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Structural Analysis of Chassis Frame of a Prototype Car: A Finite Element Method

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ABSTRACT

Cars are a means of transportation that is considered very important in human life, so it requires a high level of safety and comfort. Currently, there has been a lot of research on the manufacture of prototype category energy-efficient car chassis with electric motor drive. The frame is an integral part and an important part in the design of a vehicle. The frame was design using software with frame dimensions of 2.230 mm long and 360 mm wide. The material used is 7075 aluminum prototype chassis. Furthermore, the chassis frame construction was evaluate using the static simulations in order to determine von misses stress, displacement, and safety factor. The analysis carried out with a maximum load of 1.000 N, the results of the von misses stress analysis were obtained with the highest stress level of 13.8 MPa. The maximum displacement result is 0.39 mm was in the driver position, with a maximum safety factor of 3 and a minimum of 1, it is declared safe.

Keywords: Vehicle frame, prototype, static load simulation

Introduction

A vehicle is a means of transportation that is considered very important in human life, so it requires a high level of safety and comfort. There are several things that affect driving safety and comfort, such as vehicles, drivers, and the environment. With the economic development and population growth of a country, the proportion of motorized vehicles per population will also increase sharply, especially in developing countries. In Indonesia alone, data from the Central Bureau of Statistics recorded that the number of motorized vehicles has reached 114.209.266 units consisting of 12.599.138 passenger cars, 2.398.846 buses, 6.235.136 freight cars, and 92.976.240 motorcycles. The average increase in the number of motorized vehicles per year in Indonesia is 14.55%, this increase is a very high increase when compared to the average increase in population in the 2010-2016 range of 1.36% (Kresnanto, 2019).

Currently, there have been many studies on the manufacture of energy-efficient car chassis in the prototype category with electric motor drives. The frame is an integral part and an important part of the design of a vehicle. All existing loads, be it vehicle, passenger, and engine loads, are all placed on the frame. The chassis is the most important part of the stability and balance of the vehicle (Ellianto & Nurcahyo, 2020). Therefore, in order to function properly a frame must be strong and sturdy so that it can support the load from passengers, the engine and its accessories are damaged or deformed. In addition, the frame must also be lightweight so as not to burden the engine work and have a flexibility value that serves to reduce vibrations caused by damaged road conditions and by the engine. The frame function is very important in every vehicle, it is necessary to know the maximum stress that

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occurs in each load by analyzing the frame with Solidworks Premium 2020 software (Budarma et al, 2020). Based on the construction where the body is attached to the frame is divided into 2 types, namely separate construction and fused construction. The frame presented on the vehicle must be strong, lightweight, and resistant to shocks received from the road condition (Isworo et al, 2019).

Solidworks Premium 2020 is software used to help the design process of the frame. This software is a CAD (Computer Aided Design) program that has the ability to create 2-dimensional and 3-dimensional models that are useful for helping the process of making 2-dimensional and 3-dimensional prototype designs visually (Wahab et al, 2022). Aluminum has many uses for applications in various fields. The properties of high strength, low specific gravity, high castability, high wear resistance, low thermal expansion, and high corrosion resistance make Aluminum have wide applications in different domains, such as transportation, home decoration and accessories, building and tire construction to the aircraft industry. Al 7075 alloy is more often used to reduce the weight of the material while retaining its brittle strength, and there are some unforeseen consequences in applications involving exposure to heat for high temperatures.

This study will focus on the design and simulation of prototype vehicle chassis. The software used is Solidworks Premium 2020 to design the chassis frame as well as evaluate the von Misses stress, displacement, and safety factor of the frame through the static simulation.

Material and Methods

This research first started with making a sketch drawing of the chassis. The design process is carried out using manual drawings (sketches). The type of chassis chosen is a ladder frame, which is a frame that is used to receive loads. The ladder frame-type chassis has a simple design resembling a ladder. which will prioritize the efficiency of energy use, strength, and safety of vehicles for drivers and other people on the road. The concept in this prototype category is that the vehicle uses three wheels, two at the front and one at the rear. The wheels on the front are also used as the direction of the vehicle when the vehicle is moving and the wheels on the back are used as a drive that comes from an electric motor. Making 2D and 3D chassis designs aims to provide a detailed explanation of the chassis design. 2D and 3D chassis designs were created using Solidwork Premium 2020 software. After the design is made, analyze it in order to get an overview of the strength of the chassis frame structure. The material used adjusts the material available on the market, namely 7075 Aluminum. This material is more often used to reduce the weight of the material but still maintains its brittle strength without overriding the strength and safety factors of the chassis. In this design, the frame is divided into two parts, namely the main frame and the upper frame. The design of the main frame and upper frame parts is as follows: The main frame in this prototype is the main frame that will support the load from the driver's body and the components in the prototype include: the drive motor, transmission system, lightweight fire extinguisher (APAR) as one of the safety components, battery, and other electrical components. With a cross section measuring 20 x 40 x 1.5 mm. The structure is in the form of two long parallel aluminum rods connected to each other by transverse and perpendicular short rods which are connected using welding for the assembly process. The specifications and structure of the prototype main frame are shown in Figure 1. The main frame is designed with a length of 2230 mm and a width of 360 mm. At some points, the connection is made to add a reinforcing structure to the frame with the aim that the frame becomes sturdier and stronger in accepting the load of the driver's body and the components in the prototype.

The upper frame on the prototype uses mm for the unit. This frame serves to maintain or protect the driver during an accident (crash), the main frame is equipped with an upper frame, namely the roll bar. In addition, the roll bar functions as a separator between the steering room and the engine room. In terms of ergonomics, the roll bar is designed to tilt backward at an angle of 70 degrees to expand the steering wheel space and make the half-sitting driver comfortable. In Figure 2 the roll bar frame on each vehicle must be able to withstand a predetermined force load without large deformations and have a

good safety factor. The forces exerted on the roll bar are 700 N in the horizontal direction on the right and left sides of the frame (in all directions) and 700 N in the vertical direction (in all directions).

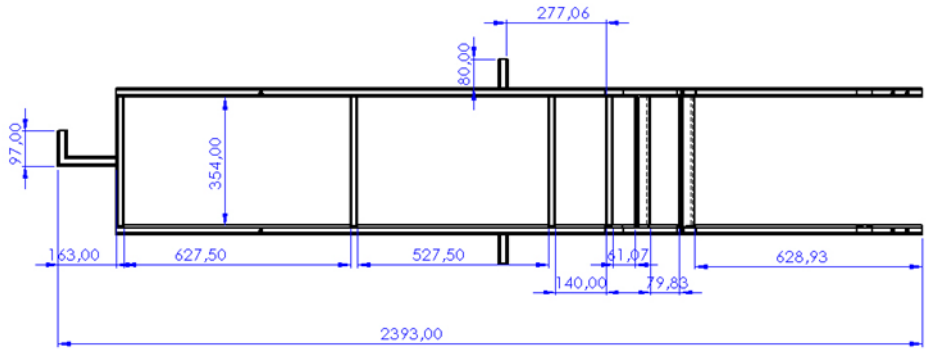

Figure 1. Main frame design (top view)

Figure 2. (a) front view and (b) side view of roll bar frame

The chassis design simulation aims to determine the amount of von Mises stress, displacement, and safety factors. The chassis design simulation uses Premium 2020 Software to make it faster and more efficient to find, calculate, or determine the stress on an object. Giving a gravity load serves to determine the heavy point on the frame. The value used is 9.810 mm/s2. In Figure 3, we can see the gravitational force that occurs on the chassis frame structure and the direction of the force received by the chassis frame structure. The support (fixed geometry) is given at the fulcrum of the frame, namely the front and rear wheels as shown in Figure 3.

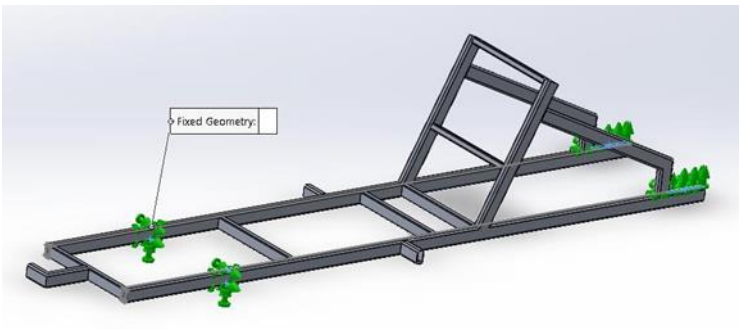

Figure 3. Fixed geometry on the prototype frame

Furthermore, the load is given to the frame, and the load given to the frame is in the form of driver load, engine load, and other components located close to the engine. The driver load is given and placed in a place that matches the position of the driver's body while driving. The driver's loading position on the frame while driving is illustrated in Figure 4.

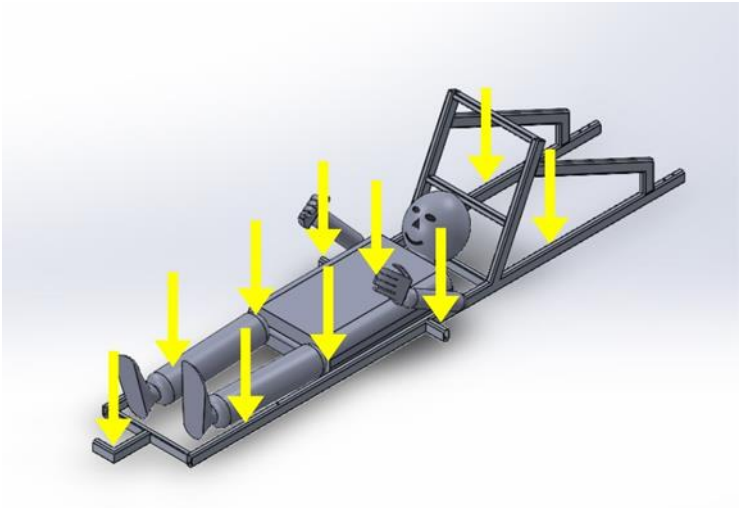

Figure 4. Load distribution of driver while driving and engine load in rear part of frame

The driver must have a minimum weight of 50 kg. In this test the author assumes the weight of the driver is 65 kg, this aims to determine the ability of the frame to receive the maximum load. In addition, giving more than the minimum load also aims to ensure that the frame is really strong if it receives other loads from outside. Based on the maximum gross vehicle weight intended for above-normal road use only, the minimum factor of safety for racing or offroad vehicle chassis is 5 (Ellianto & Nurcahyo, 2020). After applying the load and fixing geometry on the frame generated, the next step is the meshing process with a size of 30 mm. Meshing is a calculation process by dividing a component into several very fine element parts so that each element is analyzed very critically.

Results and Discussion

On the chassis, von Mises stress analysis was conducted for a maximum stress of 13.8 MPa. The highest stress is found in the front wheel mount support, while the minimum stress is found in the sensor support frame of 1.207e-04 Mpa. The simulation results of von Mises stress distribution can be seen in Figure 5.

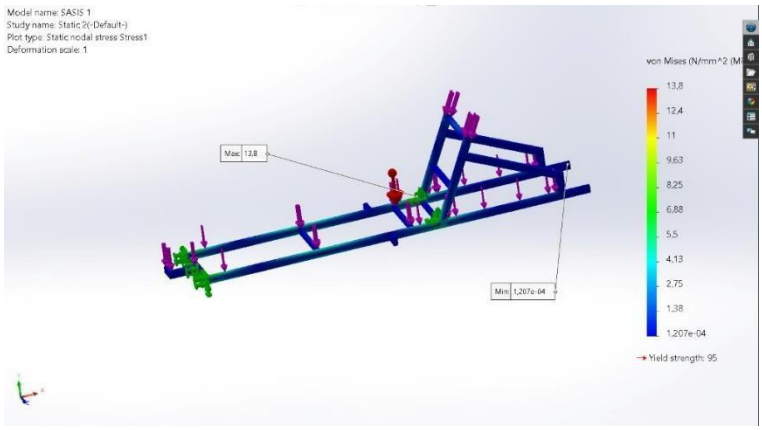

Figure 5. Von Mises stress of chassis

The next simulation is to analyze the displacement that occurs due to the load on the frame. Figure 6 shows that the blue field is the minimum displacement, while the red field is the maximum displacement. When viewed from the results of the analysis of the load on the driver's seat, the maximum

displacement result is 0.39 mm in red, and the minimum displacement of 1e-30 mm is shown in blue contour.

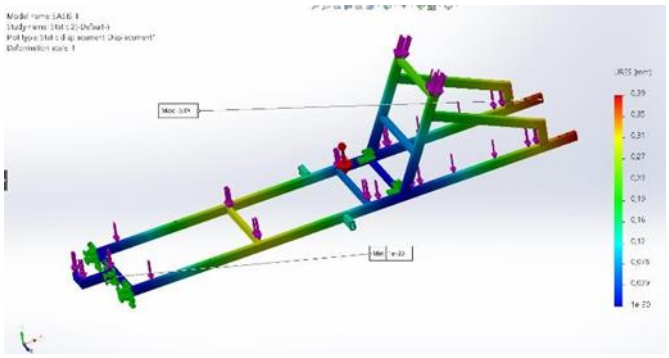

Figure 6. Displacement of the frame during loads applied

The maximum safety factor value of the frame is 3 and the minimum safety factor value is in the middle of the frame, which is 1. The minimum safety factor occurs in the middle frame due to this section receives vertical downward loading, namely the driver load. According to the results of the safety factor analysis above, it can be concluded that the frame is very safe.

Conclusion

Based on the results of the frame design using software, a technical drawing of the vehicle frame with frame dimensions of 2,230 mm long and 360 mm wide is obtained. The vehicle frame is equipped with a roll bar that extends around the driver's helmet. The frame uses 7075 aluminum material. Based on the results of the analysis carried out with a maximum load of 1,000 N, the von misses stress value is obtained with the highest stress level of 13.8 MPa. This value is still within safe limits because in the simulation results the red color indication is almost invisible and the value shows less than the material yield strength of 95 MPa. Based on the results of the maximum load analysis of 1,000 N, it shows a maximum displacement of 0.39 mm located in the area near the driver. This value can still be categorized as a small value, so it does not really affect the strength of the frame. Based on the results of the safety factor analysis, it is declared safe because it has a maximum safety factor of 3 and a minimum of 1. From the overall analysis results show that the design of the car vehicle chassis is still in the safe limit category, so it can be said to be safe and can be continued in the frame manufacturing process.

Acknowledgment

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