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Finite element method based analysis of lower body structural strength on rekarya ev electric car

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Abstract

In line with current technological developments, the use of electric vehicles is expected to increase due to their environmentally friendly nature—primarily because they produce no exhaust emissions. One of the critical structural components of an electric car is the lower body. The lower body of the Rekarya EV has been specifically designed to accommodate three rows of seating. This study aims to evaluate the structural strength of the Rekarya EV's lower body under static loading conditions by analyzing von Mises stress, displacement, and safety factor values. The analysis was carried out using the Finite Element Method (FEM) through Autodesk Inventor Professional 2020. A static stress analysis was performed using ASTM A36 steel material with three different thickness variations: 1.0 mm, 1.2 mm, and 1.4 mm. The resulting von Mises stress values were 72.88 MPa, 62.24 MPa, and 51.66 MPa, respectively. The corresponding displacement values were 1.366 mm, 1.295 mm, and 1.212 mm. The calculated safety factors were 3.41, 3.99, and 4.8. Additionally, the total weight of the lower body for each thickness was calculated as 88.012 kg, 100.823 kg, and 113.613 kg. The results indicate that all three thickness variations provide adequate safety factors; however, increasing material thickness significantly affects the overall weight of the structure. Therefore, a balance between strength and weight must be considered in the design process.

1. INTRODUCTION

Transportation plays a crucial role in supporting nearly all aspects of human activity. According to data compiled by *Databoks* from the Central Statistics Agency (BPS), in 2022, approximately 93% of commuter workers in Indonesia relied on private vehicles as their primary mode of transportation, while only 6.3% used public transportation (Muhammad, 2023). Among the various private vehicles, cars remain the most commonly used option for daily activities by a majority of Indonesians.

In general, most cars in Indonesia still rely on gasoline and diesel engines to generate power through combustion. However, the continued use of conventional engines poses serious environmental concerns. As noted by Andrian & Marpaung (2019); Iskandar et al. (2020); and Iskandar et al. (2024), conventional engines consistently emit harmful compounds such as carbon monoxide (CO), total hydrocarbons (THC), particulate matter (TSP), nitrogen oxides (NOx), and sulfur oxides (SOx), all of which contribute to air and environmental pollution. These vehicles depend on fossil fuels (BBM) to initiate the combustion process and produce the power required to operate.

According to data from the Ministry of Energy and Mineral Resources in 2020, Indonesia's total oil reserves amounted to 4.17 billion barrels, with 2.44 billion barrels classified as proven reserves. Based on these figures, the reserves are projected to last for approximately 9.5 years (Pribadi, 2021). Faced with this situation, it is essential to optimize the use of renewable technologies in today's modern era—one promising solution being the development of electric vehicles. Electric cars are expected not only to reduce reliance on fossil fuels but also to help decrease air pollution in the surrounding environment. According to the Air Quality Life Index (AQLI) published by the Energy Policy Institute at the University of Chicago (EPIC), poor air quality in Indonesia is projected to reduce the average life expectancy of its citizens by 2.5 years, based on standards set by the World Health Organization (WHO) (Lee & Greenstone, 2021).

Along with the advancement of electric vehicle technology, various components of these vehicles have also evolved, driven by the development of science and technology. One such component is the vehicle body. The design of a vehicle's body is a critical aspect that influences overall performance, alongside other systems such as the engine, transmission, steering, suspension, braking, electrical systems, and aesthetics (Amaluddin, 2022). A key structural part of the vehicle body is the lower body, as it supports both the weight of the passengers and the entire vehicle structure. For this reason, the lower body must be constructed using materials that are not only strong and durable, but also resistant to corrosion over time.

In the case of the Rekarya EV electric car, the lower body is specifically designed to accommodate three rows of seats, fulfilling its role as a commercial electric vehicle for transporting both passengers and goods. This study aims to assess the structural strength of the Rekarya EV's lower body using the Finite Element Method (FEM).

Finite element analysis offers an effective and efficient method for evaluating various design and manufacturing parameters under specific conditions (Tjiptady et al., 2020). In this study, the Finite Element Method is utilized to calculate the deflection and stress experienced by the lower body structure of the vehicle. These calculations aim to determine the capability of the lower body to support both the vehicle frame and the seating structure in a commercial electric car. Through this approach, the structural strength of the Rekarya EV's lower body can be accurately assessed.

2. RESEARCH METHODS

This study employs a simulation-based experimental method using the Finite Element Method (FEM), conducted through Autodesk Inventor Professional 2020 software. The type of data collected in this research is quantitative. Finite Element Analysis (FEA) is used to evaluate the structural strength of the lower body of a commercial electric vehicle by comparing the analysis results across different material types.

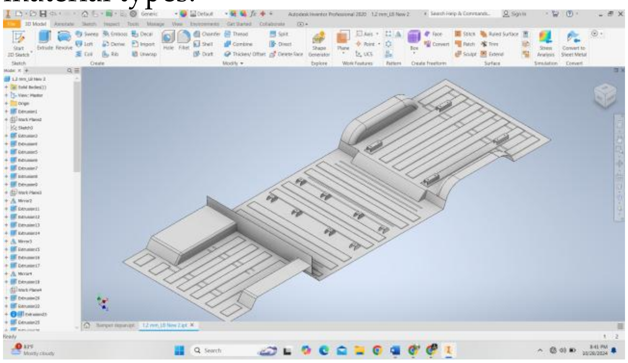


Figure 1. Lower Body of Rekarya EV

Material selection plays a crucial role in structural analysis. In this study, ASTM A36 steel is used and analyzed in several thickness variations to serve as a comparison material. ASTM A36 is a type of low-carbon steel, which means it has a lower hardness level compared to high-carbon or alloy steels. However, it offers good strength and excellent formability, making it suitable for machining and welding processes

(Humaidi et al., 2022). Due to its relatively low carbon content, ASTM A36 also has higher ductility than high-carbon or alloy steels. Moreover, this type of steel is widely available on the market and is considered cost-effective, as it contains fewer alloying elements, making it a popular choice for various structural applications.

The steps in this research are outlined as follows:

1. **Observation and Literature Review**: Conducting an initial review of relevant literature to gather background information and insights.
2. **Conceptualization and Design Planning**: Defining the concept, shape, and dimensions of the lower body based on the study objectives.
3. **3D Modeling**: Creating a detailed 3D model of the lower body using appropriate design software.
4. **Material Data Input and Setup**: Inputting material properties, applying constraints, defining loads, setting up contacts, and generating the mesh for the simulation.
5. **Simulation and Results Analysis**: Running simulations and analyzing the results to assess the structural performance.

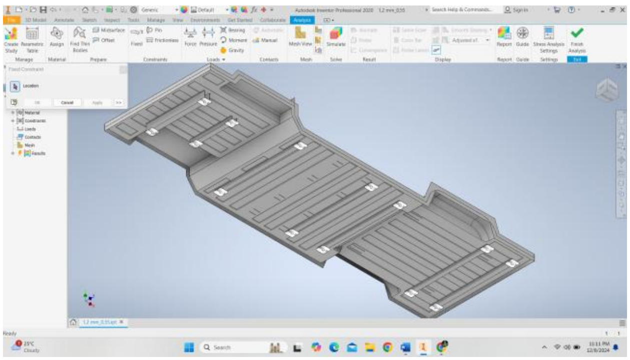


Figure 2. Providing Support

The support is given to the bracket which is under the lower body which will later be supported by the chassis.

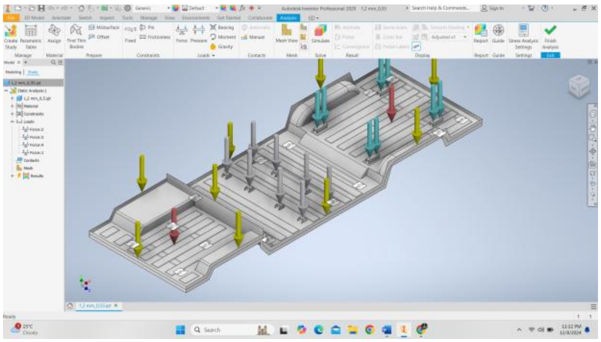


Figure 3. Assignment of Load

The load assignment is adjusted to the location of the load, so that the simulation can be assumed as a real load. That way, more objective and maximum data can be produced. Load allocation data is divided into 4 loads, as follows:

Table 1. Allocation of Loads

Location in EV	Allocation of Load in EV	Load	Total Load
Location 1 (Around the Body)	Body	2942 N	2942 N
Location 1 (Front and Back)	Luggage Compartment	1471 N	1471 N
Location 2 (Middle)	Passengers (2)	1373 N	1569 N
	Seats (2)	196 N	
Location 3 (Rear of EV)	Passengers (5)	3432 N	3922 N
	Seats (5)	490 N	

The data collection technique in this study uses observation techniques. In data collection, there are instruments used to facilitate data collection. The data collection instrument used in this study is the Research and Development data collection method using Autodesk Inventor Professional 2020 Software to analyze and collect data based on the results of the simulation that has been running. The data collection process uses the following test table:

Table 2. Material Standards for Data Collection

Material ASTM A36	Von Misses Stress	Displace ment	Safety Factor
Thickness 1 mm			
Thickness 1 mm			
Thickness 1 mm			
Type	**Lower Body**		

Lower Body Dimension	L=4200mm	W=1400 mm	H=307.5 mm

Research location Analysis of Lower Body Structural Strength on REKARYA EV Using Finite Element Method was conducted in CAD Lab, E9 Building, Semarang State University.

In assisting the implementation of the research, the following devices were used: (a) 3 laptop with specifications: Windows 11, AMD ATHLON 300u processor, 8 GB RAM, and 512 GB SSD, (b) Autodesk Inventor Professional 2020 software, (c) Microsoft Word software, (d) Stationery, and (e) Printer.

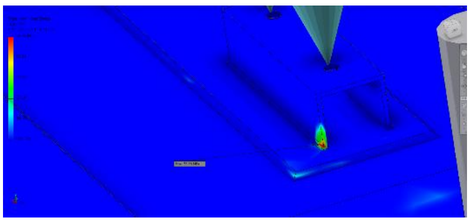
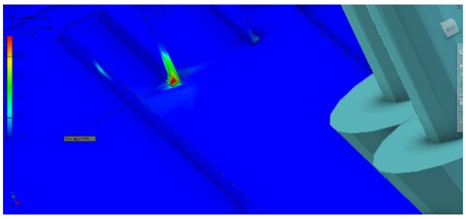
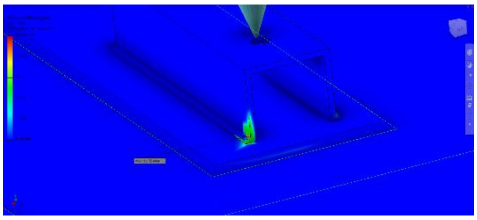
3. RESULTS AND DISCUSSION

The simulation results, processed using Autodesk Inventor Pro 2020 software, provide analysis of the von Mises stress, displacement, and safety factor values for the lower body of the Rekarya EV electric vehicle. In this simulation, three variations of lower body thicknesses were subjected to static loading conditions. The results of the simulation are presented through illustrations showing deformation, stress distribution, and key points representing the maximum stress levels identified in the analysis. These results are then compiled into tables and graphs for further examination and comparison.

3.1. Von Misses Stress Results

The discussion of the von Mises stress values is based on the simulation results of the three material thickness variations. For each thickness, the maximum von Mises stress value and its location were identified. These stress values will also be used later to calculate the safety factor for each material variation tested in the simulation

Table 3. Results of Von Misses Stress

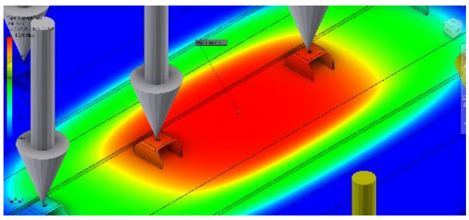
Thickness	Results
1 mm	 72.88 MPa
1.2 mm	 62.24 MPa
1.4 mm	 51.66 MPa

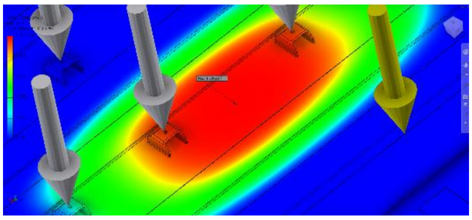
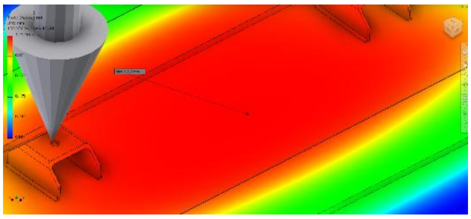
Based on the table, the von misses stress values at thickness variations of 1 mm, 1.2 mm and 1.4 mm have similarities at the location with the highest von misses stress value, namely on the left middle seat bracket, but have differences in the von misses stress value, namely for the 1 mm thickness variation has the highest stress value of 72.88 MPa and for the 1.2 mm thickness variation has the highest stress value of 62.24 MPa and for the 1.4 mm thickness variation has the highest von misses stress value of 51.66 MPa.

According to the theory of elasticity, von Mises stress is used as the failure criterion of ductile materials. The thicker the plate, the higher the resistance to deformation, so the von Mises stress decreases. Niu et al. (2019) found that increasing the thickness of the vehicle structure can significantly reduce the stress concentration in the critical area of the electric vehicle body structure.

3.2. Displacement Results

Table 4. Displacement Results

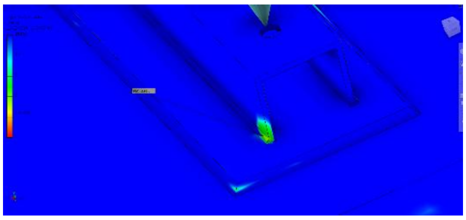
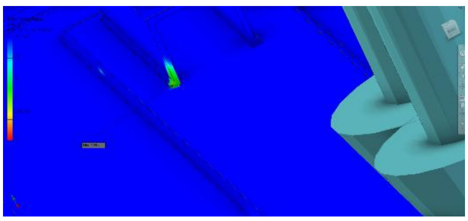
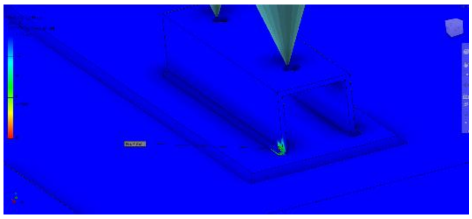
Thickness	Results
1 mm	 1366 mm

1.2 mm	
	1295 mm
1.4 mm	
	1212

Based on the table, the highest displacement results for thickness variations of 1 mm, 1.2 mm and 1.4 mm have the same displacement location in the middle of the lower body plate, but have different displacement values, namely for the 1 mm thickness variation the highest displacement value is 1.366 mm and for the 1.2 mm thickness the highest displacement value is 1.295 mm, while for the 1.4 mm thickness variation the displacement value is 1.212 mm. The elastic modulus and plate thickness affect the structural stiffness; increasing the thickness increases the stiffness, thereby reducing the total deformation under constant load. Chen et al. (2021) proved that material thickness greatly affects the structural stiffness and displacement, especially in steel-based lightweight automotive structures.

3.3. Safety Factor Results

Tabel 5. Safety Factor Results

Thickness	Results
1 mm	
	3.41
1.2 mm	
	3.99
1.4 mm	
	4.8

Based on the table above, the safety factor values for the thickness variations of 1 mm, 1.2 mm, and 1.4 mm show the same point of vulnerability, which is located at the left middle seat bracket. However, the safety factor values differ for each thickness variation. The minimum safety factor is calculated by dividing the yield strength of ASTM A36 steel by the von Mises stress value. Using this calculation, the safety factor values for each thickness variation are as follows: for the 1 mm thickness, the safety factor is 3.41; for the 1.2 mm thickness, it is 3.99; and for the 1.4 mm thickness, it is 4.8. A higher safety factor indicates a stronger lower body structure, while a safety factor below 1 would suggest a design failure, as the structure would not be able to withstand the applied loads. Safety factor is the ratio between the material strength (yield strength) and the actual working stress. Structures with values above 2.5 are considered safe in structural engineering. A study by Kim et al. (2017) on modular electric vehicles showed that optimizing the safety factor against weight is important for structural efficiency.

Based on the safety factor value of the three thickness variations that have been carried out, the minimum safety factor value is obtained which is still above the minimum limit of the safety factor criteria that has been determined, which is less than 2.5. However, in selecting thickness variations, not only the safety factor is used as a reference, but also takes into account the weight in selecting the plate thickness. The results of the total accumulated weight of the material obtained from the software after simulation at each thickness are as follows:

Table 6. Total Massa

No	Thickness	Massa

1	1 mm	88.012 Kg
2	1.2 mm	100.823 Kg
3	1.4 mm	113.613 Kg

From the table above, the larger the size of the thickness variation, the heavier the load that will be given. According to Zhang et al. (2020), the selection of the thickness of the electric vehicle structure must consider the trade-off between strength, displacement, and mass to maintain the energy efficiency of the vehicle. So from the research data collected in a table and graph to analyze the thickness of the material to be used.

Table 7. Data Collection Results

Material ASTM A36	Von Misses Stress	Displacement	Safety Factor
Thickness 1 mm	72.88 MPa	1.366 mm	3.41
Thickness 1 mm	62.24 MPa	1.295 mm	3.99
Thickness 1 mm	51.66 MPa	1.212 mm	4.8
Type	**Lower Body**		
Lower Body Dimension	L = 4200mm	W = 1400 mm	H = 307.5 mm

4. CONCLUSION

This study, titled "Analysis of Lower Body Structural Strength on REKARYA EV Electric Cars Using Finite Element Method," concludes that material thickness significantly affects the von Mises stress, displacement, and safety factor values. The results show that a thicker material improves the test outcomes, with all thickness variations having a safety factor above the minimum limit of 2.5. However, using thicker material also increases the vehicle's load and cost. Therefore, the ideal and most effective thickness is 1.2 mm, considering the balance between strength and efficiency. Future studies could explore the impact of different materials and advanced alloys, as well as investigate the influence of dynamic loading and real-world operational conditions on structural performance.

5. DECLARATION/STATEMENT

5.1. Acknowledgment

We would like to thanks to all parties who helped this research.

5.2. Author Contribution

Kristian Wibisono contributed to do the research. Widya Aryadi contributed as supervisor.

5.3. Conflict of Interest

Authors declare no conflict of interest.

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