ISSN 3047-5473
Innovation in Engineering, Volume 1, Nomor 1, 2024, pp. 50-59

Revitalizing vehicle innovation: Exploring electric car chassis structures through finite element analysis

Hafidz Dwi Anggara*

Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang, INDONESIA

*Corresponding Author: hafidzdwianggara@gmail.com

DOI: https://doi.org/10.58712/ie.v1i1.6

Abtract: The increasing number of motor vehicles contributes significantly to air pollution, resulting in global environmental degradation due to CO2 emissions. Electric cars offer an environmentally friendly solution to this issue. Vehicle chassis plays a critical role as the support structure for various components. This study aims to design an optimal electric vehicle chassis considering weight, safety, and strength aspects, utilizing von Mises stress analysis to assess stress levels and safety factors. The research focuses on determining the chassis' safety factor and stress distribution, employing alloy steel material and subjecting it to a 5000 N force using finite element analysis (FEA). Analysis results show von Mises stress ranging from 0.002 N/mm^2 to 167.549 N/m^2, displacement ranging from 0.000 mm to 1.812 mm, strain ranging from 0.000 to 0.0001, and safety factors ranging from 2.327 to 371,181.531. Consequently, overall simulation on the chassis is targeted to run optimally, which fulfills the objectives of this research.

Keywords : Vehicle frame; Electrical vehicle; Green car; Transportation

1. Introduction

The advancement of electric vehicle technology has become a primary focus in the automotive industry in response to the need for environmentally friendly transportation solutions [1]–[3]. Electric vehicles offer the potential to reduce greenhouse gas emissions and air pollution, leading to increased interest from consumers and vehicle manufacturers worldwide [4], [5]. In efforts to enhance the performance and safety of electric vehicles, special attention is directed towards developing an optimal chassis structure.

In the evolving automotive industry, efforts to introduce environmentally friendly vehicles are gaining prominence [6]. Electric cars are the primary focus as a cleaner and more sustainable alternative in transportation [7]. An essential aspect of electric car

Received: January 20, 2024. **Revised**: February 26, 2024. **Accepted**: March 15, 2024

design is the chassis structure, which is vital in determining vehicle performance and safety. The chassis is a critical element in the design of both conventional and electric vehicles [8]. However, with technological advancements and evolving electric vehicle needs, a fresh approach to chassis structure design and analysis is necessary. This underscores the need for revitalizing innovation in developing electric car chassis to enhance vehicle efficiency, performance, and safety [9].

Amidst advancing technology, finite element analysis has emerged as a valuable tool for understanding and enhancing electric car chassis design [10], [11]. Reviving innovation in chassis structure is crucial to addressing current technical and environmental challenges in the automotive industry [12]. Despite progress in electric vehicle design and technology, challenges persist, particularly concerning chassis structure. The proper design of the chassis can influence various aspects of vehicle performance, including maneuverability, stability, and crash response [13], [14]. Therefore, further exploration of electric car chassis structures is highly significant for refining and enhancing future vehicle designs.

Finite element analysis has become a crucial tool in optimizing the structure of electric car chassis [15], [16]. This analysis enables engineers to model and predict structural behavior under various load and environmental conditions, facilitating the identification of areas requiring improvement or enhancement [17]. Thus, this study aims to design an electric car chassis that considers weight, safety, and strength, utilizing von Mises stress analysis to determine stress levels and safety factors. Moreover, this research aims to offer innovative potential in electric car chassis structures through a meticulous and comprehensive finite element analysis approach. Consequently, this study is expected to advance more sophisticated and sustainable electric vehicle technology significantly.

2. Methods

This study employed software and hardware tools to develop an optimal design for the electric vehicle chassis [18], [19]. The research utilized customized chassis structure designs tailored to the requirements of electric vehicles as the research material. The chassis is the vehicle frame that integrates all vehicle components and constitutes the most substantial element, ensuring driver safety. Various types of chassis exist, including ladder frame, monocoque, and space tube frame architectures [20].

2.1 Research variables

This study utilized a ladder frame chassis comprising two main longitudinal components with several other parts perpendicular to the main components, as illustrated in Figure 1. The choice of material for the chassis varies depending on its type. Manufacturers typically construct conventional vehicles from aluminum or iron [21].

The advantage of this frame lies in its simple form, making it easier and more cost-effective to manufacture. However, its drawback is its low torsional stiffness. Consequently, racing contexts do not utilize this chassis type, where high torsional stiffness is crucial [22].

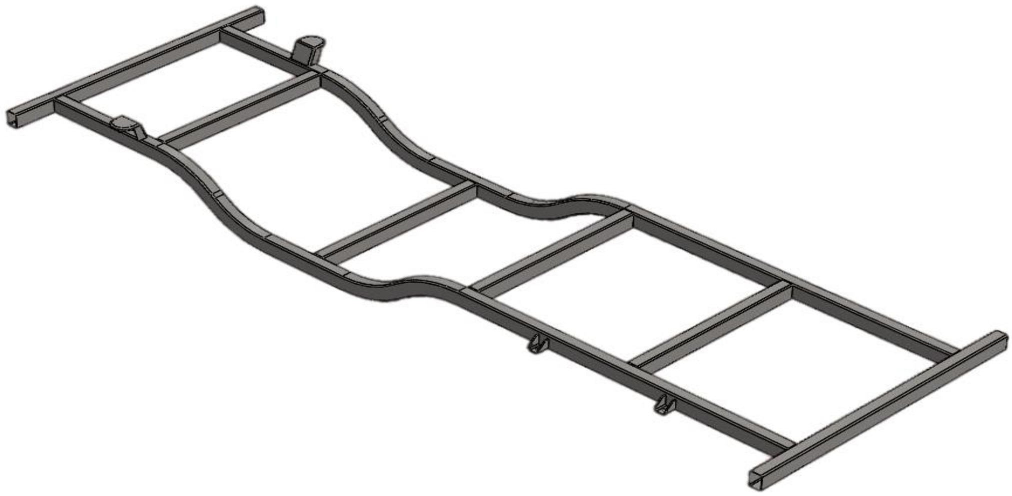

Figure 1: Chasis ladder frame

Figure 1 illustrates the electric vehicle chassis structure design created using SolidWorks. The material employed is alloy steel, with a thickness of 3 mm, and its profile measures 5128 x 1800 mm in dimensions.

2.2 Material

Based on the analysis conducted during the fabrication of the electric vehicle chassis, the measurements of alloy steel thickness, serving as the fundamental material for constructing the electric vehicle frame, are presented in Table 1.

Table 1: Material properties alloy steel

Property	Value	Units
Elastic Modulus	210000	N/mm
Poisson's Ratio	0,28	N/A
Shear Modulus	79000	N/mm
Mass Density	7700	Kg/m
Tensile Strength	723,8256	N/mm
Yield Strength	620.422	N/mm
Thermal Expansion Coeficcient	1.3e-05	/K
Thermal Conductivity	50	W/(m·k)
Specific Heat	460	J/(kg·K)
Compressive Strength		N/mm
Material Damping Ratio		N/A

ISSN 3047-5473
Innovation in Engineering, Volume 1, Nomor 1, 2024, pp. 50-59

The method employed is a simulation procedure based on the finite element method, which utilizes computational techniques to obtain approximate solutions for boundary value problems. Put simply, a boundary value problem is a mathematical issue that requires one or more dependent variables to satisfy differential equations within a known range of independent variables, meeting certain conditions at the boundary of that range [23].

2.3 Eletric car chassis modeling

We conducted the 3D modeling of the electric car chassis frame using SolidWorks 2021, and Figure 2 displays the full dimensions.

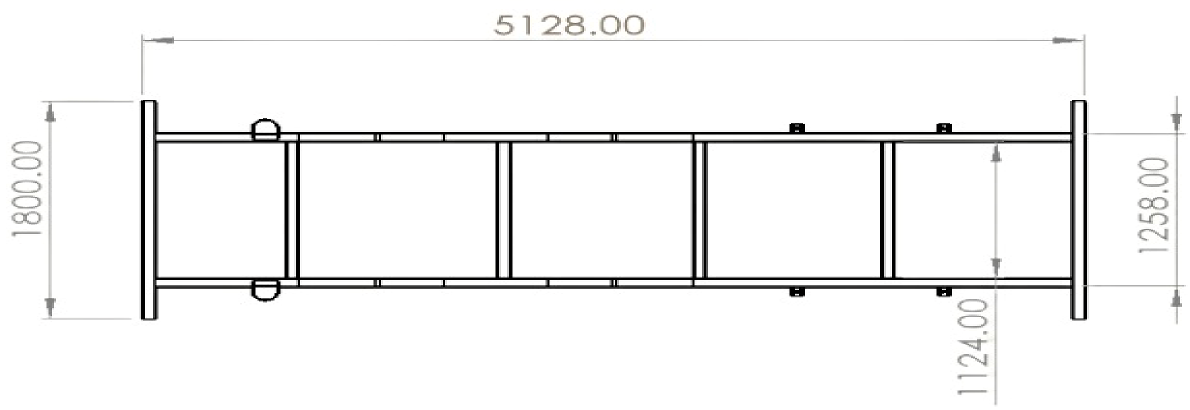

Figure 2: Electric car chassis and dimensions

2.4 Meshing

Mesh testing uses standard mesh parameters to determine the quantity of elements, nodes, and element size in the electric car chassis [24]. The mesh analysis yielded solid mesh elements, with 388,942 nodes and a minimum element size of 14.3979. The mesh results are depicted in Figure 3, while Table 2 presents a detailed breakdown of the mesh outcome.

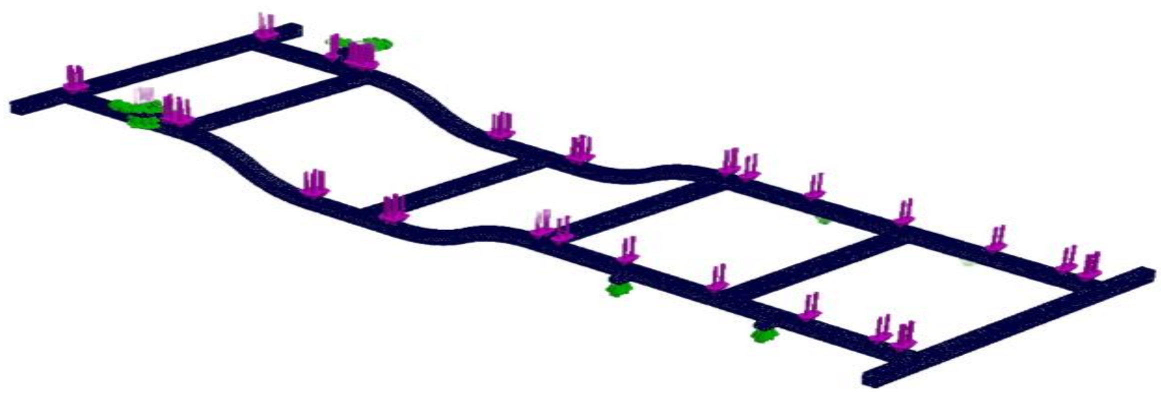

Figure 3: Mesh simulation results

ISSN 3047-5473
Innovation in Engineering, Volume 1, Nomor 1, 2024, pp. 50-59

Table 2: Detail mesh

Mesh Details	Description
Mesh Type	Solid Mesh
Mesher Used	Curvature-based mesh
Jacobian point for high-quality mesh	16 Points
Element size maximal	71,9894 mm
Element size minimal	14,3979
Mesh Quality	High
Total Nodes	388942
Total Elements	195354
Maximum aspect ratio	78.485
% of elements with an aspect ratio < 3	2,59
Percentage elements with aspect ratio > 10	5,19
Percentage of distorted elements	0
Number of distorted elements	0
Time to complete mesh (hh; mm; ss)	00:00:44

3. Results and discussion

Upon completion of the electric car chassis frame design, an analysis was conducted on the structure, subjecting it to a load of 5000 N. The simulation results are depicted in Figure 4.

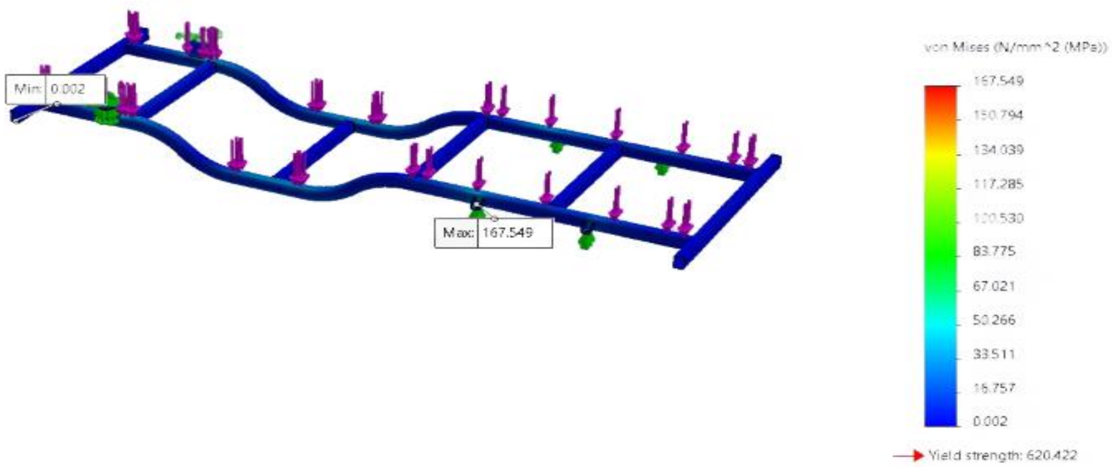

Figure 4: Stress analysis results

The stress analysis yielded a minimum value of 0.002 N/mm^2 and a maximum value of 167.549 MPa, as shown in Figure 4. The displacement plot analysis resulted in a minimum value of 0.000 mm and a maximum value of 1.812 mm, as illustrated in Figure 5.

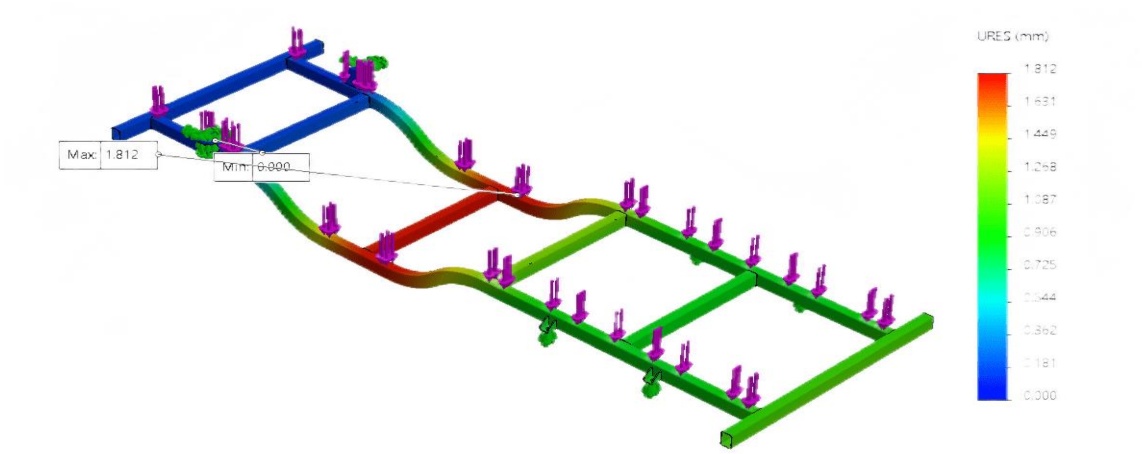

Figure 5: Displacement plot analysis results

The strain analysis yielded a minimum value of 0.000 and a maximum value of 0.0001, as presented in Figure 6.

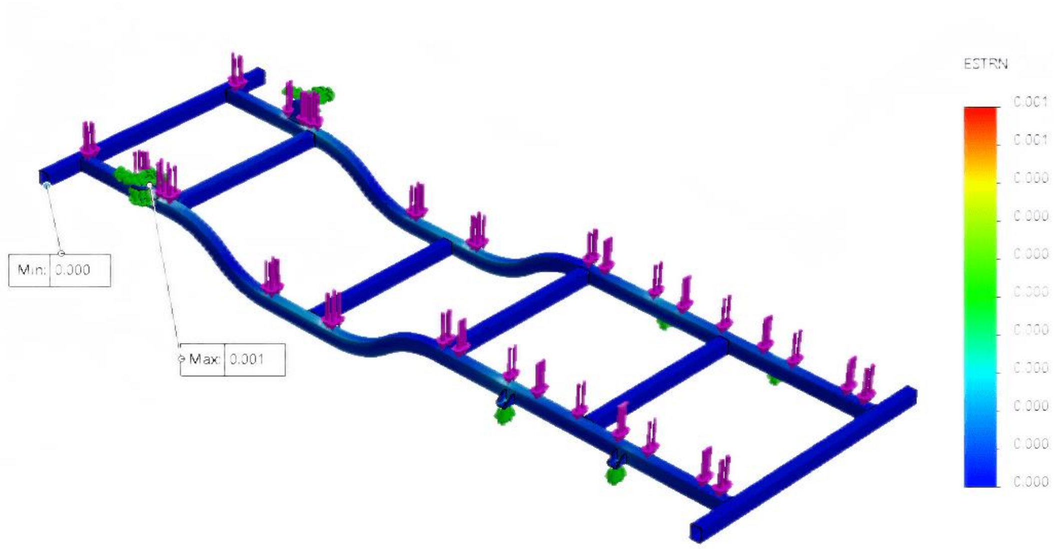

Figure 6: Strain analysis results

The safety factor analysis resulted in a minimum value of 2.327, illustrated in Figure 7. The findings of this study, in contrast to other research, indicate that employing alloy steel material yielded a minimum stress distribution of 0.002 N/mm^2 and a maximum stress distribution of 167.549 MPa, along with a minimum safety factor value of 2.327. Conversely, in the compared study utilizing aluminum material, the stress distribution was 43.0767 MPa, with a safety factor of 6.38396 [25].

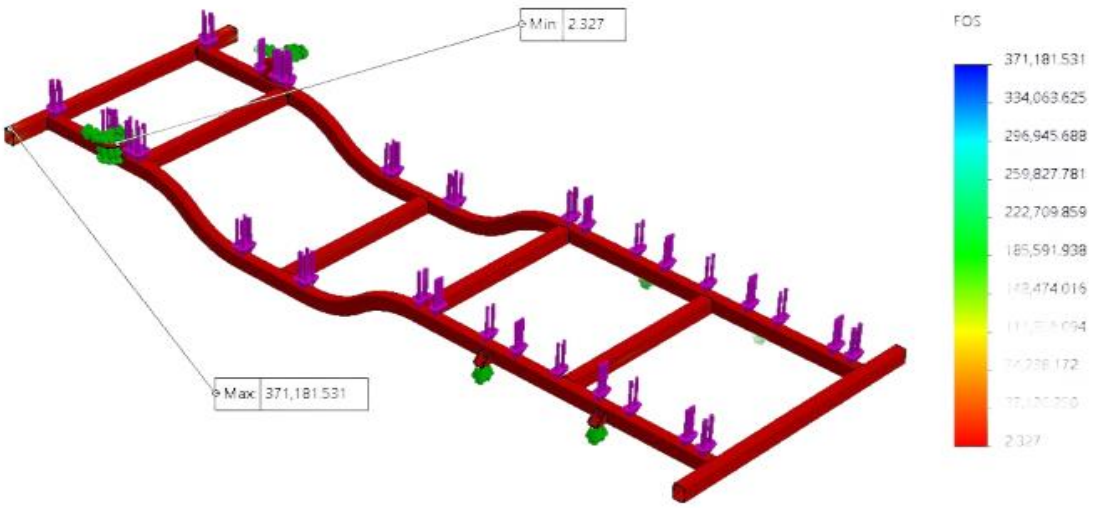

Figure 7: Safety factor analysis results

4. Conclusion

This study reveals that finite element analysis plays a crucial role in the design of electric vehicle chassis structures measuring 5128 x 1800 mm and utilizing alloy steel material capable of withstanding a load of 5000 N. Analysis results indicate that the chassis made of alloy steel and subjected to a 5000 N load exhibits varied stress distribution, with minimum values of 0.002 N/mm^2 and maximum values of 167.549 MPa. Furthermore, the displacement plot shows a range of displacements from 0.000 to 1.812 mm, while strain analysis indicates a range from 0.000 to 0.0001. The safety factor analysis results reveal minimum and maximum values of 2.327 and 371,181.531, respectively.

In future research, we could explore several areas. Firstly, we could expand this study to compare the utilization of different materials, such as aluminum, with alloy steel in the design of electric vehicle chassis to assess their strength and safety. Additionally, further research could integrate deeper analyses of other factors affecting chassis performance, such as vehicle dynamics, maneuverability, and crash response. Moreover, research on the development of electric vehicle technology could also consider sustainability aspects, including material life cycles and the environmental impact of vehicle production and usage. Continuous research and innovation in designing electric vehicle chassis structures are expected to lead to significant progress in developing more efficient, safe, and environmentally friendly electric vehicles.

Funding statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors are grateful to the manufacturing laboratory, Universitas Negeri Padang for the use of computers for Solidworks simulations.

Conflict of interest statement

The authors declare no conflict of interest in this research and publication.

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