

Structural Design, Analysis and Fabrication for Electric Three-Wheeler Chassis

Dr. Mayur Jagtap¹, Onkar Patil², Sanjyot Dhaygude³, Prashant Bandgar⁴

¹ Assistant Professor, Department of Mechanical Engineering, SB Patil College of Engineering, Vangali

^{2,3,4} Student of Department of Mechanical Engineering, SB Patil College of Engineering, Vangali

mayurdjagtap@gmail.com¹, Onkarpatil5554@gmail.com², dhaygudesanjyot@gmail.com³,
prashantbandgar2804@gmail.com⁴

Abstract

The chassis is one of the most important structural components of a vehicle because it supports all major systems and withstands different loading conditions during operation. In developing countries, three-wheelers are widely used due to their low cost, compact size, and fuel efficiency. Therefore, the development of a lightweight, safe, and economical chassis is essential for improving vehicle performance and reliability.

In this research work, a ladder-type three-wheeler chassis was designed, analysed, and fabricated using AISI 1020 carbon steel. The chassis geometry was developed using PTC Creo software, while structural analysis was performed using ANSYS Workbench 2026 R1. Static structural analysis was carried out by applying driver and passenger loads under practical operating conditions.

The Finite Element Analysis (FEA) results showed that the maximum equivalent stress developed in the chassis was 92.392 MPa, which is well below the yield strength of AISI 1020 steel. The maximum total deformation obtained was 1.438 mm, which is within the allowable deformation limit. The factor of safety obtained was 3.18, confirming that the chassis is structurally safe and reliable.

The chassis was successfully fabricated using arc welding and CO₂ welding processes. The fabricated model showed good dimensional accuracy, weld quality, and structural rigidity. The total fabrication cost was economical, making the design suitable for practical low-cost vehicle applications.

Keywords: Three-Wheeler Chassis, FEA, ANSYS, CAD Modelling, AISI 1020 Steel, Structural Optimization, CO₂ Welding.

1. Introduction

The automotive industry plays a major role in transportation and industrial development. Among various automobile categories, three-wheelers are widely used in developing countries due to their affordability, compact design, and low maintenance costs. These vehicles are commonly used for passenger transportation and delivery of goods.

The chassis is the main structural framework of the vehicle. It supports the engine, suspension, steering system, battery, seating structure, and payload. A properly designed chassis must possess sufficient strength, stiffness, and durability while maintaining the minimum possible weight.

Traditional chassis designs are often overdesigned, resulting in increased material usage and higher weight. Excessive chassis weight reduces fuel efficiency and increases manufacturing cost. Therefore, optimisation of chassis design is necessary to improve overall vehicle performance.

This research focuses on the design, structural analysis, and fabrication of a lightweight and cost-effective three-wheeler chassis using Finite Element Analysis (FEA).

1.1 Problem Statement

Many existing three-wheeler chassis designs are either heavy or structurally inefficient. Small-scale manufacturers often lack advanced design and simulation methods, resulting in increased cost and reduced performance.

1.2 Objectives

- To design a three-wheeler chassis using CAD software.
- To perform structural analysis using ANSYS Workbench.
- To evaluate stress, deformation, and factor of safety.
- To fabricate the chassis using suitable welding techniques.
- To develop a lightweight and economical chassis structure.

1.3 Research Gap

Most previous studies focused mainly on analysis and optimization but provided limited integration of CAD modelling, FEA, fabrication, and cost estimation together in a single project.

1.4 Methodology Overview

The research methodology adopted in this project includes:

1. Literature review
2. Chassis design and CAD modelling
3. Material selection
4. Finite Element Analysis
5. Fabrication and welding
6. Result evaluation

2. Literature Review

Several researchers have contributed to the development and optimization of automotive chassis structures.

Wong (2008) explained the importance of chassis rigidity and lightweight structures in vehicle design. Rao and Kumar (2017) discussed the significance of material selection in automotive applications and highlighted the advantages of mild steel for chassis fabrication.

Zienkiewicz and Taylor (2013) described Finite Element Analysis as an effective numerical technique for evaluating structural performance. Kumar and Singh (2017) performed stress analysis on a three-wheeler chassis using ANSYS and observed maximum stress concentration near suspension regions.

Ahmed et al. (2018) performed optimization studies on a three-wheeler chassis and achieved weight reduction through structural modifications. Kou (2003) discussed welding metallurgy and emphasized the importance of proper welding techniques in structural fabrication. From the literature survey, it was observed that limited studies combine CAD modelling, FEA, fabrication, and practical implementation for low-cost three-wheeler chassis development.

3. Design and Modelling

3.1 Material Selection

Material selection is one of the most important stages in chassis design because the overall strength, weldability, durability, and cost depend on the selected material.

After comparing different materials, AISI 1020 carbon steel was selected due to the following reasons:

- Good weldability

- Adequate strength
- Easy availability
- Low cost
- Good ductility and toughness
- Suitable for tubular chassis fabrication

Material Properties of AISI 1020 Steel

Property	Value
Yield Strength	293.5 MPa
Young's Modulus	2.1×10^5 MPa
Density	7.85×10^{-6} kg/mm ³
Poisson's Ratio	0.29

3.2 Chassis Design Overview

A ladder-type chassis frame was selected because of its simple structure, good load-carrying capacity, and ease of fabrication.

The chassis consists of:

- Longitudinal members
- Cross members
- Front support structure
- Rear passenger support structure

Square hollow sections and circular hollow sections were used to obtain better stiffness-to- weight ratio.

3.3 CAD Modelling

The complete 3D CAD model of the chassis was developed using PTC Creo software. The model included all structural members and mounting regions.

The CAD model helped in:

- Visualizing the chassis geometry
- Checking dimensions and alignment
- Preparing the model for FEA

Page 4

4. Finite Element Analysis (FEA)

Finite Element Analysis was performed using ANSYS Workbench 2026 R1 to evaluate the structural behaviour of the chassis under loading conditions.

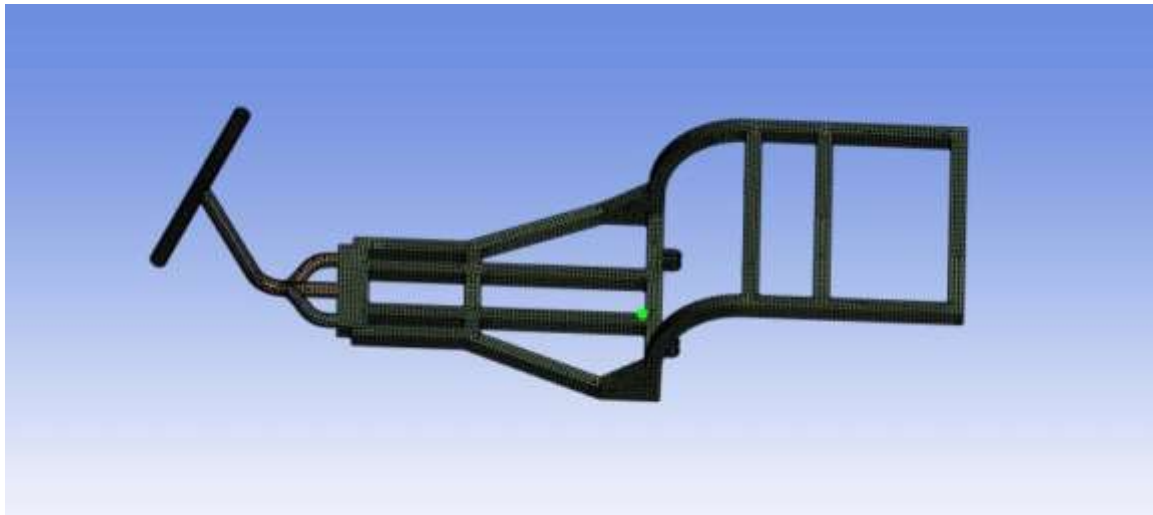
4.1 Meshing

The chassis geometry was divided into finite elements using tetrahedral mesh.

Meshing Details

Parameter	Value
Element Type	Tetrahedral
Number of Nodes	12,704
Number of Elements	12,867

Mesh refinement was performed near joints and support regions to improve result accuracy.



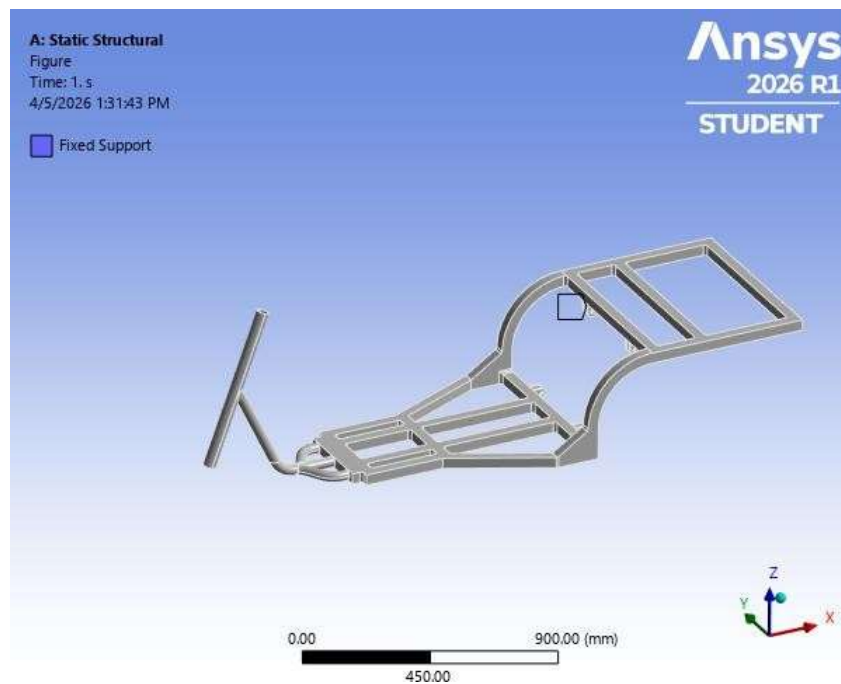
Meshed Model of Chassis

4.2 Boundary Conditions

Proper boundary conditions were applied to simulate actual operating conditions.

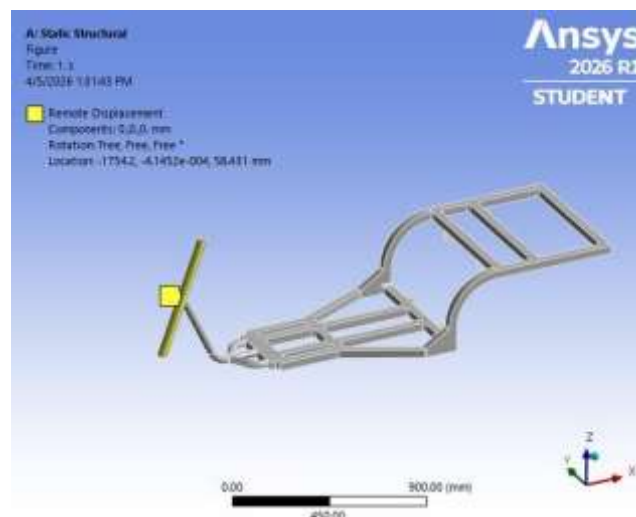
- Fixed supports were applied at suspension mounting points.
- Remote displacement was applied at the front head tube region. These conditions stabilized the chassis during analysis.

Fixed Support:



Fixed Support

Remote Displacement:



Remote Displacement

4.3 Load Application

The following loads were applied:

Driver Side Load

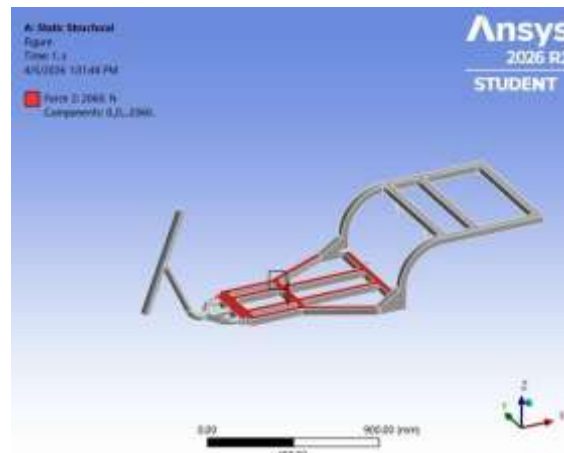
- Driver load = 2060 N

Passenger Side Load

- Passenger load = 3000 N

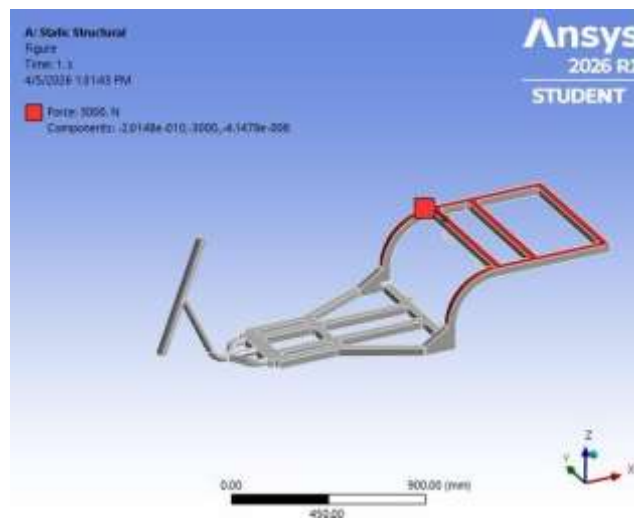
The loads were applied vertically downward at seating locations.

Driver Load Application:



Driver side Load

Passenger Load Application



Passenger side Load

5. Results and Discussion

The FEA results obtained from ANSYS Workbench were used to evaluate the structural performance of the chassis.

5.1 Equivalent Stress Result

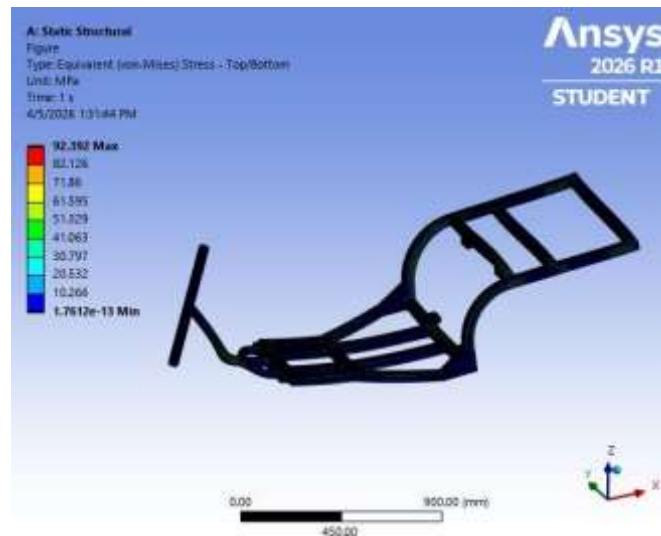
The maximum equivalent (Von-Mises) stress obtained was:

Maximum Stress = 92.392 MPa

The developed stress was significantly lower than the yield strength of AISI 1020 steel, confirming safe structural behaviour.

Stress concentration was mainly observed near support and welded joint regions.

Equivalent Stress Distribution



Equivalent Stress Distribution

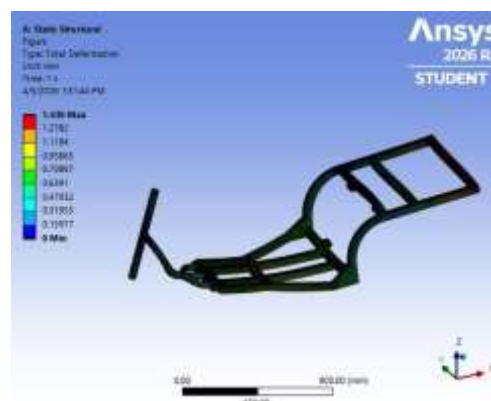
5.2 Total Deformation Result

The maximum total deformation obtained was:

Maximum Deformation = 1.438 mm

The deformation value was well below the allowable limit of 3 mm. Therefore, the chassis possesses sufficient stiffness and rigidity.

Total Deformation Result

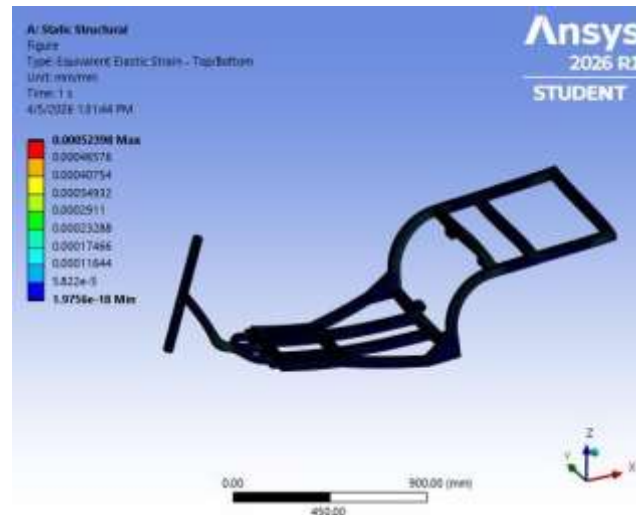


Total Deformation Result

5.3 Equivalent Elastic Strain

The maximum equivalent elastic strain obtained was very low, indicating elastic behaviour of the material under loading conditions.

Equivalent Elastic Strain:



Equivalent Elastic Strain

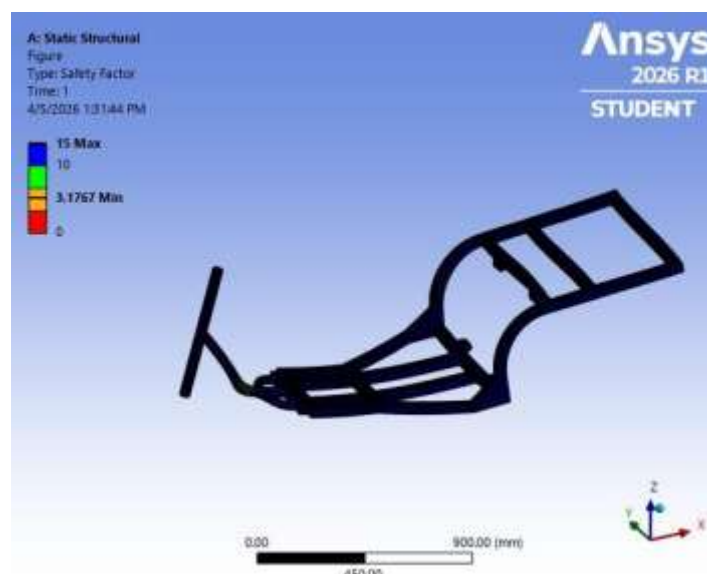
5.4 Factor of Safety

The minimum factor of safety obtained from the analysis was:

Factor of Safety = 3.18

Since the obtained value is greater than the required minimum value, the chassis is structurally safe and reliable.

Factor of Safety Distribution:



Factor of Safety Distribution

5.5 Discussion

The FEA results confirmed that the designed chassis can safely withstand the applied loading conditions. The stress and deformation values were within allowable limits, and the factor of safety was sufficiently high.

The results also confirmed that the selected material and frame geometry are suitable for practical three-wheeler applications.

Result Summary Table

Parameter	Obtained Result	Observation
Maximum Stress	92.392 MPa	Safe
Total Deformation	1.438 mm	Acceptable
Factor of Safety	3.18	Structurally Safe
Structural Stability	Stable	Satisfactory

6. Fabrication Process

After successful completion of FEA, the chassis was fabricated practically using standard workshop tools.

The fabrication process included:

- Material preparation
- Cutting operation
- Tack welding
- Final CO₂ welding
- Grinding and finishing

6.1 Welding Process

Initially, arc welding was used for tack welding to maintain alignment of structural members. Final welding was carried out using the CO₂ welding process (GMAW).

ER70S filler wire electrode and CO₂ shielding gas were used to obtain good weld quality and penetration.

Arc Welding Process:



Arc Welding Process

CO₂ Welding Process:



CO₂ Welding Process

6.2 Weld Quality

The welded joints were visually inspected for:

- Cracks
- Porosity
- Undercut
- Incomplete fusion

The welds showed good penetration and satisfactory structural rigidity.

6.3 Final Fabricated Chassis

The fabricated chassis closely matched the CAD model in terms of dimensions, alignment, and structural layout. Proper fitting and welding of all structural members resulted in good rigidity and dimensional stability. The final fabricated frame demonstrated satisfactory strength and manufacturability for practical three-wheeler applications.

Final Fabricated Chassis:



Final Fabricated Chassis

6.4 Cost Estimation

The total fabrication cost of the chassis was economical and suitable for low-cost vehicle applications. The overall cost included raw material, welding, finishing, painting, and miscellaneous expenses.

Component	Cost (₹)
Raw Material	657
Fabrication & Welding	1500
Finishing	400
Painting	850
Miscellaneous	600
Total	₹4,007

The low fabrication cost confirms that the developed chassis design is economically feasible for practical manufacturing.

7. Conclusion and Future Scope

7.1 Conclusion

This research successfully achieved the objective of designing, analysing, and fabricating a lightweight and structurally safe three-wheeler chassis using AISI 1020 carbon steel. A ladder-type chassis frame was developed using PTC Creo software and analysed under practical loading conditions using ANSYS Workbench 2026 R1.

The Finite Element Analysis results confirmed that the maximum equivalent stress developed in the chassis was 92.392 MPa, which is well below the yield strength of the selected material. The maximum total deformation obtained was 1.438 mm, indicating sufficient stiffness and rigidity of the chassis structure. The factor of safety obtained from the analysis was 3.18, confirming safe and reliable operation under applied loading conditions.

The chassis was successfully fabricated using arc welding and CO₂ welding techniques. The fabricated model showed good dimensional accuracy, satisfactory weld quality, and proper structural stability. The overall fabrication cost was also economical, making the design suitable for practical low-cost vehicle applications.

Therefore, the developed chassis design was found to be lightweight, cost-effective, structurally reliable, and suitable for real-world three-wheeler applications.

7.2 Future Scope

The following improvements can be considered for future research and development:

- Dynamic and fatigue analysis of the chassis under real road conditions
- Further weight optimization using advanced design techniques
- Use of lightweight materials such as aluminium alloys or composites
- Experimental validation using strain gauges and testing equipment
- Improvement in welding quality using advanced welding methods
- Corrosion protection and surface treatment for increased durability
- Development of electric three-wheeler chassis configurations

8. References

- [1] Wong, J. Y. (2008). *Theory of Ground Vehicles* (4th ed.). John Wiley & Sons.
- [2] Patel, R., & Sharma, A. (2015). Design optimization of automotive chassis using FEA. *International Journal of Automotive Engineering*, 6(3), 145-152.
- [3] Rao, K., & Kumar, V. (2017). Material selection for automotive chassis applications: A review. *Materials Today: Proceedings*, 4(2), 7350-7357.
- [4] Callister, W. D., & Rethwisch, D. G. (2018). *Materials Science and Engineering: An Introduction* (10th ed.). John Wiley & Sons.
- [5] Zienkiewicz, O. C., & Taylor, R. L. (2013). *The Finite Element Method: Its Basis and Fundamentals* (7th ed.). Butterworth-Heinemann.
- [6] Reddy, P., & Kumar, A. (2019). Finite element analysis in automotive chassis design: A comprehensive review. *Engineering Science and Technology*, 22(3), 789-802.
- [7] Kumar, V., & Singh, P. (2017). Stress analysis of three-wheeler chassis using ANSYS. *International Journal of Engineering Research*, 6(4), 234-239.
- [8] Ahmed, S., et al. (2018). Weight optimization of three-wheeler chassis using FEA. *Materials Today: Proceedings*, 5(9), 18765-18772.
- [9] Patel, D. (2019). Experimental validation of FEA results for automotive chassis. *Journal of Testing and Evaluation*, 47(5), 3456-3468.
- [10] Kou, S. (2003). *Welding Metallurgy* (2nd ed.). John Wiley & Sons.