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Installation of gussets to reduce stress on the junction between the arm and bridge on the swing arm

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Abstract: The swing arm is one of the main components of a motorcycle that functions as a connection between the rear wheel and the frame. Under loading conditions, the joint area between the arm and the bridge experiences significant stress, leading to fractures in that region. This study aims to investigate the effectiveness of installing gussets to reduce the stress that occurs at the joint area between the arm and the bridge in the swing arm of ELGO electric motorcycles. The research was conducted using the static analysis simulation method with Solidworks 2021-2022 Research License software. The loading conditions were simulated based on the actual usage of the electric motorcycle. The simulation results revealed that without the installation of gussets, the joint area between the arm and the bridge in the swing arm experienced stress exceeding the yield strength of the material. This would inevitably lead to the breakage of the swing arm and potentially cause accidents for motorcycle riders. However, after the gussets were installed, the stress at the joint area between the arm and the bridge remained below the yield strength of the material. Based on these findings, it can be concluded that the installation of gussets successfully reduced the stress at the joint area between the arm and the bridge in the swing arm. This research outcome can serve as a reference for the design of swing arms for electric motorcycles.

Keywords*:* Swing arm; Gusset; Electric motorcycle; Solidwork simulation

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1. Introduction

Motorcycles are commonly used vehicles among the public due to their relatively affordable purchase prices (Winarno & Marliana, 2023). he technological advancements in motorcycles have been continuously increasing and even surpassing the technology in the automotive industry (Maddaiah & Reddy, 2018). In 2019, more than 30% of electric motorcycles had already gained significant market share (Spanoudakis et al., 2020), while it is well-known that gasoline-powered motorcycles are the commonly used vehicles (Sariman et al., 2019). This proves the rapid development of motorcycle technology (G & Dr.K.Vasantha Kumar, 2021). One of the main components of a motorcycle is the swing arm, which serves as a linkage between the rear wheel and the frame, connected to the front part of the motorcycle (Chacko, 2013). Its purpose is to connect the rear suspension to absorb vibrations and support the rear wheel axis while allowing vertical rotation, enabling the suspension to dampen vibrations caused by road irregularities (Malppan & Sunny, 2015).

Swing arm, as one of the vital components of a motorcycle, is frequently found to encounter critical issues at the junction between the arm and the bridge (Kaur et al., 2021). he vulnerable angle of the connection often experiences fractures that may potentially lead to serious accidents for motorcycle riders (Rege et al., 2017). This condition calls for a revolutionary breakthrough in swing arm design to create an effective solution. State-of-the-art design innovations are needed to minimize the stress on that junction area, thus enhancing safety and stability levels for riders. The problem-solving solution to reduce the stress occurring at the junction between the arm and the bridge involves the installation of Gussets.

Gusset is a reinforcement used to strengthen joints that form angles. This research is focused on testing and revealing the effectiveness of installing gussets on the junction between the arm and the bridge in the Swing Arm of ELGO Electric Motorcycles. The Swing Arm is a crucial element in motorcycles, responsible for connecting the rear wheel to the vehicle's frame. Harsh environmental conditions and heavy operational loads often put significant pressure on these connections, making them critical areas susceptible to structural failures. Through this research, it is expected to uncover the extent to which gussets can improve the performance and reliability of these junctions. Objective and measurable research results will provide valuable insights for the design and development of more durable and safe Swing Arms for Electric Motorcycles.

2. Methods

2.1 Swing arm

The swing arm consists of several parts, including the pivot, bridge, suspension mount, and rear wheel axis, as depicted in Figure 1.

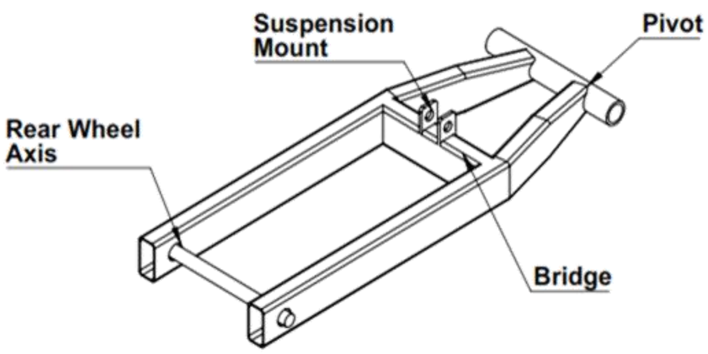

Figure 1. The parts of the swing arm

In this study, the dimensions of the Swing Arm are shown in Figure 2. The total length of the Swing Arm is 698 mm with a width of 238 mm. The bridge width at the suspension mount is 178 mm, and the pivot length is 230 mm. Meanwhile, the distance from the pivot to the bridge is 231 mm, and the distance from the bridge to the end of the swing arm is 466 mm.

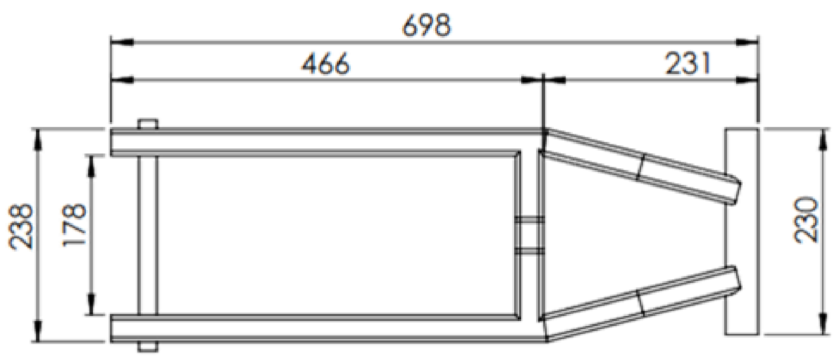

Figure 2. Dimensions of the swing arm

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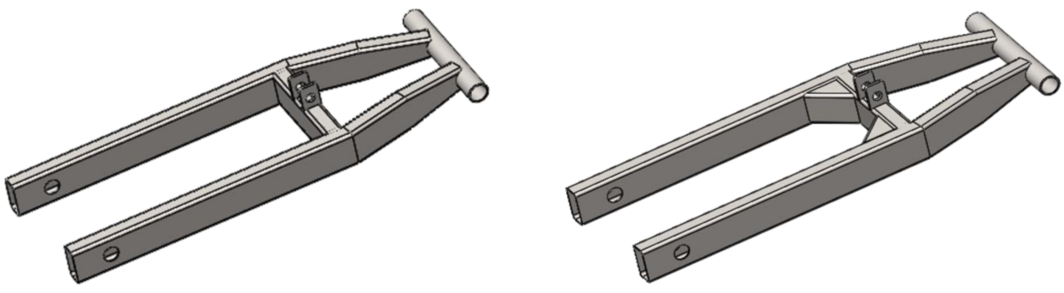
The material used for the Swing Arm is DIN 1.0038. The mechanical properties of the material can be seen in Table 1.

Table 1. 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 N/mm^2

2.2 The gusset installed on the Swing Arm

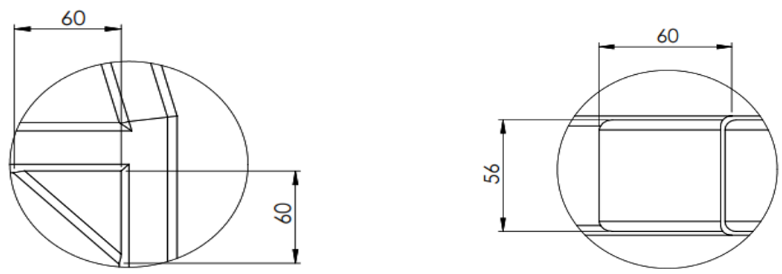
In this study, there are 2 models of swing arm, as shown in Figure 3. (a) depicts the swing arm without the installation of gussets, and Figure 3 (b) shows the swing arm with gussets installed at the angle between the bridge and the arm of the swing arm.



(a) (b)

Figure 3. Swing arm (a) without gusset installation and (b) with gusset installation

The gusset has a triangular shape with an isosceles triangle profile made from hollow material with a profile thickness of 2 mm. The length of each side of the triangle is 60 mm, as shown in Figure 4.



(a) (b)

Figure 4. Dimension of gusset

2.3 Forces at work on the swing arm

In determining the forces at work on the swing arm, the first step is to establish the Center of Gravity (CG) (Joao Diago, 2016). ach motorcycle has a different CG. Through the CG, we can

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determine the percentage of force at the rear part relative to the total weight (Mg). Figure 5 illustrates the forces at work on the ELGO Electric Motorcycle. To calculate the total weight (Mg), we add the mass of the electric motorcycle (M_{mce}) to the mass of the rider (M_{rider}) and multiply it by the Earth's gravity (g).

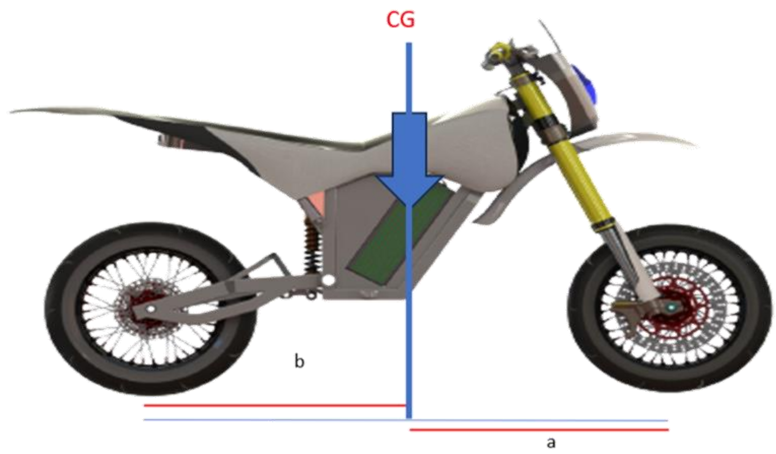

Figure 5. The centre of gravity of the ELGO electric motorcycle

$$Mg = (M_{mce} + M_{rider})\, g \tag{1}$$

From the formula and calculation, the total weight is 2,118.96 N for the ELGO electric motorcycle, with the percentage of force at the rear part being 55% of the total weight (Mg).

$$Ff = 55\%(Mg) \tag{2}$$

The force at the rear part of the swing arm is 1,165.43 N, with the swing arm's construction inclining 15 degrees, while the suspension installation inclines 65 degrees. The forces on the swing arm are present at two points: the rear wheel axis and the suspension mount, as shown in Figure 6.

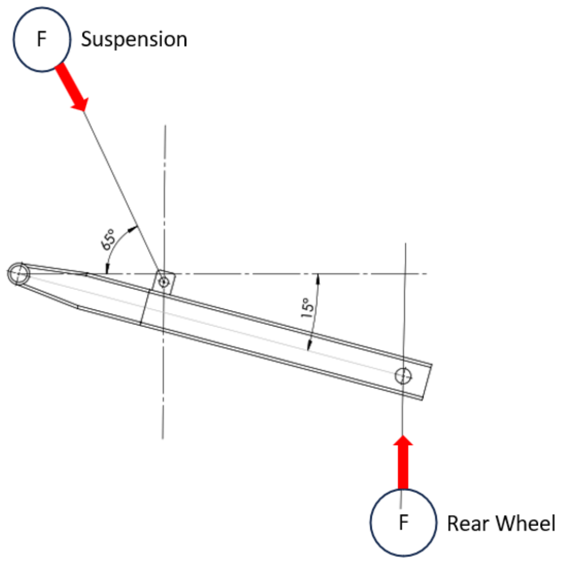

Figure 6. The force that is work on the swing arm

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2.4 Meshing

In this research, the meshing process uses the parameter "mesh blended curvature-based mesh" to achieve better results. The maximum element size is set to 3.5 mm, and the minimum element size is 0.456362 mm, with a total of 303,480 nodes. This element size has been determined in previous research as the optimal choice, producing credible data with reasonable computation time per simulation (Joao Diago, 2016). The applied mesh on the swing arm can be seen in Figure 7.

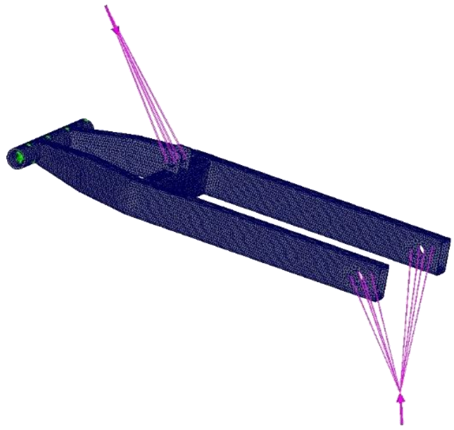

Figure 7. Meshing boundary

3. Results and discussion

In the Swing Arm without the installation of Gussets, there is a maximum stress of 15,548.37 MPa at the junction area between the Arm and the Bridge (shown in Figure 8.a). This stress exceeds the yield strength of the material DIN 1.0038 (235 MPa) and its tensile strength (360 MPa). This indicates that the material not only undergoes deformation but has also experienced failure, leading to rupture. In contrast, for the Swing Arm with Gussets (Figure 8.b), the junction area between the Arm and the Bridge no longer exhibits maximum stress. The stress occurring in that junction area is 51.93 MPa.

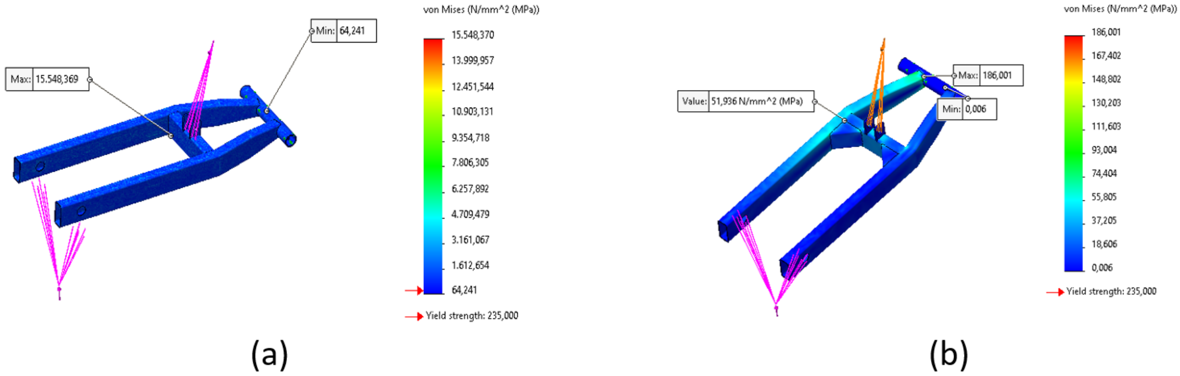

Figure 8. The Von Mises stress in the Swing Arm (a) without gusset installation and (b) with gusset installation

n the Swing Arm without Gussets, the minimum Factor of Safety occurs at the junction area between the Arm and the Bridge, with a value of 0.01. This value is less than 1, indicating that material failure occurs at that junction area. On the other hand, in the Swing Arm with Gussets installed, the Factor of Safety is 4.5 at the junction area between the Arm and the Bridge.

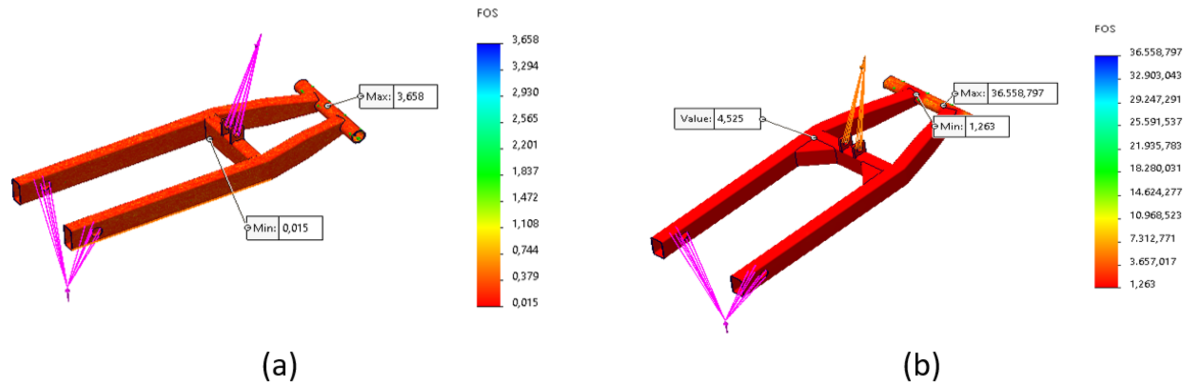

Figure 9. Factor of safety di swing arm (a) without gusset installation and (b) with gusset installation

This research compares the swing arm without gusset installation to the one with gusset installation. In the swing arm without gussets, there is stress exceeding the yield strength of the DIN 1.0038 material (235 MPa) and its tensile strength (360 MPa) at the junction area between the Arm and the Bridge, where the region forms an angle. On the contrary, the swing arm with gussets installed does not experience maximum stress at the junction angle between the Arm and the Bridge. This explains that gussets are a crucial part of a structure as they transmit forces throughout all connected parts (Roeder et al., 2011).

4. Conclusion

The purpose of this research is to compare the strength values of the swing arm without gusset installation to the swing arm with gusset installation. This comparison is based on static analysis data using the finite element method with SolidWorks Research License 2021-2022. In the swing arm without gussets, the maximum stress is 15,548.37 MPa, and the minimum factor of safety is 0.015. However, after applying gussets to the swing arm, the maximum stress is reduced to 186 MPa, with a minimum factor of safety of 1.3. This indicates that the installation of gussets in the swing arm can influence its strength by reducing the maximum stress value, especially at the junction area where the arm of the swing arm meets the bridge suspension mount, forming an angle. Overall, the research concludes that adding gussets to the swing arm can improve its strength by reducing the maximum stress at critical areas such as the junction between the arm and the bridge suspension mount.

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Declarations

Author contribution

In this research, Nailul Hidayat plays a role as the research concept designer, experimental design creator, simulation performer, and article writer. Yufizral A and Hendri Nurdin contribute to interpreting the research data, discussing research findings, and formulating conclusions. Meanwhile, Farid Kassimov and E.B. Kenzhaliyev are involved in interpreting the research data and carrying out the proofreading process.

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Conflict of interest

The authors declare no conflict of interest.

Ethical Clerance

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

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