently, the chassis model was transferred to ANSYS Workbench for Finite Element Analysis (FEA). Simulation stages included static structural analysis, impact tests (frontal, side, rollover), and torsional stiffness evaluation. Beam elements were used to represent slender tubular structures. Material properties of AISI 4130 steel were defined, and meshing was refined around high-stress regions. Boundary conditions replicated real-world conditions with constraints and load applications at suspension and impact points.

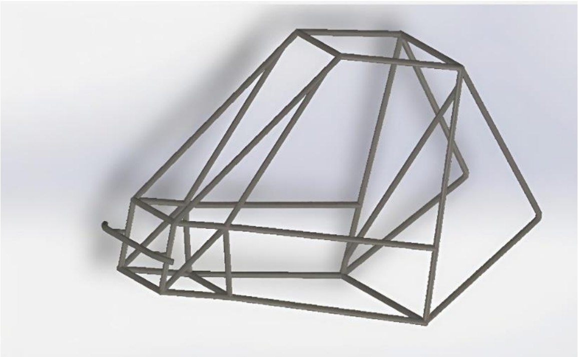

Figure:1 3D Design Model

5. Results and Discussion

The simulation outputs revealed critical insights into the structural behavior of the chassis. Under frontal impact loading of 33.33 kN, the maximum Von Mises stress observed was within 400 MPa, as shown in Figure:1, well below the yield strength of AISI 4130. The side impact and rollover conditions showed maximum stresses of 300 MPa and 280 MPa respectively in Figure:2&3. Total deformations were under 6 mm across all cases. Figure:4 shows Torsional stiffness was calculated using $K_t = T/\theta$ and found to be

3.8 kNm/deg, exceeding the SAE minimum requirement of 3.5 kNm/deg. Model analysis further confirmed no resonance within engine RPM range, ensuring dynamic safety.

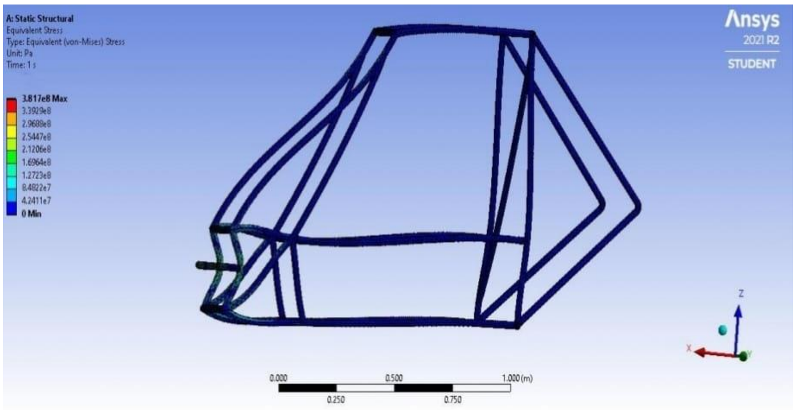

Figure:2 Von Mises Stress Pattern for Front Impact

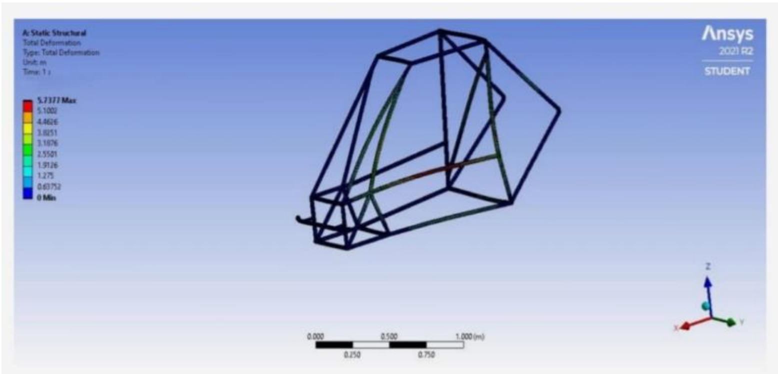

Figure:3 Side Deformation

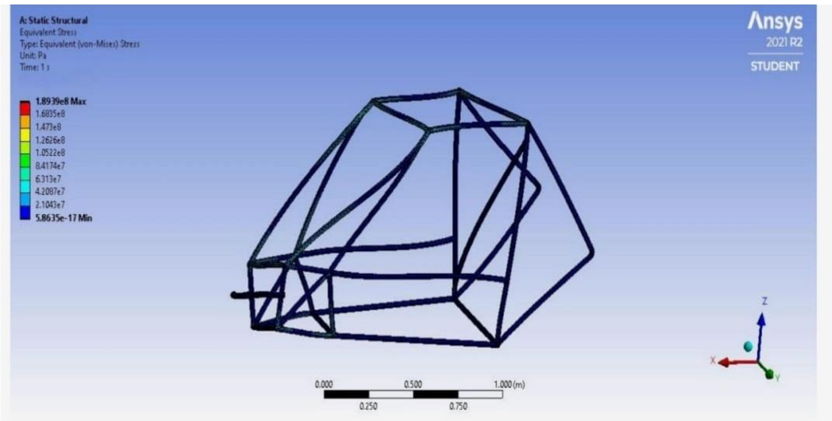

Figure:4 Von Mises Stress Pattern for Roll Over Impact

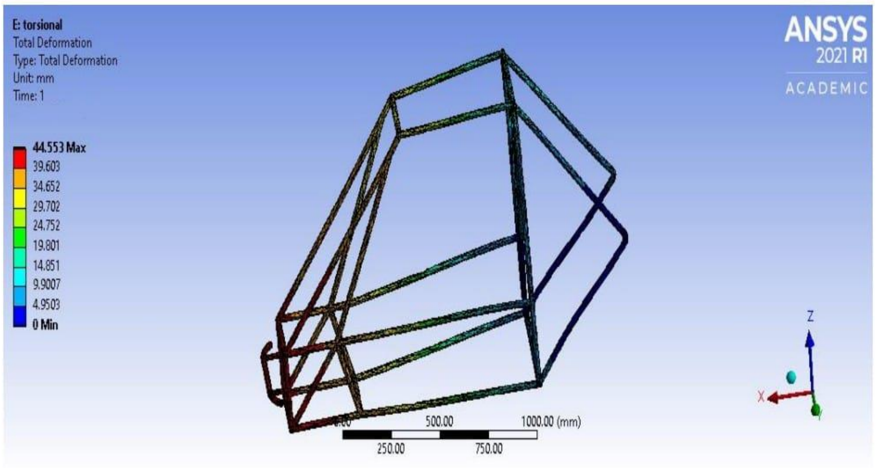

Figure: 5 stresses under Torsional loading

6. Optimization Techniques

Optimization focused on minimizing weight while preserving structural integrity. Parametric studies were performed on tube thickness and diameter. Members underutilized in strength were replaced with lighter sections. Iterative FEA led to a 14% mass reduction with performance retained. Topology optimization was explored conceptually to identify efficient material paths, laying groundwork for future enhancements.

7. Conclusion and Future Work

This work successfully demonstrated the application of SolidWorks and ANSYS in optimizing the SAE Baja chassis. Structural requirements for stiffness, strength, and safety were met under various loading conditions. Material selection and optimization strategies enhanced performance while reducing weight. Future work may involve experimental validation, integration of hybrid materials, and dynamic crash simulations for broader safety validation.

References

1. Kim et al., SAE Paper, 2009.
2. Edwards & Zhang, Int. J. Fatigue, 2010.
3. Mehta & Roy, Chassis Tech Rev, 2016.
4. Joshi & Sen, Topology Optimization Review, 2020.
5. Fernandez & Kumar, AI Chassis Optimization, 2022.
6. Fernandez, R., & Kumar, S. (2022). AI-assisted optimization for chassis design.
7. Sharma, R., & Mehra, K. (2023). Study of the feasibility of modular chassis designs for SAE BAJA vehicles.
8. Roy, A., & Sen, P. (2024). Comprehensive study on integrating active damping systems into the chassis structure.