Static Analysis in The Chassis of 2023 Polibatam KMHE (Kompetisi Mobil Hemat Energi) Prototype Car Using 6061 Aluminium Alloy and Galvanized Steel Material

Arwin Hanif Raihan, Hanifah Widiastuti, and Ninda Hardina Batubara

Politeknik Negeri Batam
Program Studi Teknik Mesin
Jl. Ahmad Yani, Batam Centre, Batam 29461, Indonesia
E-mail: arwinhr18@gmail.com

Abstract

The chassis is a frame structure that must withstand compressive, shear, and tensile forces. In the context of vehicles, the function of the chassis is as an internal frame that is the basis for vehicle production, which will later be combined with other components such as the engine, steering, brakes, body, and electrical system. The chassis also serves to support the weight of the vehicle and driver and ensure that the car remains sturdy and stable to prevent deformation that can cause damage. In the chassis design process, it is important to pay attention to the latest developments to produce an optimal design. After conducting a thorough analysis including evaluating the advantages and disadvantages, the next step is to determine the strength analysis by considering stress, strain, and factor of safety. "Kontes Mobil Hemat Energi" (KMHE) is a contest to find the most energy-efficient car prototype. Therefore, a lightweight chassis is also a key factor that can make a prototype car more fuel efficient. This is also what causes the need for simulation as a reference so that the lightness of the chassis made still meets safety standards. The following conclusions were obtained that after reducing the size of the chassis, the chassis still meets the need for the required strength according the shown analysis result that has been done. The loaded stress value is smaller than the weakest material yield stress and the factor of safety value is above than 1.

Keywords: Chassis, Analysis, Prototype Car

Abstrak

Sasis merupakan struktur rangka yang harus mampu menahan gaya tekan, geser, dan tarik. Dalam konteks kendaraan, fungsi sasis adalah sebagai rangka internal yang menjadi dasar produksi kendaraan, yang nantinya akan dipadukan dengan komponen-komponen lain seperti mesin, kemudi, rem, bodi, dan sistem kelistrikan. Sasis juga berfungsi untuk menopang berat kendaraan dan pengemudi serta memastikan mobil tetap kokoh dan stabil agar tidak terjadi deformasi yang dapat menyebabkan kerusakan. Dalam proses perancangan sasis, penting untuk memperhatikan perkembangan terkini agar menghasilkan desain yang optimal. Setelah melakukan analisis menyeluruh termasuk mengevaluasi kelebihan dan kekurangannya, langkah selanjutnya adalah menentukan analisis kekuatan dengan mempertimbangkan tegangan, regangan, dan faktor keamanan. "Kontes Mobil Hemat Energi" (KMHE) merupakan kontes untuk mencari prototipe mobil yang paling hemat energi. Oleh karena itu, sasis yang ringan juga menjadi faktor kunci yang dapat membuat mobil prototipe lebih hemat bahan bakar. Hal ini pula yang menyebabkan perlunya simulasi sebagai acuan agar bobot ringan sasis yang dibuat tetap memenuhi standar keselamatan. Kesimpulan yang diperoleh adalah setelah dilakukan pengurangan ukuran rangka, rangka masih memenuhi kebutuhan kekuatan yang dibutuhkan sesuai dengan hasil analisis yang telah dilakukan. Nilai tegangan beban lebih kecil dari tegangan luluh terlemah material dan nilai faktor keamanan lebih dari 1.

Kata Kunci: Sasis, Analisis, Prototipe Mobil

1. Introduction

Rapid advancements in automotive technology have propelled the development of automobile vehicles, marking a significant era in the evolution of transportation. One crucial aspect of these innovative automotive designs is the structural integrity of the chassis frame. The chassis serves as the backbone of any vehicle, providing support, stability, and safety. In the pursuit of creating efficient and high-performance vehicles, it becomes imperative to conduct a comprehensive analysis of the material strength within the chassis framework.

Kontes Mobil Hemat Energi (KMHE) is a vehicle competition that focuses on fuel savings at the national level. In order to save fuel consumption, all of the components used in the prototype car must be carefully planned, so that they have minimum weight with strength that meets design standards [5]. One of the prototype car components is the chassis which will be discussed in more detail in this study.

The objective of this research to make sure that the designed chassis is safe to be use. The design of the frame should have enough strength to bear all the deformation [4]. The key factor is the minimum value of factor of safety (FoS) is above 1. The problem limitations of this research are within the scope of static analysis of aluminium 6061 alloy and galvanized steel materials, using Solidworks 2022 software.

A prototype is a system design scheme that forms a model and standard for the size or scalability that will be worked on later [1]. Strength analysis of materials, also known as strength science of materials or mechanics of materials, is a branch of engineering that studies the behavior of materials when subjected to external forces [5]. The basic theory in material strength analysis includes several key concepts:

- Stress is the force that acts per unit area on a material.
- Strain is the relative change in dimensions of a material due to stress.
- Factor of safety is the ratio between the maximum stress that a structure or component can withstand and the anticipated load.

Stress analysis is important in knowing the stress, fatigue deformation and prediction of the service life experienced by components to determine the highest stress point which is usually known as the critical point that initiates failure [2].

In this research, the author will present the results of an analysis using Solidworks Analysis software of a prototype car chassis that has been designed using aluminium 6061 alloy and galvanized steel material. Starting from stress, strain, and factor of safety. Referring to previous studies, it was found that the analysis results already had met the strength standards and factor of safety. However, the challenge was given back to the author to carry out the redesign process on the previous chassis to be smaller size in order to reduce the weight of the car and reduce the cost of making the car body. Changes also occurred in the engine transmission which was replaced with a smaller size so that the author reduced the engine & transmission space on the chassis. And finally, the overall redesign results were re-analyzed in order to find out the strength that must meet the safety factor. Primarily, the author's solution on this challenge is by not making major changes to the main frame but strengthen the rollbar.

2. Methodology

2.1. Research

This project was done in a team from January 2023 to August 2023 during project-based learning activities in Politeknik Negeri Batam.

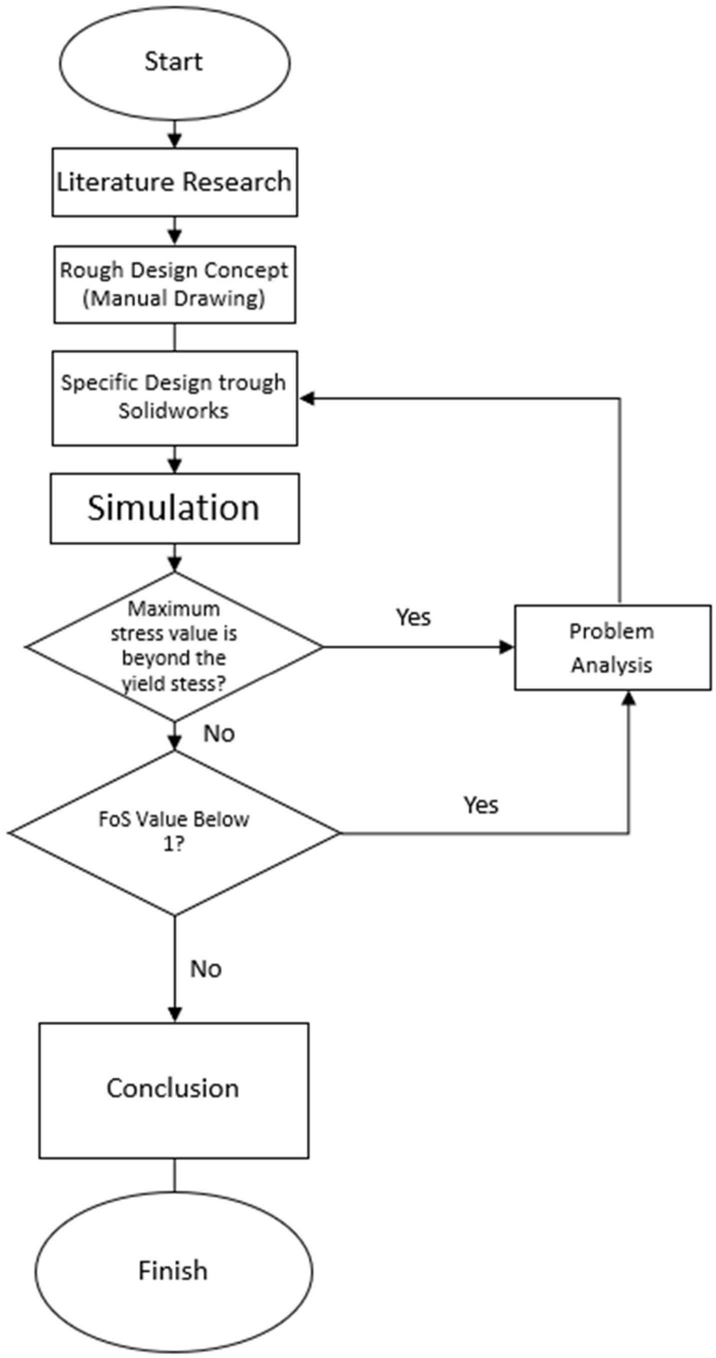

Figure 1. Flowchart of the study.

2.2. Stages

2.1.1. Literature Research

The literature study is looking for several research references related to the needs for making the chassis of the prototype car that will be made. Starting from KMHE guidelines [3], material classification, to engineering analysis guidelines.

2.1.2. Rough Design Concept

At the beginning of the design, the chassis frame uses basic manual drawings. The chassis design is designed according to the results of discussions with team members. Such as the engine room, steering and wheel mounts. The design must also be based on the 2023 KMHE guidelines, which are having a maximum height of 100 cm, a minimum track width of 50 cm, a minimum wheelbase of 100 cm, an overall width of 130 cm, an overall length of 350 cm, and a maximum total weight of 140 kg. [3]

2.1.3. Specific Design Through Solidworks

After the chassis concept and dimensions are determined, the image is transferred to Solidworks software to get a more detailed view. By using Solidworks, the author can have more flexibility in working on several details on the chassis which will also be easier to communicate it with the team and lecturers.

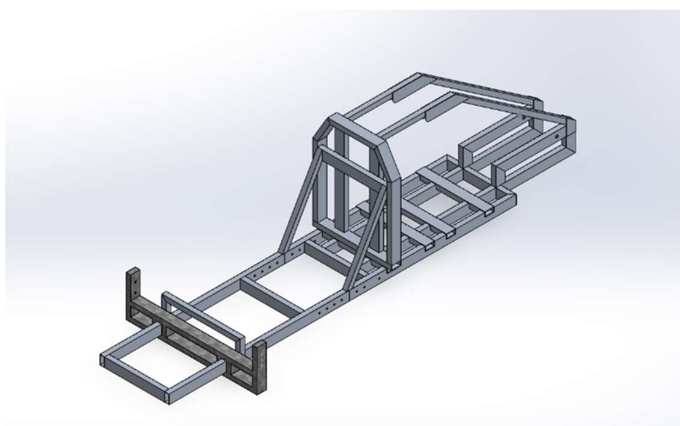

Figure 2. The chassis design.

2.1.4. Simulation

For the simulation, the author used Solidworks Analysis software. Analysis was carried out to find the strain value and factor of safety (FoS). By placing a load on the chassis area, several loads will be placed, such as the engine, body, steering wheel, braking system, fire extinguishers, and the weight of the driver. The materials that used in the chassis are 6061 aluminium alloy and galvanized steel. 6061 aluminium is a precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. And galvanized steel is a type of standard steel that undergoes a process where a protective zinc coating is applied to the steel or iron.

Property	Value	Units
Elastic Modulus	69000	N/mm^2
Poisson's Ratio	0.33	N/A
Shear Modulus	26000	N/mm^2
Mass Density	2700	kg/m^3
Tensile Strength	124.084	N/mm^2
Compressive Strength		N/mm^2
Yield Strength	55.1485	N/mm^2
Thermal Expansion Coefficient	2.4e-05	/K
Thermal Conductivity	170	W/(m·K)
Specific Heat	1300	J/(kg·K)
Material Damping Ratio		N/A

Figure 3. 6061 aluminium alloy material specification.

Property	Value	Units
Elastic Modulus	200000	N/mm^2
Poisson's Ratio	0.29	N/A
Shear Modulus		N/mm^2
Mass Density	7870	kg/m^3
Tensile Strength	356.9006745	N/mm^2
Compressive Strength		N/mm^2
Yield Strength	203.9432426	N/mm^2
Thermal Expansion Coefficient		/K
Thermal Conductivity		W/(m·K)
Specific Heat		J/(kg·K)
Material Damping Ratio		N/A

Figure 4. Galvanized steel material specification.

2.1.5. Problem Analysis

Problem analysis will be held is there any failure in the simulation of the chassis. As the flowchart shown the maximum stress value is must be below than the yield stress from the material and the factor of safety value must be above 1.

3. Results and Discussion

3.1. Comparison of 2022 and 2023 KMHE Chassis

- **2022 Chassis**

Reflecting to the previous study, the specific design and material specification of 2022 KMHE Chassis are shown below:

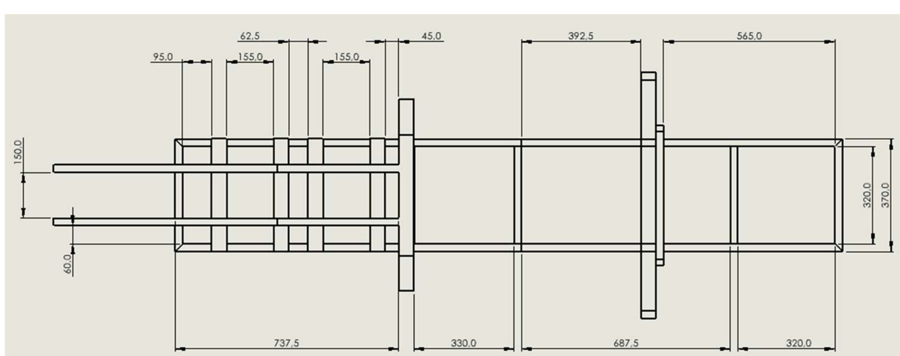

Figure 5. Upper side view of 2022 KMHE chassis.

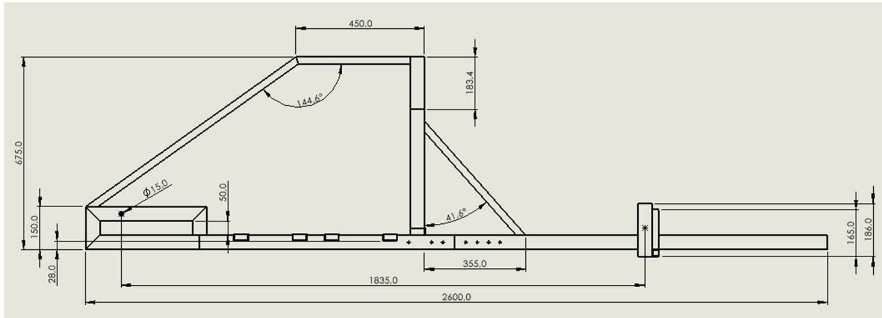

Figure 6. Side view of 2022 KMHE chassis.

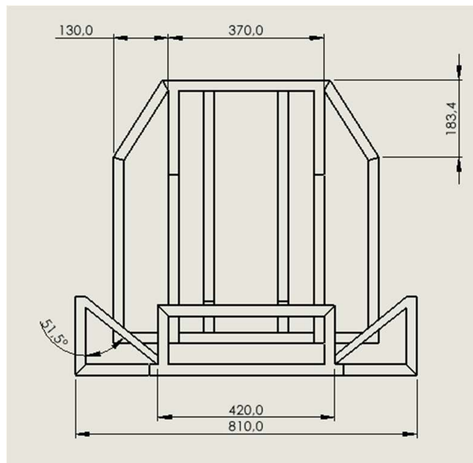

Figure 7. Front view of 2022 KMHE chassis.

Where the total height is 675 mm, the total width is 810 mm, and the total length is 2600 mm. The material size & specification, the visualization of this chassis knock-down system, and the tress analysis will be shown below:

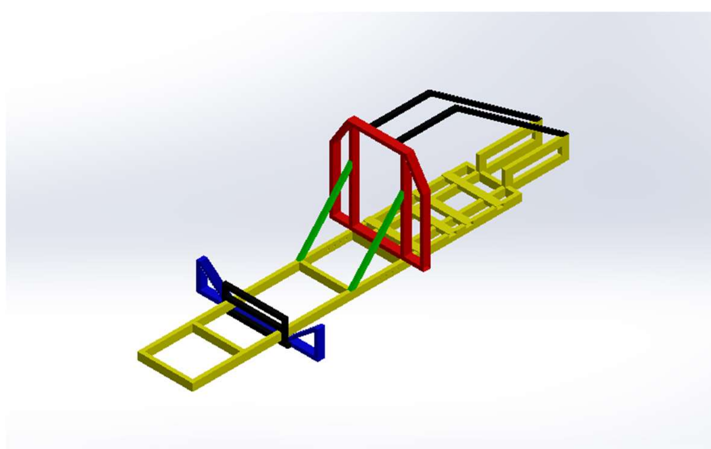

Figure 8. The classification of frame size types.

Details:

- Blue : Galvanized steel (hollow) 25 x 50 x 1 mm
- Black : 6061 aluminium (hollow) 25 x 25 x 2 mm
- Yellow : 6061 aluminium (hollow) 25 x 50 x 2 mm
- Red : 6061 aluminium (hollow) 25 x 50 x 1 mm

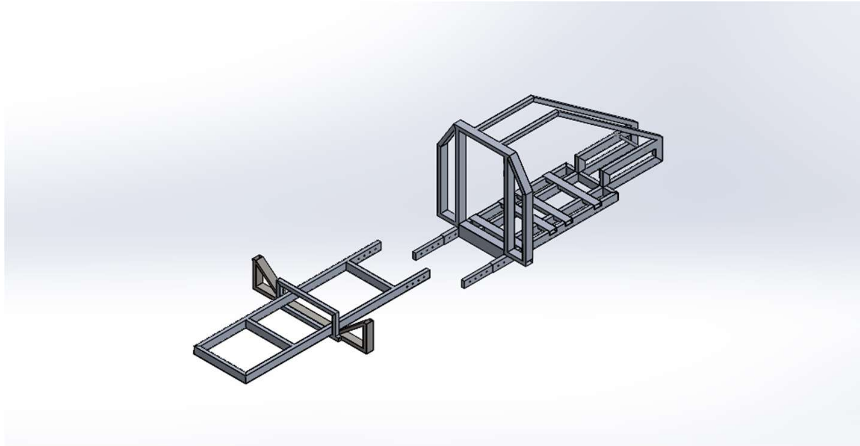

Figure 9. Knock-down system of 2022 KMHE chassis.

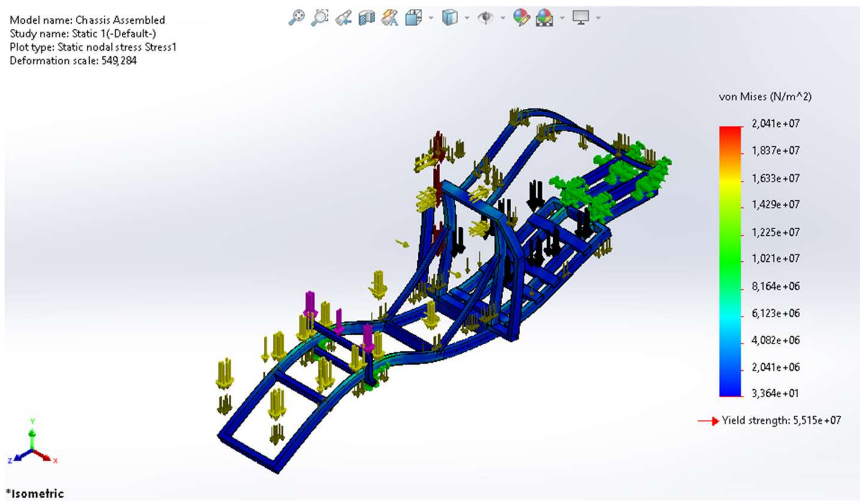

Figure 10. Stress analysis result of 2022 KMHE chassis.

From this analysis the 2022 chassis has experienced the largest maximum stress of 20,41 MPa in the area shown in the analysis image above. While the minimum stress is 0.03364 MPa.

- **2023 Chassis**

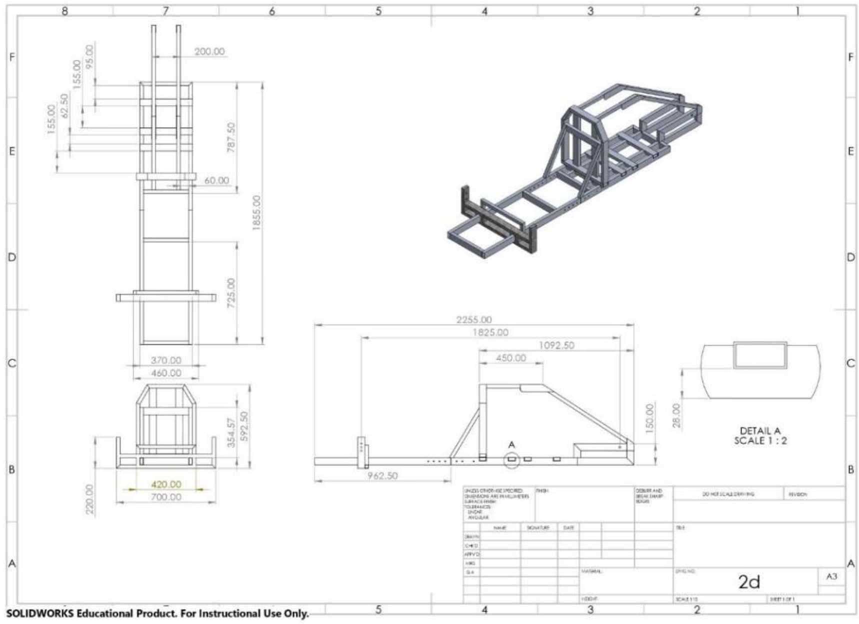

Figure 11. Design result.

As the figure x show above, the total length of the chassis is 2255 mm, the total width is 700 mm and the total height is 192,5 mm. The figure shows that the overall chassis dimension is reduced. Since the driver's posture is short and the requirement of the space of the engine & transmission is smaller, the front chassis dimension can be reduced and the rollbar can be placed further back. The rollbar width is also reduced so the car body width can also be reduced.

For the classification of the material and the frame size are shown below:

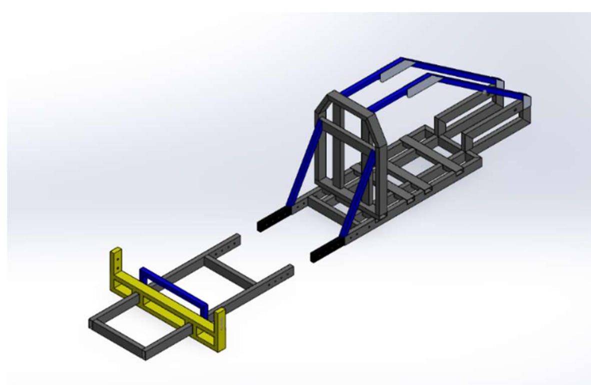

Figure 12. The classification of material and frame size types.

Details:

- Blue : 6061 aluminium (hollow) 25 x 25 x 2 mm
- Dark grey : 6061 aluminium (hollow) 25 x 50 x 2 mm
- Yellow : Galvanized steel (hollow) 25 x 50 x 1 mm
- Black : 6061 aluminium (solid) 21 x 46 mm

As the shown figure above, the major change happened in the rollbar, where its frame thickness is increased 1 mm, this change will make the rollbar stronger.

3.2. Load Layouts of 2023 Chassis

- Driver's weight (55 Kg):

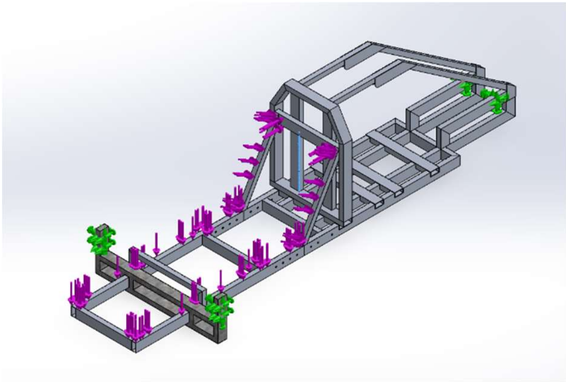

Figure 13. The layout of driver's weight load.

- Body (21 Kg):

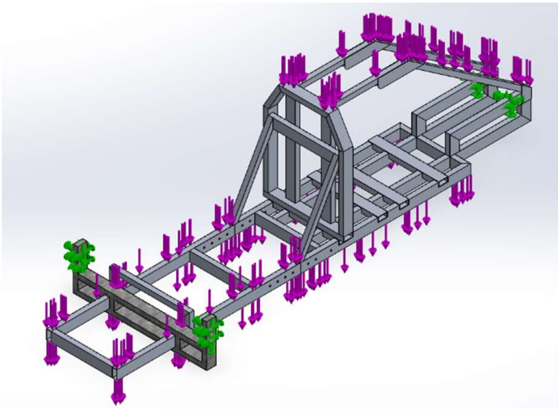

Figure 14. The layout of the prototype car body load.

- Engine and transmission (45 Kg):

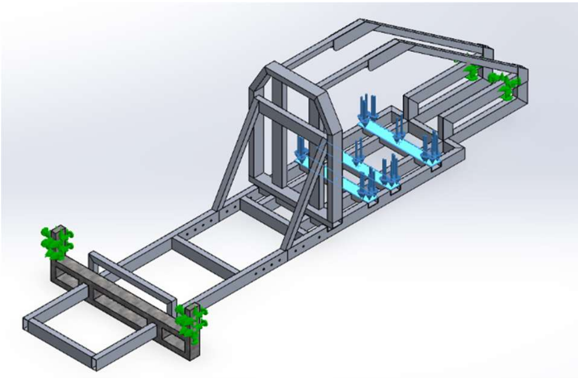

Figure 15. The layout of the prototype car engine load.

3.3. Analysis Results

- **Stress**

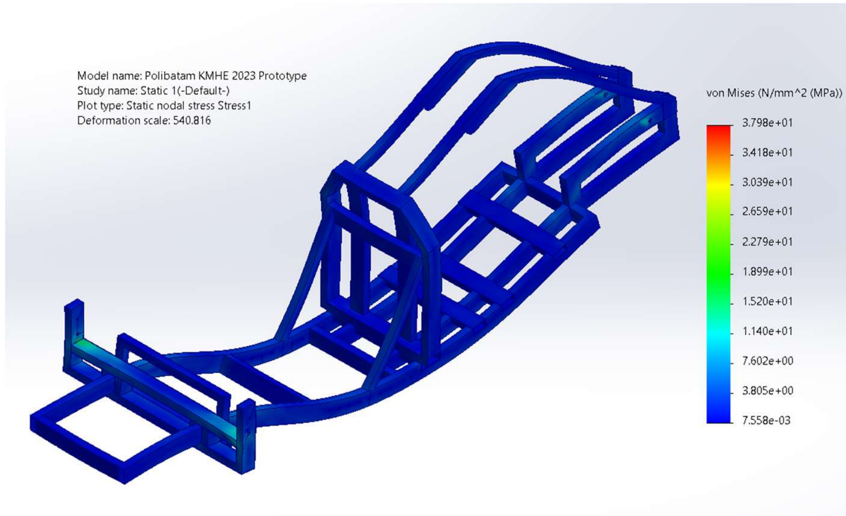

Figure 15. Stress result in Solidworks.

From this analysis the frame has experienced the largest maximum stress of 37.98 MPa in the area shown in the analysis image above. While the minimum stress is 0.007558 MPa.

- **Strain**

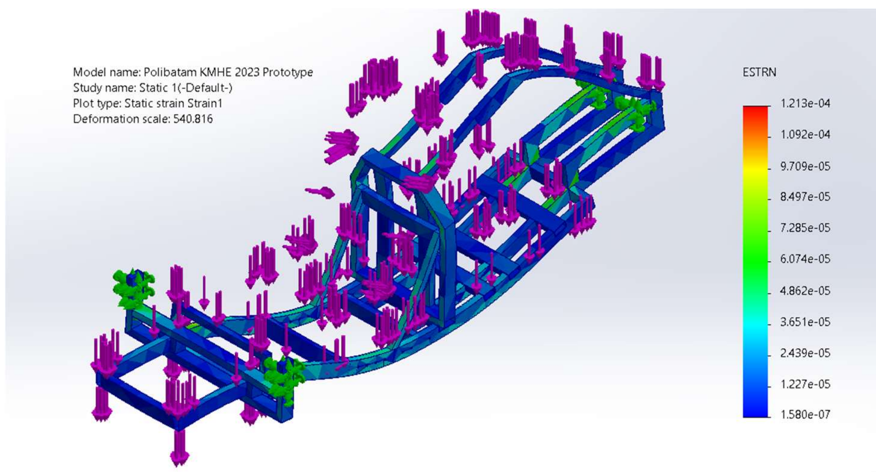

Figure 16. Stress result in Solidworks.

From the picture above, Chassis have a maximum strain value of 0.000121, with the spread of strain symbolized by the colour shape as shown.

- **Factor of Safety**

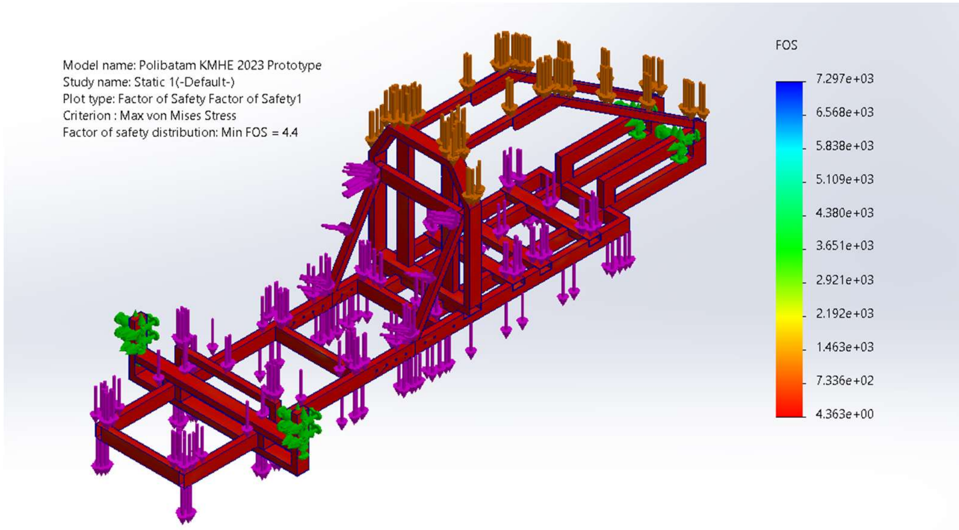

Figure 17. Factor of safety (fos) result in Solidworks.

In the force analysis process that occurs in the frame, the minimum factor of safety (FS) produced is 4.4. This shows the ultimate stress of the material value is bigger the loaded stress. As the result the chassis can be stated will be safe when functioning.

From the results of the analysis above, it can be said that materials that are stronger and generally heavier than aluminum alloy 6061 do not need to be used to replace the role of this material.

4. Conclusion

From the analysis report above, the following conclusions were obtained that after reducing the size of the chassis, the chassis still meets the need for the required strength according the shown analysis result that has been done. The loaded stress value is smaller than the weakest material yield stress and the factor of safety value is above than 1. This means that the chassis is safe to be fabricated.

5. Bibliography

[1] Fu'ad, N., & Nugroho, A. (2023, November). Analisa Kekuatan Chasis Belakang Pada Mobil Lintang Samudra Tahun 2022. In Prosiding Seminar Sains Nasional dan Teknologi (Vol. 13, No. 1, pp. 433-442).

[2] Budiman, F. A., Septiyanto, A., Dwi, A., Indriawan, N., & Setiadi, R. (2021). Analisis Tegangan von Mises dan Safety Factor pada Chassis Kendaraan Listrik Febrian Arif Budiman dkk / Jurnal Rekayasa Mesin. 16(1), 100–108.

[3] Balai Pengembangan Talenta Indonesia. (2023). Pedoman Kontes Mobil Hemat Energi Tahun 2023. Jakarta: Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

[4] Idrees, U., Ahmad, S., Shah, I. A., Talha, M., Shehzad, R., Amjad, M., & Koloor, S. S. R. (2023). Finite element analysis of car frame frontal crash using lightweight materials. Journal of engineering research, 11(1), 100007.

[5] Hidayat, Taufik, Nazaruddin Nazaruddin, and Syafri Syafri. Perancangan dan analisis statik chassis kendaraan shell eco marathon tipe urban concept. Diss. Riau University, 2017.