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STRUCTURAL ANALYSIS AND OPTIMIZATION OF AN ELECTRIC VEHICLE CHASSIS

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Abstract - *The vehicle chassis is the major structural framework for a vehicle system. Its principal function is to safely carry the maximum load for all designed operating conditions. This study focuses on the structural analysis and optimization of an electric vehicle chassis, with the objective to minimize stress and maximize the fatigue life. The methodology combines CAD, theoretical calculations, and Finite Element Analysis using ANSYS. The chassis, based on a C-channel section, was analysed for a gross vehicle weight of 770 kg. Theoretical validation found the design to be safe, with a calculated stress below the permissible stress and a maximum deflection less than the allowable deflection. FEA confirmed that maximum deformation occurs at the middle of the chassis. Based on the generated bending and torsion load cases and fatigue life analysis, the proposed chassis design using aluminium is considered safe. Future work includes modal analysis and vibration analysis and improving strength by adding gussets.*

***Key Words*: Electric Vehicle Chassis, Finite Element Method, Structural Steel, Aluminium 6061, Stress Analysis, Fatigue Life and Optimization.**

INTRODUCTION

The global automotive industry is currently undergoing a transformative period, driven by the increasing need for sustainability, improved fuel economy, and reduced emissions. This shift has positioned electric vehicles (EVs) as an attractive alternative to conventional combustion engine cars. Successfully navigating this transition requires innovative design strategies focused on maximizing energy efficiency, extending driving range, and optimizing overall vehicle performance.

The vehicle chassis is a major component in a vehicle system, serving as the framework for mounting components such as the engine, transmission system, axles, wheels, and electrical systems. The chassis of an electric vehicle is its framework, integrating main components like the wheel motor, battery, and tires.

The principal function of the chassis is to safely carry the maximum load for all designed operating conditions. Key characteristics determined through static and dynamic analysis include identifying the location of the critical stress area and determining the maximum deformation, strength, and stiffness of the chassis. The chassis must be rigid enough to withstand shock, twist, vibration, and other stresses, accommodating twisting on uneven road surfaces and absorbing vibration from the battery and wheel motor. The chassis is typically loaded by static, dynamic, and cyclic loading.

1.1. Chassis Failures and Mitigation

Fatigue is estimated to be responsible for 85% to 90% of all structural failures or crack propagation on the chassis. The vehicle powertrain is also significantly impacted by vibration and noise. To overcome these failures, the concept of a Sub-frame has been introduced.

1.2. Types of Electric Vehicle Chassis

The overall design of a car body consists of two parts: the chassis and the bodywork (or superstructure). Some EV chassis designs are equipped with an open-box bed and a hydraulic lift. The Volkswagen Group has licensed its MEB electric chassis to the German start-up e.Go , a platform that can be used for a variety of car models.

The US start-up Bollinger Motors bases its B1 (off-road vehicle) and B2 (pickup) models on the same electric chassis platform, similar to the skateboard platform used by companies like Rivian.

2 Literature Review

A review of prior work related to vehicle structural design, analysis, and optimization found that chassis analysis primarily involves stress analysis to predict weak points and fatigue analysis to predict the life of the chassis.

2.1 Static and Dynamic Analysis Researchers used

CAE Software for modelling and simulation, considering self-weight for static analysis and Acceleration, Braking, and Road Roughness for dynamic analysis. Stresses caused by braking were observed to be greater than those from acceleration. Dynamic analysis involves determining characteristics such as natural frequency, frequency response, and mode shape using the Finite Element Method. In one heavy vehicle study, the dominant loading was understood to come from the cargo as static loading, with road roughness having no significant effect on the stress.

2.2 Finite Element Method (FEM) and Optimization

Failure Simulation and Improvement: Hyper mesh and Opti-struct software were used to analyse and simulate the failure of a light commercial vehicle chassis. Introducing local stiffeners reduced the magnitude of stress in the modified chassis by 44%. To overcome failure in a longitudinal stringer, six different types of reinforcement were investigated using Hyper mesh, with the sixth type yielding the best results. This software analysis helped eliminate many laboratory tests, reducing testing costs.

Material and Weight Optimization: Studies analyzed alternative materials (e.g., AL and steel) and various cross sections like C, I, and Box type. Optimizing the thickness of a middle tonnage truck chassis using FEM suggested that a 4mm thickness was safe to carry a 15-ton load. Numerical results on a truck chassis with riveted joints showed that stresses on the side member could be reduced by increasing the side member thickness.

2.3 Problem Statement and Objectives

Gross Vehicle Weight and battery power are the two most important parameters influencing a vehicle's performance. An increase in vehicle weight can lead to more acceleration and increased vibration on the chassis. The industry requires good ride comfort, necessitating a chassis with a high-strength cross-section to minimize failures and a low weight.

A material with a low density and higher compressive and bending stress would help reduce weight while maintaining safe transmission. The current problem in electric vehicles is that the load acting on the sub-frame due to the powertrain provides continuous vibration, which decreases the fatigue life of the main frame.

Objective: The effort of the present work is to optimize the sub-frame and, therefore, the chassis. The goal is to minimize the stress and maximize the fatigue life of the chassis.

3 Methodology & Flow chart

The analysis of the chassis uses a methodology that combines

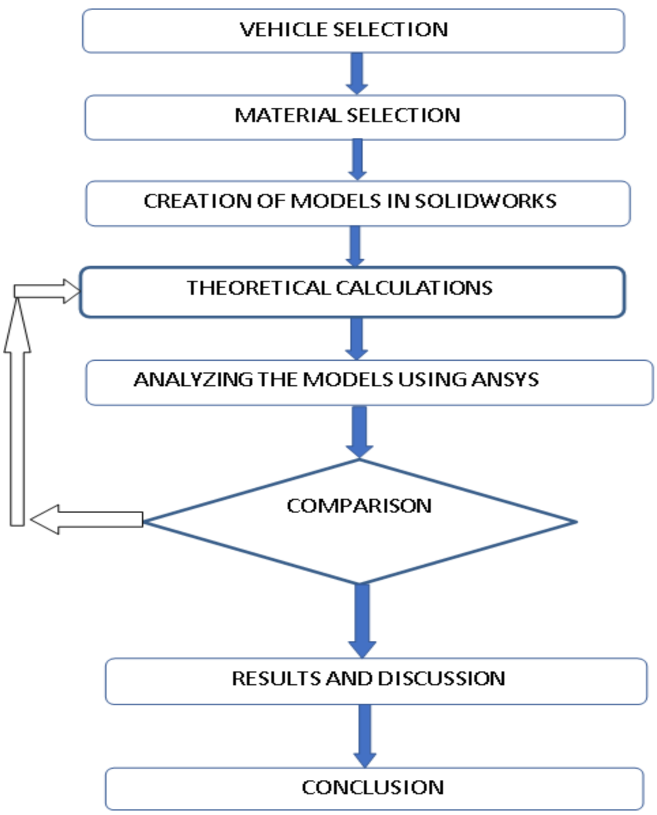

Figure 1. Methodology & Flow chart

Computer-Aided Design, theoretical calculations, and Finite Element Analysis (FEA), as illustrated in the flow chart

3.1 Material Selection

The material chosen for the chassis is structural steel with the constraint of having a low density and high strength. The vehicle frame is constructed from standard C-channel and horizontal beam type members. The properties of the tested materials are shown in Table 1.

Table 1. Material Properties

Material Properties	High strength structured steel
Young's Modulus (E)	2.10e+005 MPa
Poisson ratio (μ)	0.3
Yield Strength	Range 230 Mpa to 410 MPa
Ultimate Strength	360 MPa
Density	7.85e-006 kg mm^-3
Material Properties	Aluminium 6061
Young's Modulus (E)	70,300 MPa
Poisson ratio (μ)	0.3
Yield Strength	Range 125 Mpa to 290 MPa
Ultimate Strength	275 MPa
Density	2.66e-006 kg mm^-3

3.2 Vehicle Specifications

The total load acting on the chassis is the Gross Vehicle Weight, which is the sum of the Net Vehicle Weight and the Payload.

Table 2. Vehicle Over All Dimension

Parameter	Value Source
Length of the vehicle	2100 mm
Net Vehicle Weight	600 kg
Payload	170 kg
Gross Vehicle Weight (GVW)	770 kg

Theoretical Design Validation

Over All Design CalculationFigure 2. Loading Condition. a simply supported beam with supports at points A and B, each located 300 mm from the respective ends C and D, subjected to a central downward point load of 7554 N applied at the midpoint between A and B, spanning a distance of 1498 mm.

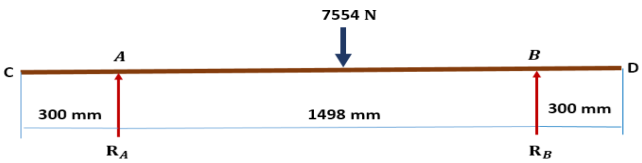

Figure 2 Loading Condition

The chassis was modeled as a simply supported beam with a central point load of 7554 N. The reaction forces were calculated as

$$R_A + R_B = 7554\ N$$

$$R_B * 1498 = 7554 * 1498/2$$

$$R_B = 5657946 / 1498$$

$$\boldsymbol{R_B = 3777\ N}$$

$$R_A = 7554 - 3777$$

$$\boldsymbol{R_A = 3777\ N}$$

Maximum allowable deflection in beam = $OVER\ ALL\ LENGTH$ /GROUND CLERANCE

= 2098 / 350

= 6MM

The E-vehicle chassis has two longitudinal members with cross sectional members. Generally, C – channels are used in the vehicle structures available in this particular type of variant in the market. The C channel has been selected on the basis of bending stress induced in the structure. Deflection produced in the structure for structural steel and Aluminium.

Where, h = 100 mm and b = 50 mm T= 6

$$I_{CD} = 150828000\ mm^4$$

ZXX

$$Z_{CD} = 42500\ mm^3$$

$$M_{max} = 69360000\ Nmm$$

Permissible stress =

YIELD STRENGTH / FACTOR OF SAFTEY

= 360 / 2 = 180 N/ MM^2

According to the bending equation

$$\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}$$

Stress produced in the beam

$\sigma = M_{MAX} / Z_{MAX}$ = 69360000 / 42500

= 163.2 $/mm^2$

Since $\boldsymbol{\sigma}$ is less than the permissible stress. Hence, the design is safe

According to Macaulay's Theorem the maximum deflection is produced in beam is

$$M_{CD} = E\ X\ d^2y/dx\text{^}2$$

with respect to x we get

$$M_{CD} = \text{EI X}\ dy/dx$$

Again with respect to x we get

$$M_{CD} = EI * y$$

Therefore, maximum deflection is produced in beam

$$y_{max} = 410.96 * 10^9/EI$$

$$410.96 * 10^9/205 * 109 * 150828000$$

y_{max} = 13.29 mm (Tensile and compression)
Maximum Deflection (y max), based on Macaulay's Theorem: y max≈13.29 mm.
Maximum Allowable Deflection: 17.4 mm.
Conclusion: Since the calculated maximum deflection (13.29 mm) is less than the maximum allowable deflection (17.4 mm), the design is also considered safe from a deflection standpoint.

Results of Finite Element Analysis

The CAD model was imported into the ANSYS pre-processing environment as an IGS file and meshed in 3D using tetra elements.
Figure 3 Ansys Geometric Model shows a 3D model of a closed frame structure made of several connected straight segments, each shown in different colors to represent separate parts of the geometry.

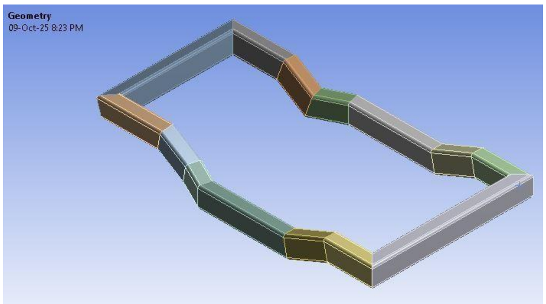

Figure 3 Ansys Geometric Model

Figure 3 Mesh Model. the meshed geometry used for structural analysis of the frame.

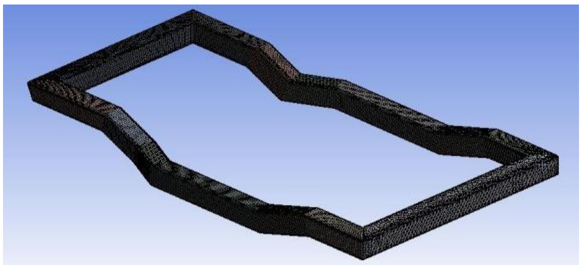

Figure 3 Mesh Model Figure 3 Mesh Model

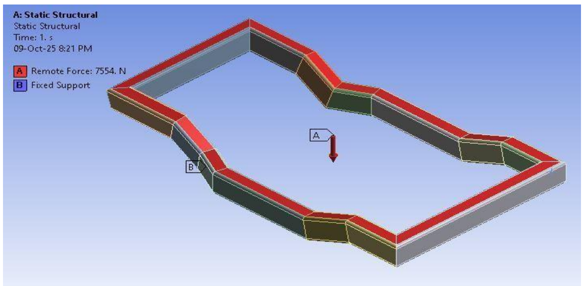

Figure 4 shows the loading and boundary conditions applied for the Static Structural analysis of the frame.

Figure 4 loading and boundary conditions
Bending and torsion were evaluated as the maximum load cases, with the vertical load case found to be the most severe.

Total Deformation The maximum total deformation was found to be at the
Figure 5 show the Total Deformation results from the static structural analysis of the frame under different loading conditions.

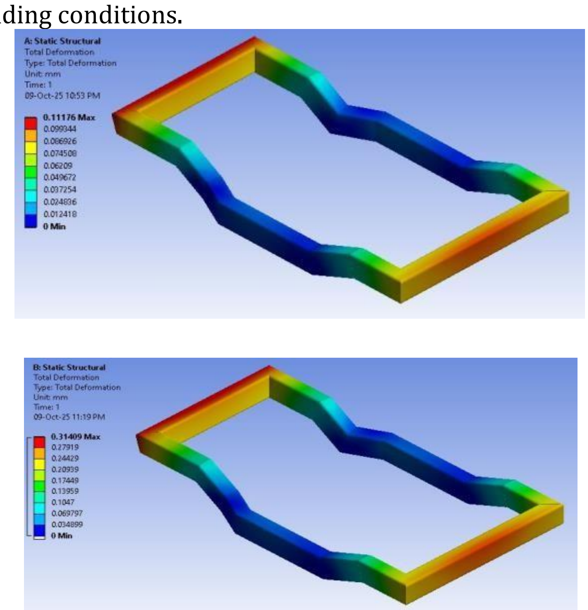

Figure 5 Total Deformation value for Structural Steel and Aluminium

middle of the chassis. The deformation gradually decreased from the middle towards the front and back.

Material	Maximum Total Deformation	Source
Structural Steel		0.111 mm
Aluminium (Al)		0.314 mm

Von-Mises Stress Distribution The maximum Von-Mises stress was obtained for both bending and torsion cases:

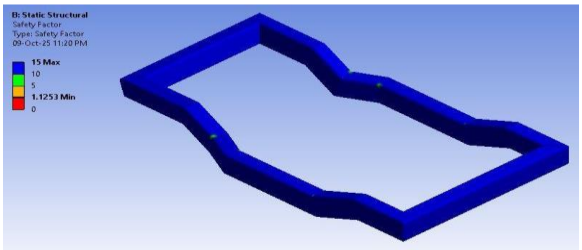

Figure 6 show the Equivalent (von-Mises) Stress distribution across the frame under the analyzed loads.

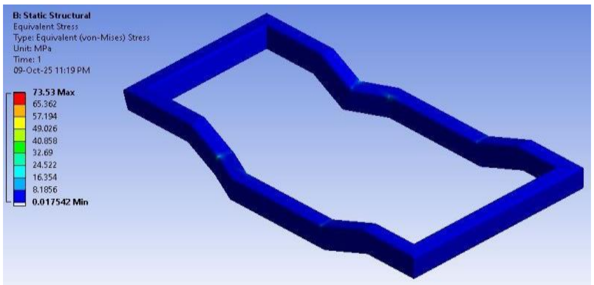

Figure 6 Von-Mises Stress value for Structural Steel and Aluminium

Maximum Von-Mises stress for Steel:73.63 MPa.
Maximum Von-Mises stress for Aluminium:75.53 MPa.

Shear Stress (Bending and Torsion)

Torsion, which is the twisting of an object due to an applied torque , was also referred to as the left ramp load and right ramp load conditions.

Figure 7 show the distribution of the Maximum Principal Stress across the frame for both analysis cases.

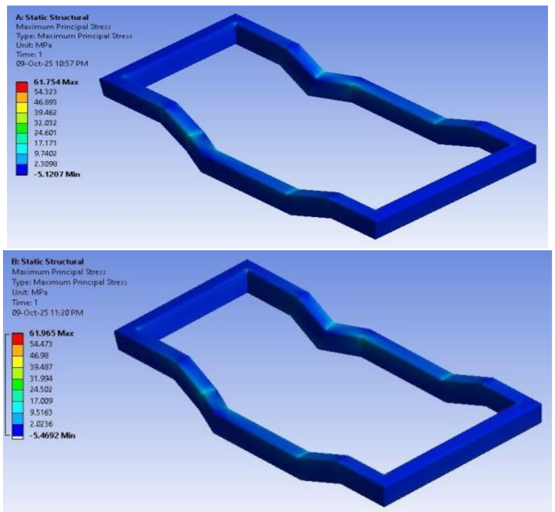

Figure 7 Maximum Principle Stress value for Structural Steel and Aluminium

Load Case	Average Shear Stress	Maximum Shear Stress	Source
Bending	270.99 MPa		155.2 MPa
Torsion	247.26 MPa		141.6 MPa

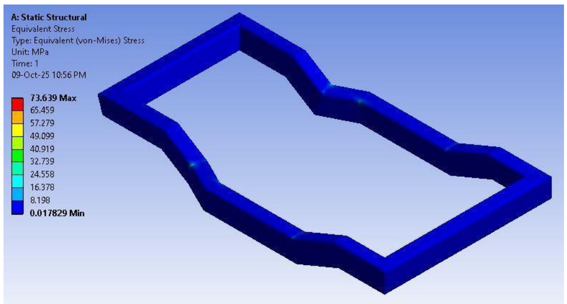

Figure 8 Show the Factor of Safety (F.S.) distribution for the frame, demonstrating the component's safety margin.

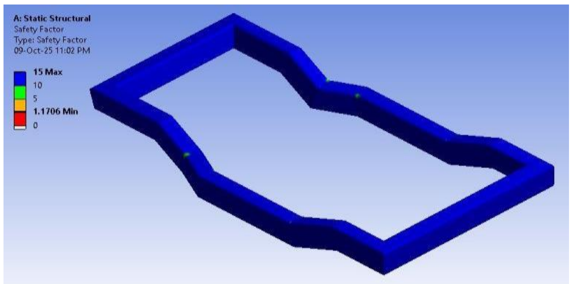

Figure 8 Safety Factor value for Structural Steel and Aluminium

Conclusion

- The electric vehicle chassis was successfully analyzed using CAE simulation software (ANSYS).
- The results show that the maximum deformation and maximum stress distribution are within the standard and recommended values.
- The maximum deformation is located at the middle of the structure.
- The analysis of the generated bending and torsion load cases and fatigue life indicates that the proposed chassis design with aluminium will be safe.
- For future improvements, the stress concentration areas of the chassis structure can be addressed to improve strength and increase stiffness by adding gussets. Future scope of work includes performing modal analysis and vibration analysis of the chassis.

References

[1] Alireza Arab Solghar, Zeinab Arsalanloo (2013). Were studied about the chassis of Hyundai Cruz Minibus.

[2] CicekKarao, glu, N. SefaKuralay (2001). Have analyzed truck chassis with riveted joints using FEM.

[3] K. Chinnaraj, M. Sathya Prasad, Lakshmana Rao (2008). Have chosen to optimize the weight of chassis frame assembly of a heavy truck.

[4] Kurdi, O., & Rahman, R. A. (2010). Studied the road roughness effects on stress distribution of heavy vehicle chassis.

[5] KutayYilmazcoban, Yasar Kahraman (2011). Have studied and optimized the thickness of a middle tonnage truck chassis by using Finite Element technique.

[6] M. Ravichandra, S. Srinivasalu, Syed altaf Hussain (2012). Have discuss about the alternate material for chassis.

[7] N.K.Ingole, D.V. Bhope (2011). Analyzed the Tractor Trailer made by Awachat Industries, Wardha to reduce the manufacturing cost.

[8] Roslan Abd Rahman, Mohd Nasir Tamin, Ojo Kurdi (2008). Has used FEM software and determine stress analysis as a preliminary data for fatigue life prediction.

[9] S.S Sane, Ghanashyam Jadhav, H. Ananadaraj (2008). Analyzed the light Commercial Vehicle chassis using FEM and simulated the failure during testing.

[10] Teo Han Fui, Roslan Abd. Rahman (2007). Have explained about the 4.5 Ton truck chassis against road roughness and excitations.

[11] Veloso, V., Magalhaes, H. S., Bicalho, G. I., & Palma, E. S. (2009). Studied the Failure of longitudinal stringer of vehicle.

[12] Vijaykumar V. Patel, R. I. Patel (2012). Have studied the Ladder chassis frame of Eicher E2 by static structural analysis.

[13] Yongjie Lu, Shaopu Yang, Shaohua Li, Liqun Chen (2009). Have developed virtual prototype model of heavy duty vehicle (DFL1250A9) using multi body dynamics.

[14] Zhongzhe D, Ping Z. (2006). Has performed Fatigue life analysis and improvement of the auto body in a sports utility vehicle (SUV)