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ELGO electric motorcycle: Design and analysis of trail-type electric motorcycle frame using finite element analysis

Muhammad Fatiy Elmoudi*, Delima Yanti Sari and Yufrizal A

Machine Construction Laboratory, Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, **INDONESIA**

Abstract: The frame is an important part of the motorcycle as it carries the load of the passenger. Therefore, it is necessary to design a frame that can withstand the load and is lightweight. A lighter motorcycle will reduce the power required to ride it. This research aims to redesign the frame of a trail-type ELGO electric motorbike by considering a reduction in frame weight. The research was carried out using finite element analysis. The data from the analysis were checked based on the maximum stress not exceeding the yield strength of the DIN 1.0030 material and the safety factor greater than 1. The results showed that the newly designed frame has a lighter weight, with a maximum stress less than the yield strength of the DIN 1.0030 material and a safety factor value greater than 1. The simulation results also indicate the potential for further research by showing the maximum and minimum stress areas on the frame.

Keywords: Industry, innovation and infrastructure; Affordable and clean energy; Solidworks; Mesh independent test

*Corresponding Author: m.fatiyelmoudy@gmail.com

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1. Introduction

Transitioning from previously gasoline-powered motorcycles to electric motorcycles requires several design changes, one of which is the frame (Shah et al., 2021). The frame of an electric motorcycle must be lightweight, strong, sturdy and rigid to support all components and withstand various forces (Bagawan et al., 2023; VigneshM et al., 2018). The frame must be able to withstand loads and provide good stability and control while riding. The quality and design of the frame will affect the performance of the motorcycle (Wandani et al., 2018). Changes to the frame design need to be tested to match the characteristics of the electric motorbike. Frame testing is important because the frame is the basic framework of the motorcycle that supports all other components.

There are different types of motorcycles, including cruiser, touring, sport, off-road, dual-purpose, sport touring, scooter, enclosed, dan utility. Each type has a different frame shape adapted to its intended use. This study focuses on the frame of an off-road electric motorcycle of the Trails type. This motorcycle is usually used on hilly terrain and rocky roads, so the frame design needs to be adapted accordingly (Kaur

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et al., 2021). The frame design must be safe under extreme load conditions and be able to withstand all speeds (Roeder et al., 2011).

Before starting the manufacturing process, the frame design needs to be designed and tested to ensure that it meets the predetermined criteria (Jeyapandiarajan et al., 2018). Previous research has improved the quality of the ELGO Electric Motorbike's swing arm with a study of the gusset, which can increase the strength of the swing arm and reduce the maximum stress in critical areas (Hidayat et al., 2023). The design of the ELGO electric motorbike was previously submitted to the PLN ICE 2021 competition and was nominated for the top three designs. Research continued to improve the quality of the ELGO electric motorcycle, focusing on the frame. Where the frame can withstand loads and is lightweight. This research evaluates and makes the frame components lightweight, a lightweight frame will save power consumption of electric motors. The benchmarks of the simulation results are maximum stress, deformation and safety factors.

2. Material and methods

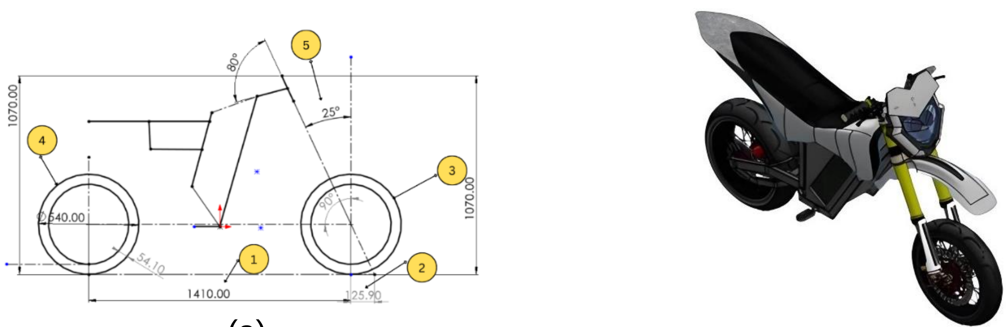
This research was conducted with the Finite Element Method (FEM) using Solidworks Research License 2021-2022 software. The boundary value problem of partial differential equations can be roughly solved numerically using the FEM (Li, 2021).

2.1 Electrical motorcycle frame specifications

The main dimensions of the electric motorcycle refer to the design of the ELGO electric motorcycle (Hidayat et al., 2023). The main dimensions of the ELGO electric motorcycle are shown in Table 1. The design of the ELGO electric motorcycle is shown in Figure 1.

Table 1. Main dimensions of the ELGO electric motorcycle

Components	Specification
Wheelbase	1410 mm
Front trail	125 mm
Front-wheel	110/70-17in
Rear wheel	120/70-17in
Rake angle	25°



(a) (b)

Figure 1. (a) ELGO motorbike frame dimensions and (b) Design of ELGO electric motorcycle

2.2 Material

The material used for the trellis frame in the static simulation analysis is DIN 1.0038. The material composition is Carbon (C)=0.15%, Silicon (Si)=0.01%, Manganese (Mn)=0.6%, Sulphur (S)=0.0011% and Phosphorus (P)=0.050%.

Table 2. Mechanical properties of DIN 1.0038

Property	Value
Elastic modulus	210000 N/mm^2
Poisson's ratio	0,28
Shear modulus	79000 N/mm^2
Mass density	7800 Kg/m^3
Tensile strength	360 N/mm^2
Yield strength	235 MPa

2.3 Support

The supports used in this study are divided into 3, namely on the Head tube, the Swing arm axis and the Pivot. As shown in Figure 3, the bracket on the head pipe is of the Fixed Hinge type and on the Pivot is of the Fixed Geometry type, then on the Swing Arm Axis, there is a bracket of the Support Bearing type because in this part in actual circumstances there is a bearing as a shaft bearing that is connected to the motorcycle frame.

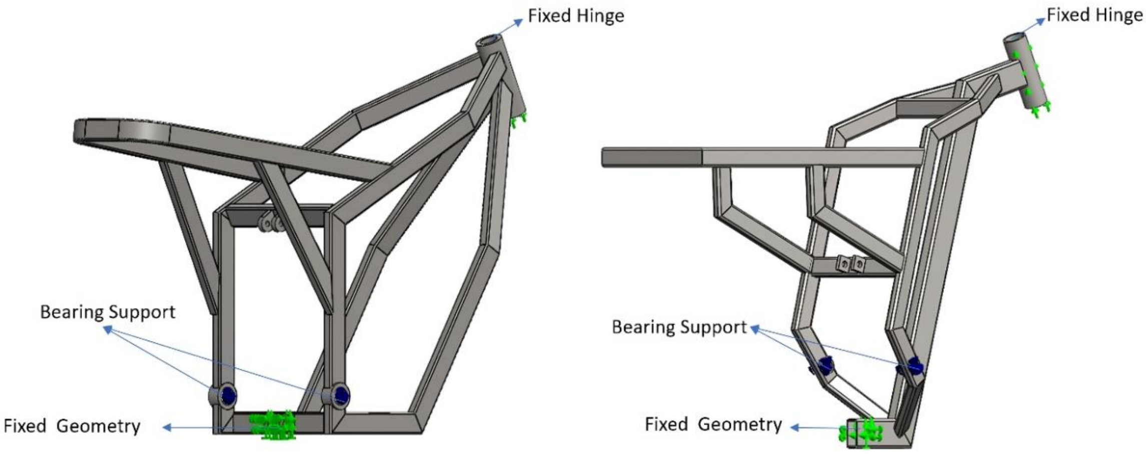
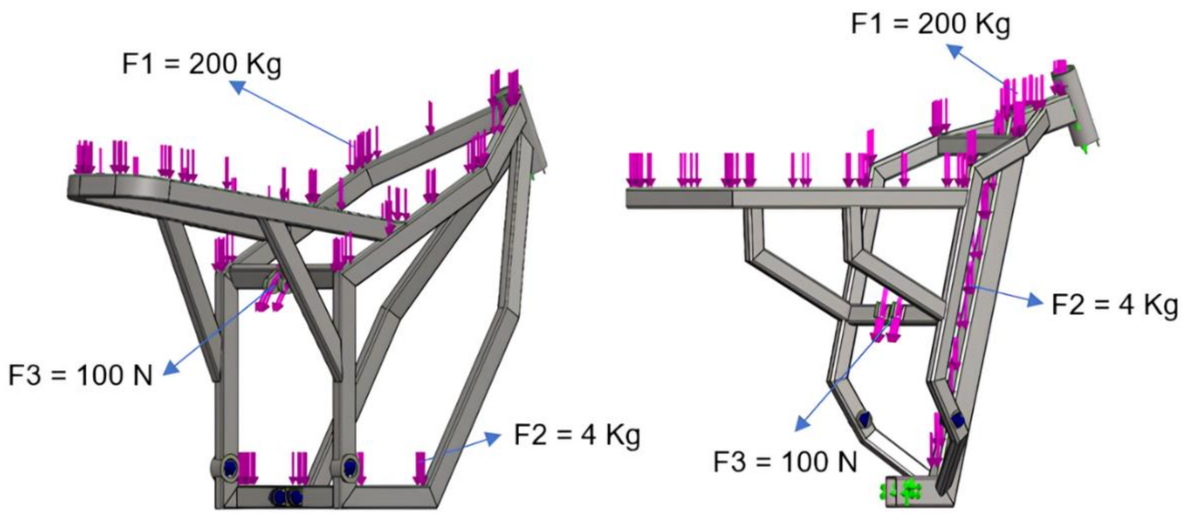


Figure 3. Supports on the frame

2.4 External load

The load on the frame is shown in Figure 4. A load of 200 kg (F1) is applied to the seat real, a load of 4 kg (F2) is applied to the inner frame (battery) and a spring force of 100 N (F3) is applied to the rear shock position (Macej et al., 2021).



(a) (b)

Figure 4. (a) Load on frame model 1 (b) Load on frame model 2

2.5 Mesh independence test

Based on the mesh independence test performed, the simulation result data (stress) and the duration of the simulation process are influenced by the element size used (Figure 5). The smaller the element size used, the higher the stress value and the longer the simulation process time. The results showed that the smaller the element size used, the closer the simulation data are to the experimental results (Diogo da Cal Ramos et al., 2016). Therefore, in this study, it was decided to use a mesh size of 1.25 mm to achieve a balance between simulation and experimental results. The 1.25 mm mesh has a total of 6.5M cells and requires a completion time of 17 minutes and 11 seconds. The mesh representation of the frame is shown in Figure 6.

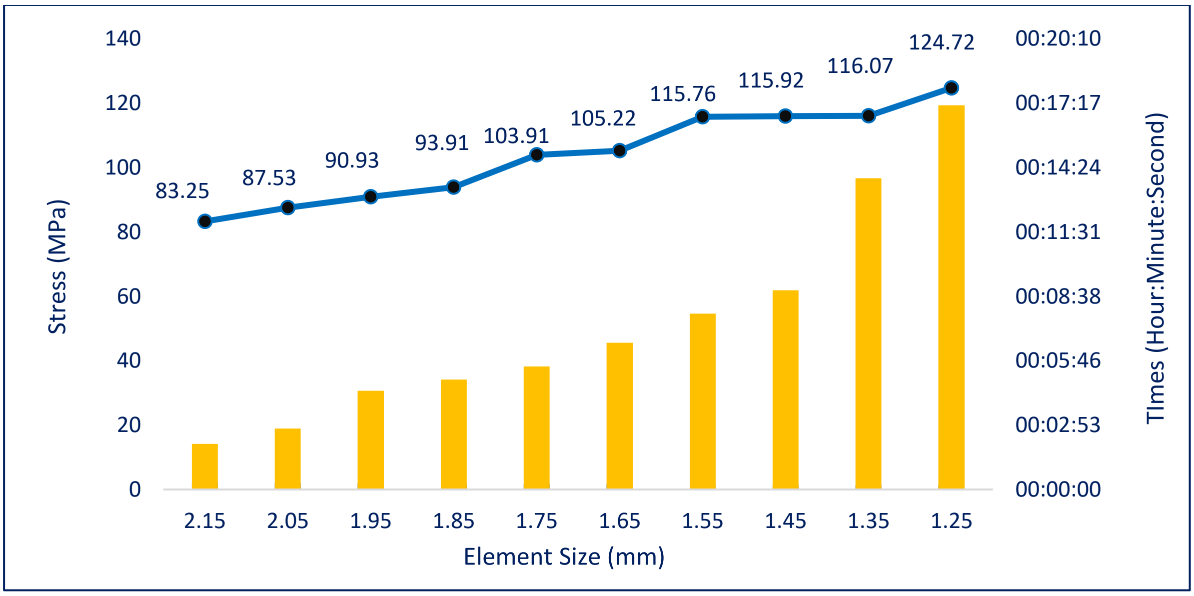


Figure 5. Mesh independence test

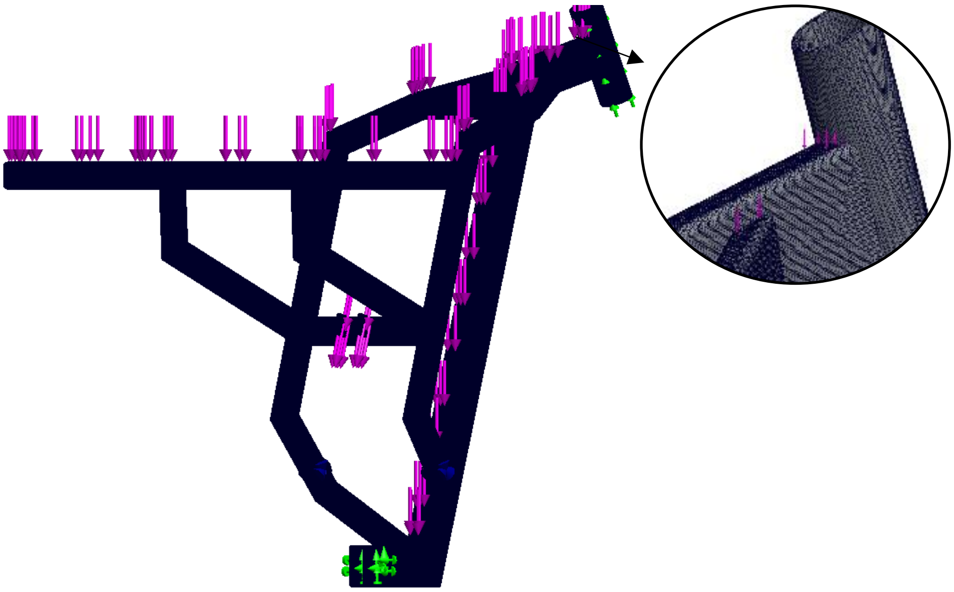
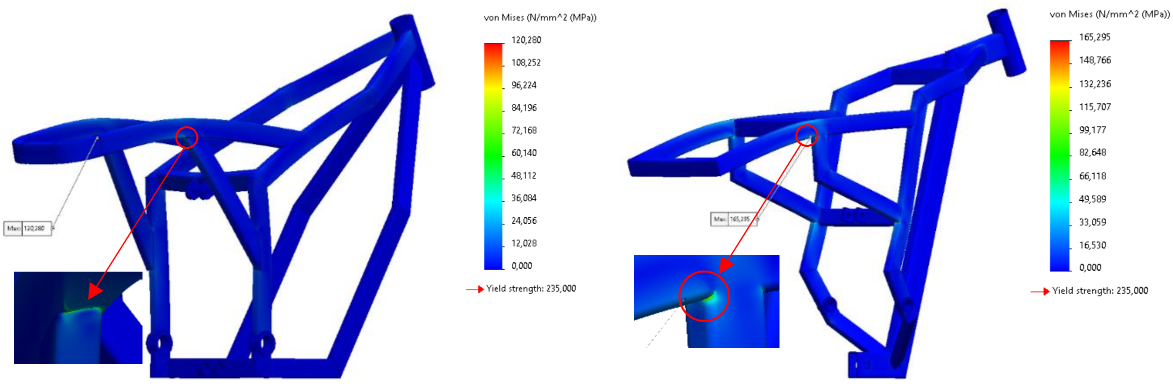


Figure 6. Meshing

3. Results and discussion

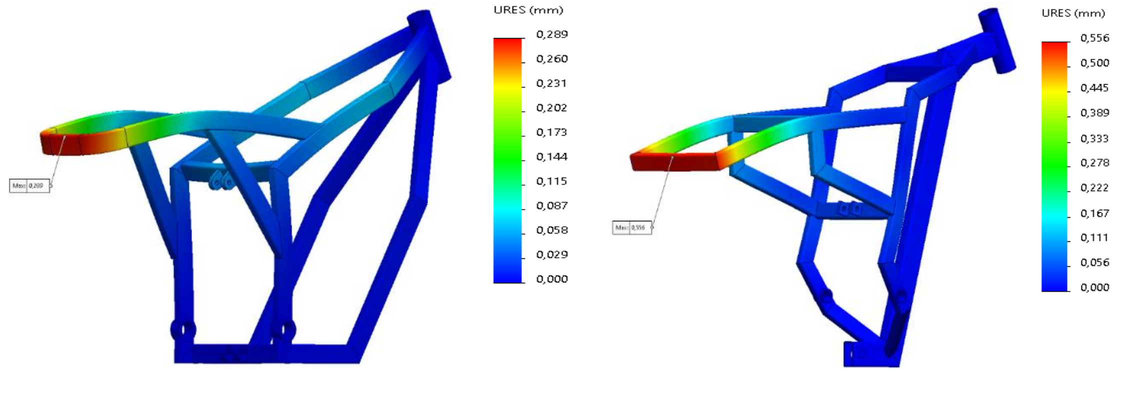
Based on the simulation results carried out, the maximum stress in both models occurs in the real seat attachment area, shown in red in Figure 7. The maximum stress on the frame of model 1 is 120.280 MPa and the maximum stress on the frame of model 2 is 165.295 MPa. The maximum stress that occurs in both frame models is below the yield strength of the DIN 1.0038 material (235 MPa). This shows that the stresses that occur in both frame designs do not cause permanent deformation or failure.



(a) (b)

Gambar 7. Stress, (a) Model frame 1 and (b) Model frame 2

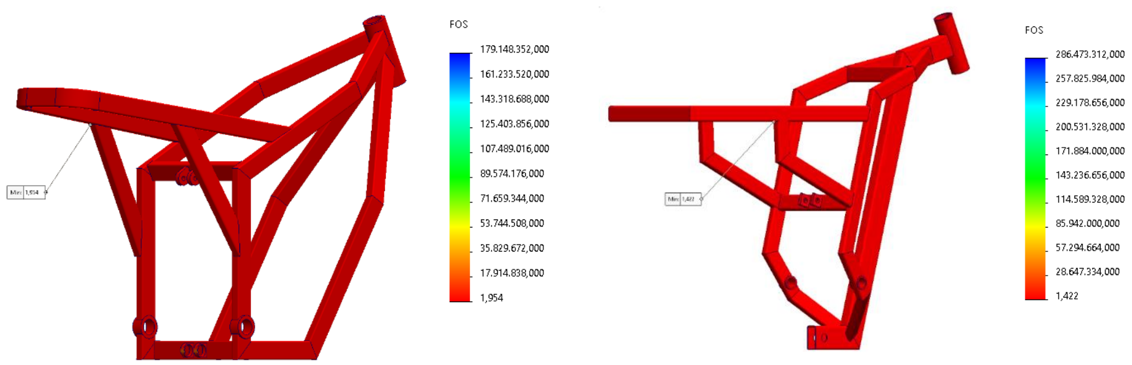
The load on both frame models caused deformation. This was 0.289 mm for frame model 1 and 0.556 mm for frame model 2 (Figure 8). Deformation occurred in the rear stay frame. However, as the stress is below the yield strength of the material, DIN 1.0038, the frame design will return to its original shape when the load is removed.



(a) (b)

Gambar 8. Deformation (a) Model frame 1 and (b) model frame 2

The minimum value of the safety factor for Frame Model 1 and Frame Model 2 is in the rear seat area as shown in Figure 9. The minimum value of the safety factor for frame model 1 is 1.954 and for frame model 2 it is 1.424. Both models have a factor of safety value > 1, so it can be said that both frame models are safe.



(a) (b)

Figure 9. (a) Factor of safety for model frame 1 and (b) model frame 2

Based on the simulation results of the two frames, the frame of model 1 is better in terms of maximum stress and deformation experienced compared to the frame of model 2. Model 1 also has a higher safety factor. The lower maximum stress indicates that the material can withstand greater loads without being damaged. Meanwhile, the lower deformation indicates that the material is more rigid and does not deform easily (Budynas & Nisbett, 2015). The factor of safety is the ratio between the strength of the material and the maximum stress that it will experience in normal use. A higher factor of safety means that the material has a greater margin before failure, which is an important indicator of safe design (Edwards, 1996).

However, due to the weight of the frame, model 2 is lighter. The maximum stress in the frame of model 2 is below the material yield strength DIN 1.0038 and the safety factor > 1. The lower frame weight has a significant effect on the energy efficiency of the vehicle. A lighter vehicle requires less energy to accelerate and manoeuvre, which is very important in the context of electric vehicles where energy efficiency is a priority (Cikanek & Bailey, 2002).

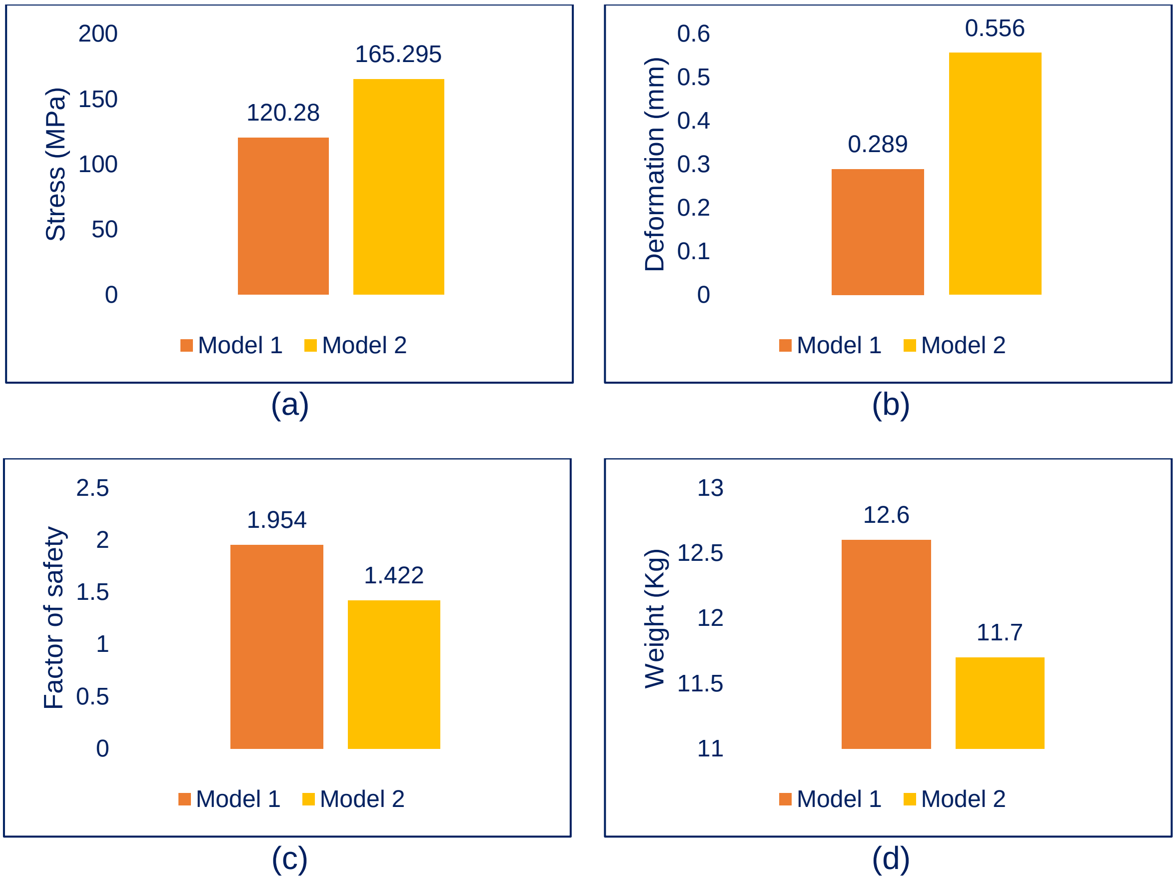


Figure 10. Comparisons: (a) Stress, (b) Deformation, (c) Factor of safety, and (d) Weight

4. Conclusion

This research aims to optimise the design of the ELGO electric motorcycle frame in terms of frame weight. The frame design tests were carried out using the finite element method with the Solidworks Research licence. The frame of model 2, designed as an evolution of the first model, is lighter. The simulation results show that the maximum stress is less than the yield stress of the materials used and the safety factor is greater than 1. This indicates that the Model 2 frame design is safe to use. The maximum stress occurs at the junction of the seat rail with the frame support. Further design improvements can be made by incorporating gussets to reduce the maximum stress in this area. In this study, the simulation was carried out with static loading. Further research can be carried out using dynamic load testing and fatigue analysis.

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Declarations

Author contribution

Muhammad Fatiy Elmoudi: Conceptualization, methodology, formal analysis, software and writing - original draft. Delima Yanti Sari: Methodology, Validation, data curation and writing – review and editing. Yufrizal: Methodology, Validation, data curation and writing – review and editing.

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Competing interest

The authors declare no conflict of interest in this study.

Ethical Clerance

There are no human subjects in this manuscript and informed consent is not applicable.

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