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DESIGN AND ANALYSIS OF CHASSIS FRAME FOR CHOPPER-STYLE MOTORCYCLE

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ABSTRAK

Selain sebagai alat transportasi, sepeda motor juga mewakili gaya hidup para pecinta otomotif. Salah satu cara para peminat ini mengekspresikan passionnya adalah dengan melakukan kustomisasi sepeda motor. Salah satu modifikasi yang umum dilakukan adalah mengubah bentuk asli sepeda motor, yang dikenal sebagai sepeda motor *custom*. Ada beberapa jenis sepeda motor *custom*, antara lain *cafe racer*, *street tracker*, *scrambler*, *bobber*, dan *chopper*. Dari jenis tersebut, sepeda motor bergaya *chopper* biasanya menggunakan rangka sasis yang dibuat dari awal. Desain *custom* sebaiknya mempertimbangkan kekuatan konstruksi tidak hanya estetika. Penelitian ini bertujuan untuk merancang dan menganalisis rangka sepeda motor *custom* bergaya *chopper*. Prosesnya meliputi pembuatan model 3D dan analisis kekuatan rangka sasis menggunakan *Finite Element Method (FEM)* dengan menggunakan *software* Autodesk Inventor Professional 2022. Massa mesin yang ditopang oleh rangka diasumsikan 30 kg. Rangka tersebut diasumsikan untuk dikendarai sendirian dan bersama penumpang, sehingga total bobot pengendara adalah 70 kg, 90 kg, 140 kg, dan 180 kg. Hasil dari penelitian ini adalah sebuah desain rangka sepeda motor *chopper* berbahan baja dengan berat 11,74 kg, mampu menopang beban pengendara hingga 140 kg, dengan nilai faktor keamanan sebesar 3,20.

Kata Kunci: sepeda motor *custom build*, gaya chopper, rangka sasis, *Finite Element Method (FEM)*.

ABSTRACT

Other than being a means of transportation, motorcycles represent a lifestyle for automotive enthusiasts. One way these enthusiasts express their passion is by customizing motorcycles. One common modification involves altering the motorcycle's original form, known as a custom-built motorcycle. There are several types of custom-built motorcycles, including cafe racers, street trackers, scramblers, bobbers, and choppers. Of these types, chopper-style motorcycles typically use a frame chassis which is built from scratch. Custom design should consider the strength of construction, not just aesthetics. This research aims to design and analyze the frame of a custom chopper-style motorcycle. The process involves creating a 3D model and analyzing the strength of the chassis frame using the Finite Element Method (FEM) by using Autodesk Inventor Professional 2022 software. The engine mass supported by the frame is assumed to be 30 kg. The frame is assumed to be ridden solo and with a passenger, resulting in total rider weights of 70 kg, 90 kg, 140 kg, and 180 kg. The result of this research is a chopper motorcycle frame design made of steel, weighing 11.74 kg, capable of supporting a rider's load of up to 140 kg, with a safety factor value of 3.20.

Keywords: *custom build motorcycle, chopper-style, chassis frame, Finite Element Method (FEM).*

1. INTRODUCTION

The population growth of motorcycles in Indonesia has steadily increased, reaching 126.99 million units by 2022 [1]. One of the reasons for this substantial population of motorcycles is their practicality, reliability, and adaptability to various road conditions and traffic congestions, making them a preferred mode of transportation. Apart from their transportation utility, motorcycles are also considered hobby items widely collected by automotive enthusiasts, contributing significantly to their rising population. For many individuals, motorcycles as a hobby represent a lifestyle, especially among automotive enthusiasts [2]–[5]. These enthusiasts have their own ways of indulging in their passion: some collect various types of motorcycles in standard or modified conditions, some enjoy traveling using motorcycles, while others express their passion through motorcycle racing. Motorcycle modifications come in various forms, ranging from simple accessory additions or replacements [6], light modifications, to extensive alterations that completely transform the motorcycle's appearance. The modification that involves altering the motorcycle's original form is commonly known as a custom-built motorcycle. A custom-built motorcycle serves as a platform for its owner to express themselves [7].

Before 2023, some automotive enthusiasts in Indonesia had concerns about customizing their vehicles. These concerns arose due to the absence of regulations governing vehicle customization. Consequently, users of customized motorcycles were afraid of being deemed in violation of traffic regulations and having their vehicles considered unfit for road use. However, with the issuance of Minister of Transportation Regulation Number PM 45 of 2023 concerning motor vehicle customization, the legality of vehicle customization became clear [8]. ith the existence of these regulations, the opportunities within the motorcycle customization industry in Indonesia have expanded significantly.

Generally, customized motorcycles encompass various styles such as cafe racer, street tracker, scrambler, bobber, chopper, and more. Cafe racer-style motorcycles feature a low handlebar, a rider's position leaning forward, and a rear body resembling a wasp's tail. The cafe racer style was inspired by the habits of young people in the 1950s who raced from one cafe to another [9]. The street tracker modification style is an adaptation from the shape of flat track racing motorcycles, altered to be ridden on regular roads. It typically features an elongated seat, mid-controls or rearsets, along with added lights and a license plate for road legality [10]. Scrambler is one of the customized motorcycle styles known for its off-road capabilities, equipped with dual-purpose tires and higher exhaust pipes [9]. Bobber-style motorcycles typically feature a short wheelbase, thick tires, and a low handlebar [11]. Chopper modification style is characterized by a larger front wheel diameter, a high handlebar, and extended front suspension [9]. Among various customized motorcycle styles, choppers usually use only the engine and front suspension from the donor motorcycle, while the frame is entirely built from scratch.

Various research studies on the design and analysis of motorcycle frames have been conducted extensively. Rege et al. designed a tubular metal tube frame for an electric motorcycle [12]. Konada and Suman also analyzed the frame of the Yamaha R15 using several material variations such as aluminum alloy, titanium alloy, grey cast iron, carbon fiber epoxy, and structural steel, compared to AISI-1020 material. Their findings indicated that carbon fiber epoxy was the most favorable material for replacing metal [13]. Perkasa et al. conducted an analysis involving the addition of stiffeners to the frame of an electric motorcycle, revealing that the inclusion of stiffeners could enhance the safety factor of the designed frame [14].

Several other studies related to frame design and analysis have focused on various types of motorcycles, including sport bikes [15], [16], cub-type motorcycles [17], [18], electric motorcycles [19], [20], mini racing motorcycles [21], and even electric motorcycles with composite monocoque frames [22]. Despite the numerous studies conducted, there hasn't been specific research dedicated to designing and analyzing frames for customized motorcycles, particularly chopper types, where the frame is entirely built from scratch. Due to this gap, it is necessary to carry out the design and analysis of chopper-style motorcycle frames to ensure that the produced frame possesses the appropriate strength and safety for use. The process of designing and analyzing chopper frames is using the Finite Element Method (FEM). The frame's strength, designed based on stress, deformation, and safety factors, is a crucial focus [23].

2. METHOD

2.1. *Tools*

In this research, the design and analysis of the chopper motorcycle frame are conducted using Autodesk Inventor Professional 2022 installed on a Lenovo laptop equipped with an Intel(R) Core(TM) i7-4700MQ processor and 16GB RAM.

2.2. *Design Geometry*

In the soft tail type, the rear part of the motorcycle is equipped with a suspension system, whereas the hard tail type remains without suspension, thus being rigid. In this study, the designed frame is of the hard tail type, as depicted in Figure 1. Figure 1 illustrates that the main frame construction is made of Sch.40 steel pipes with a 1-inch diameter, while the sub-frame consists of Sch.40 steel pipes with a diameter of ¾ inch, and the rear axle support is constructed from 6 mm thick steel plates. All frame parts are connected by welding joints.

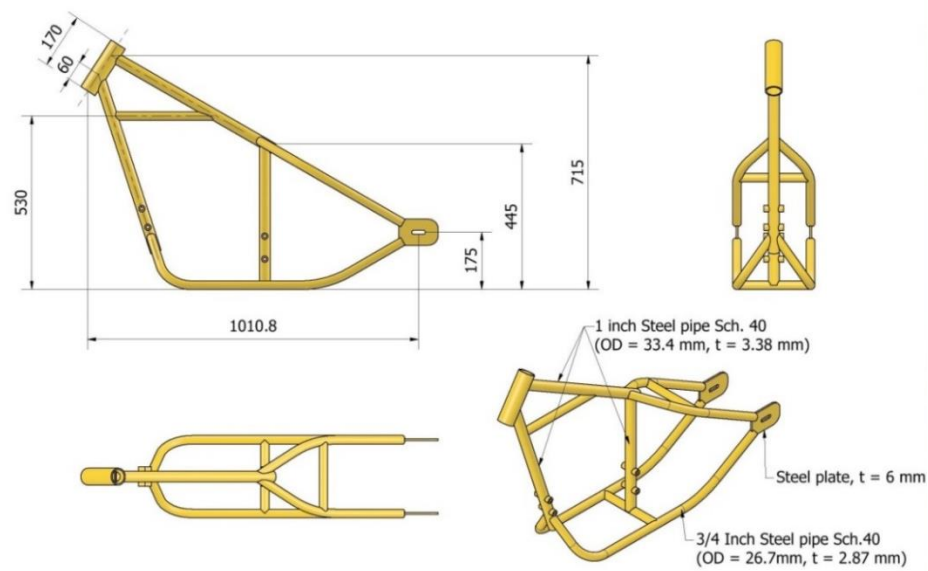

Figure 1. Design Geometry of Chopper-Style Motorcycle Chassis Frame

2.3. *Material*

Steel is the material used in the chopper frame in this study, and its properties are shown in Table 1.

Table 1. Material Properties

Material	Steel
Mass Density	7.85 g/cm^3
Yield Strength	207 MPa
Ultimate Tensile Strength	345 MPa
Young's Modulus	210 GPa
Poisson's Ratio	0.3
Shear Modulus	80.7692 GPa

2.4. *Boundary condition and loads*

The strength analysis of this chopper-style motorcycle chassis frame involves stress analysis with static loads. The frame is loaded with the rider's weight and the weight of the engine supported by the frame. The calculation of the loads acting on the frame in the analysis can be computed using the equation [24]:

$$F_r = m_r \times g \quad (1)$$

$$F_e = m_e \times g \quad (2)$$

where F_e is engine load (N), m_e is mass of engine (kg), F_r is rider load (N), m_r is mass of rider (kg) and g is gravitational force with value 9.8 m/s^2. In this frame design, it is assumed to be ridden by one person with a weight of 70 kg and 90 kg, and it is also assumed to accommodate a rider and passenger with a combined weight of 140 kg and 180 kg, along with an engine weight of 30 kg. Based on equations (1) and (2), the rider's load is calculated to be 686 N, 882 N, 1372 N, and 1764 N respectively, and the engine load is 294 N. The engine is mounted to the frame using four bolts, resulting in each load on individual mounts being 73.5 N. There are two types of constraints used in the analysis of this chopper frame: a fixed constraint at the head tube and a pin constraint at the rear wheel support. Figure 2 shows the location of constraints and loads on the chopper frame.

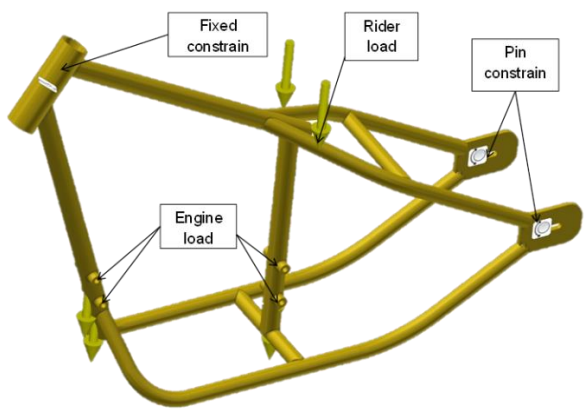

Figure 2. Load and Constrain Location on Chopper Frame

2.5. *Meshing*

In this research, the meshing settings follow the default settings of Autodesk Inventor 2022, as seen in the following Table 2.

Table 2. Mesh Setting

Properties	Value
Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

3. RESULTS AND DISCUSSION

The results of this research consist of a chopper-style motorcycle frame design weighing 12.44 kg, which has been strength-analyzed. Strength testing of the chopper frame was based on static analysis, resulting in several parameters such as Von Mises stress, deformation, and safety factor as shown in Table 3. Figure 3, Figure 4, Figure 5 and Figure 6 shows the distribution of von mises stress. Figure 7, Figure 8, Figure 9 and Figure 10 shows displacement. Figure 11, Figure 12, Figure 13 and Figure 14 depict the safety factor occurring in the designed chopper-style motorcycle frame.

Table 3. Result

Properties	Value			
	Rider (70 kg)	Rider (90 kg)	Rider+passenger (140 kg)	Rider+passenger (180 kg)
Mass			11.74 kg	
Von mises stress (MPa)	32.83	41.91	64.59	82.76
Displacement (mm)	0.27	0.35	0.53	0.68
Safety factor	6.30	4.94	3.20	2.50

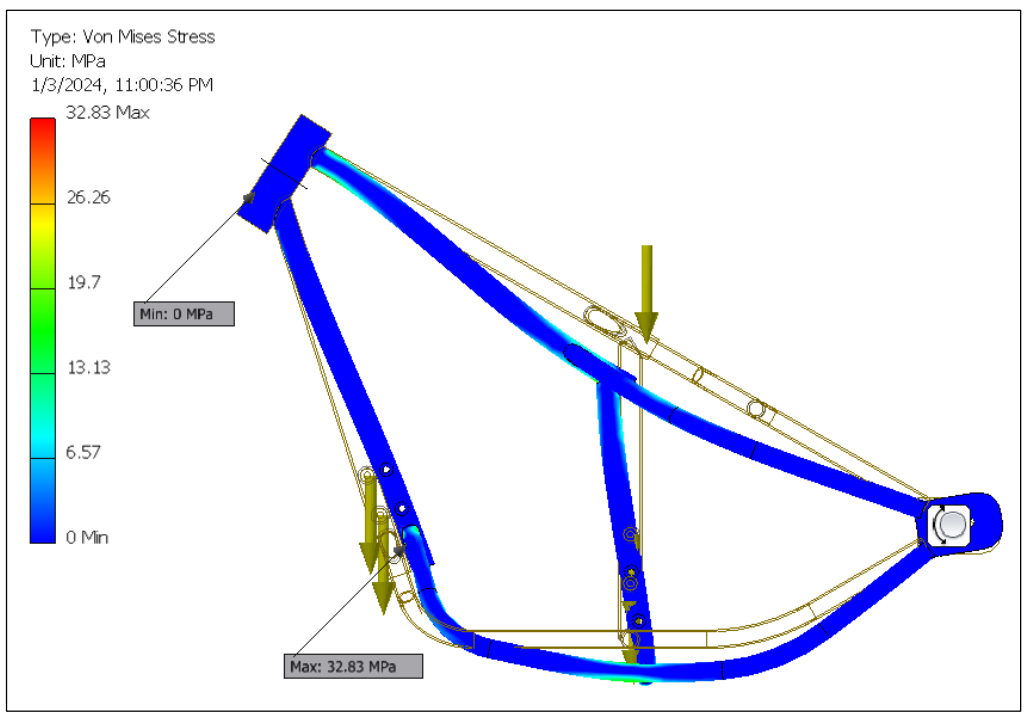

Figure 3. Von Mises Stress on Chopper Frame, 70 kg Rider Weight

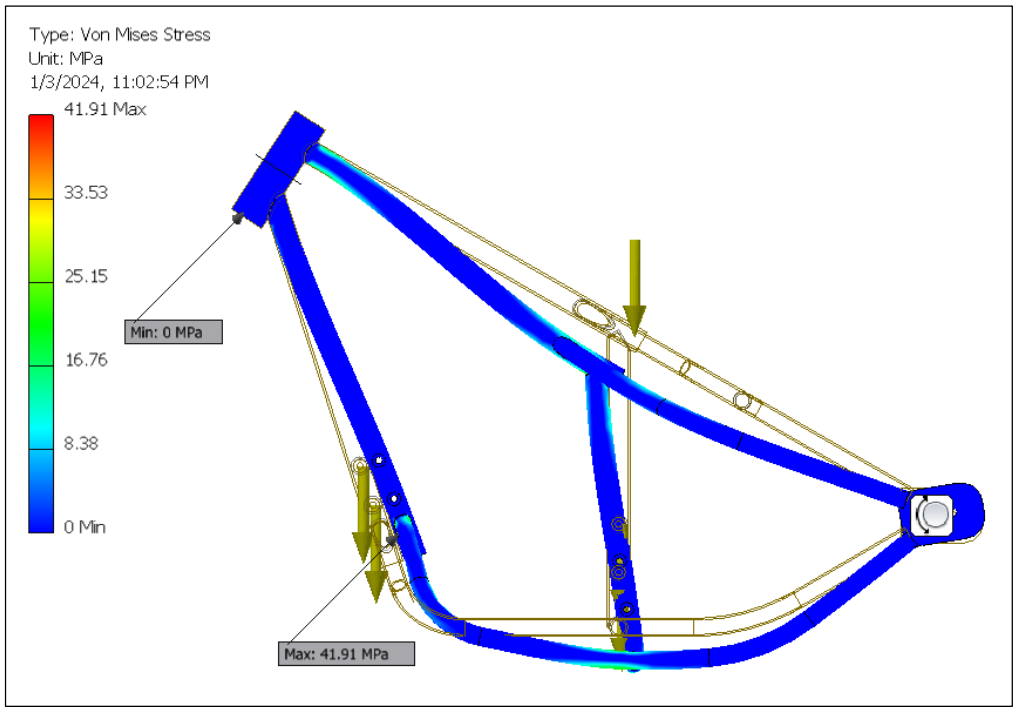

Figure 4. Von Mises Stress on Chopper Frame, 90 kg Rider Weight

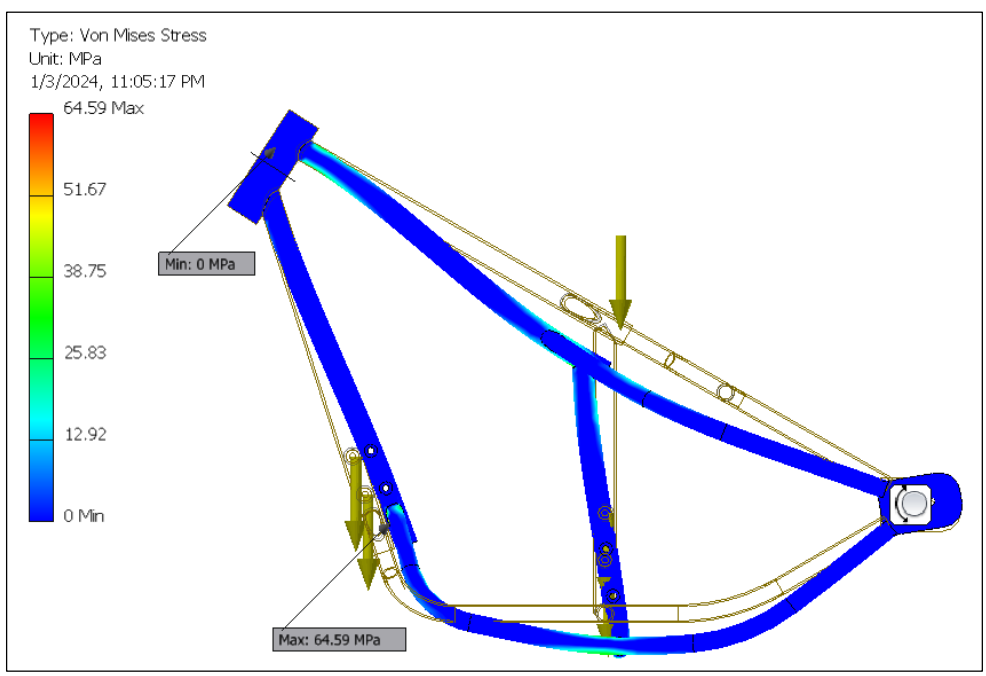

Figure 5. Von Mises Stress on Chopper Frame, 140 kg Rider Weight

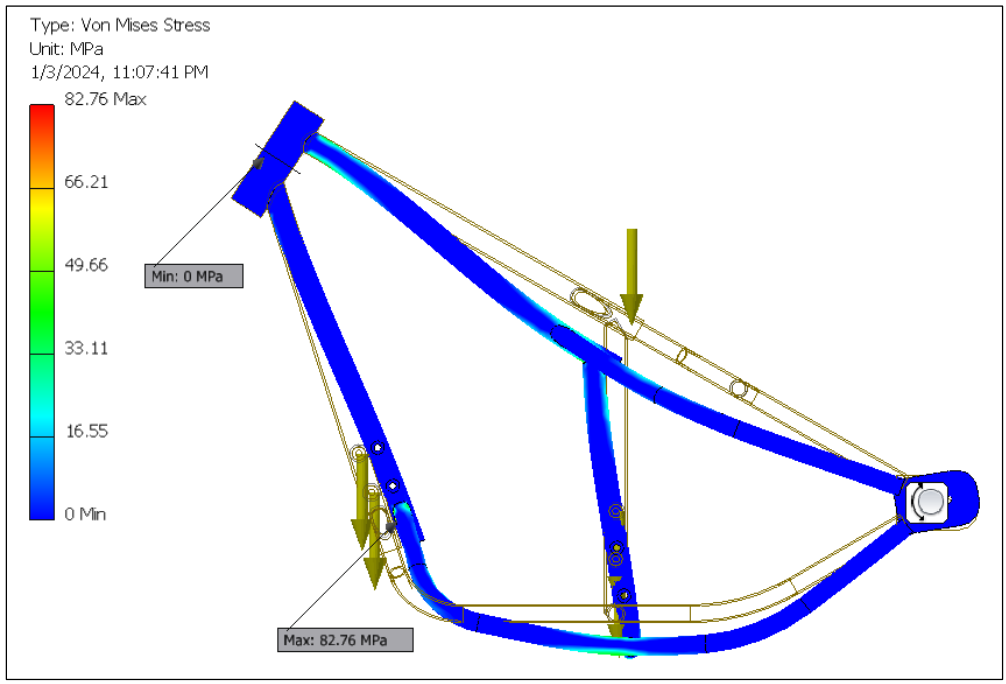

Figure 6. Von Mises Stress on Chopper Frame, 180 kg Rider Weight

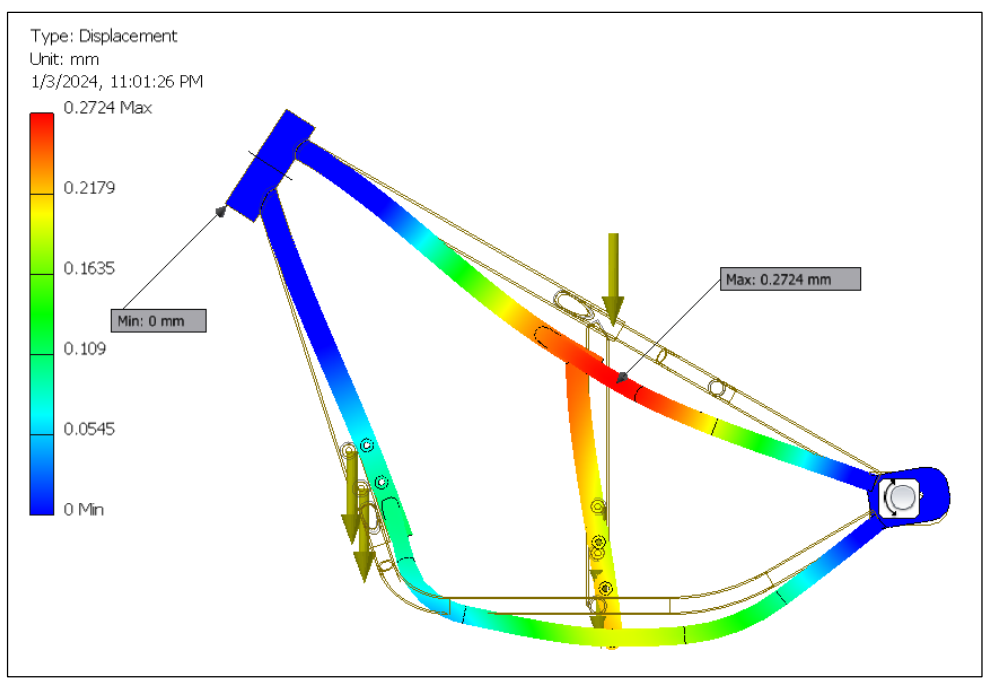

Figure 7. Displacement on Chopper Frame, 70 kg Rider Weight

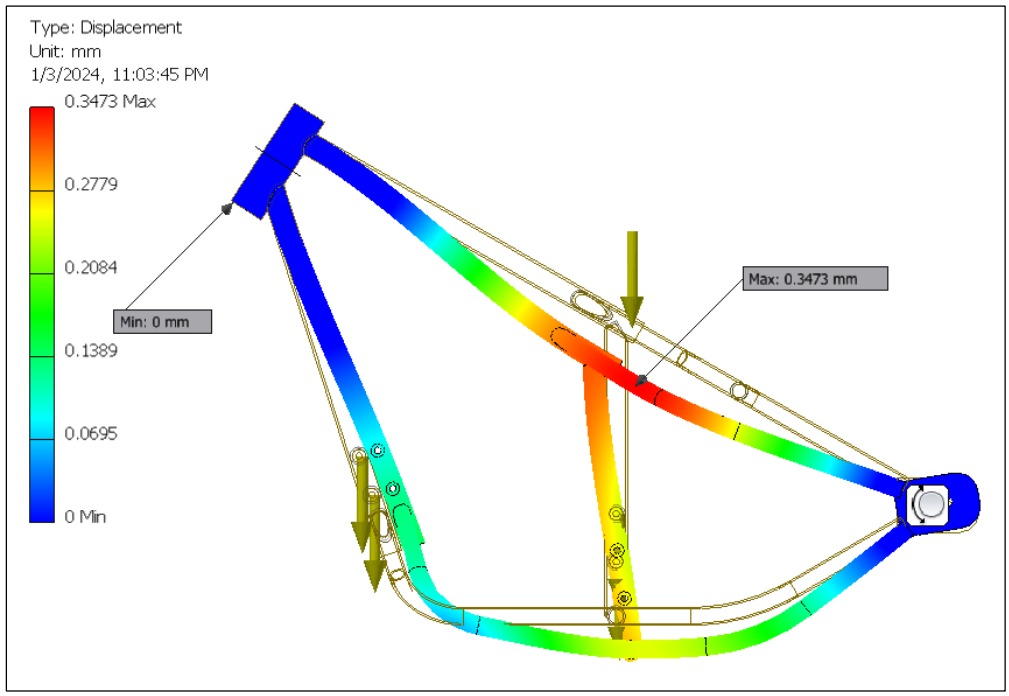

Figure 8. Displacement on Chopper Frame, 90 kg Rider Weight

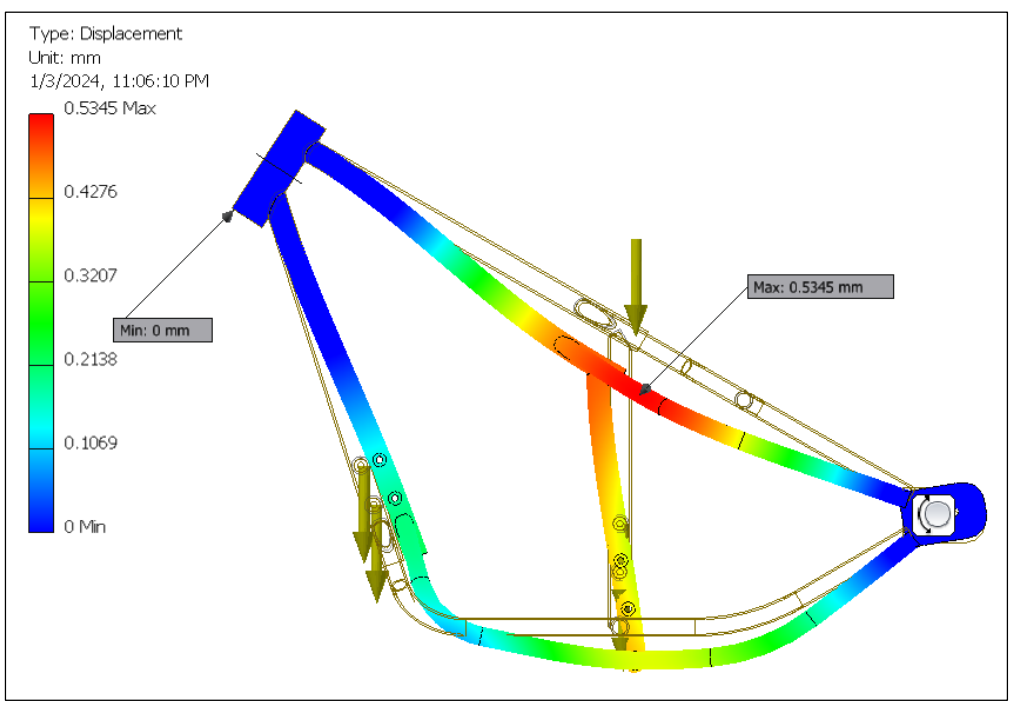

Figure 9. Displacement on Chopper Frame, 140 kg Rider Weight

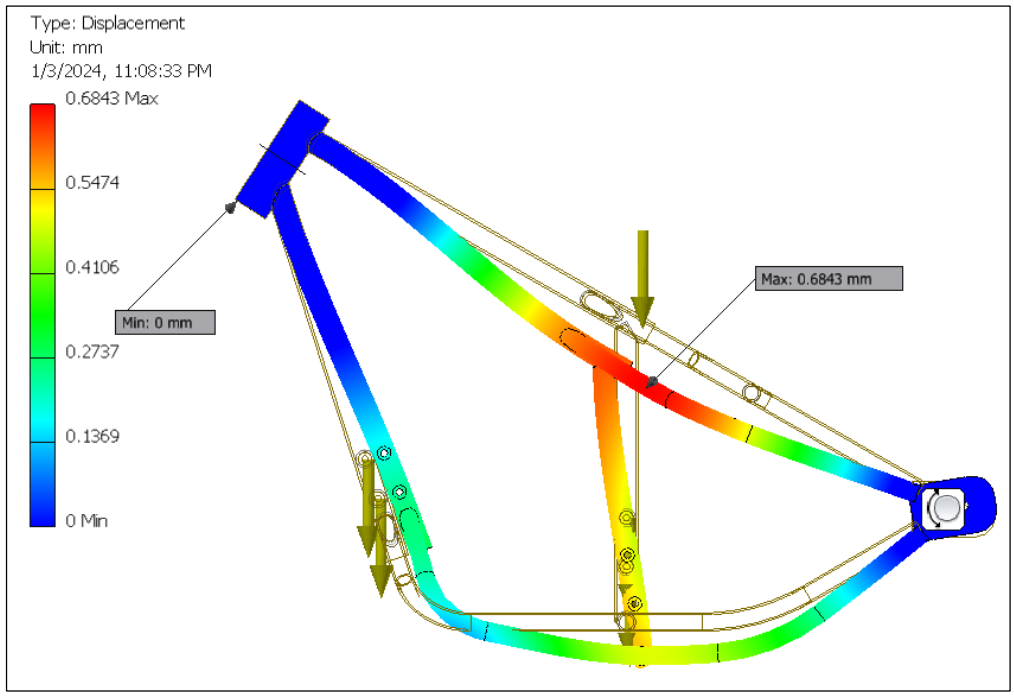

Figure 10. Displacement on Chopper Frame, 180 kg Rider Weight

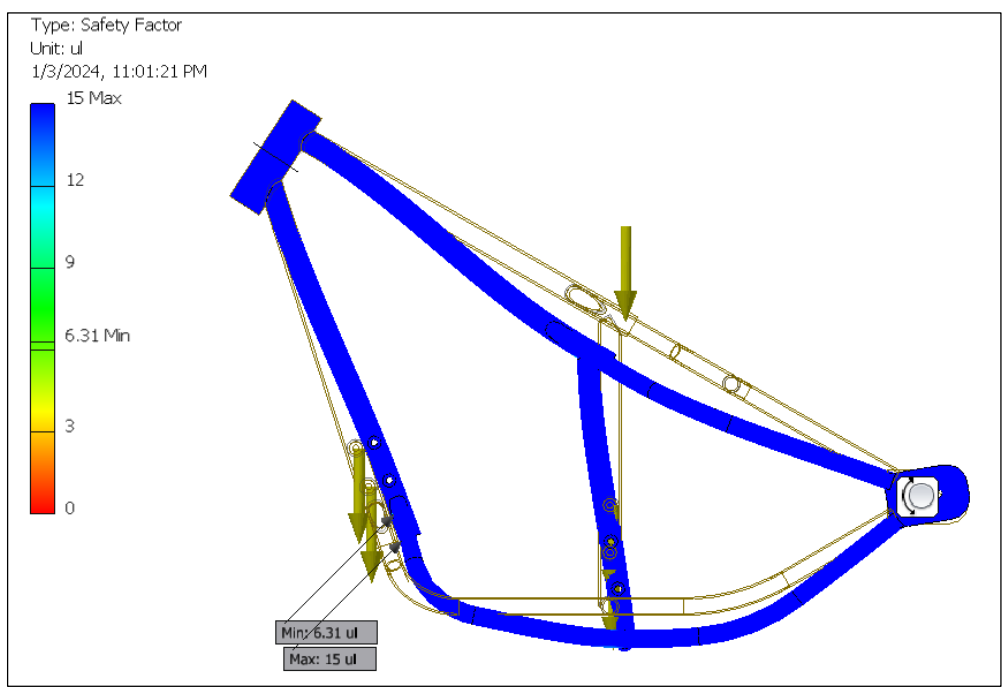

Figure 11. Safety Factor on Chopper Frame, 70 kg Rider Weight

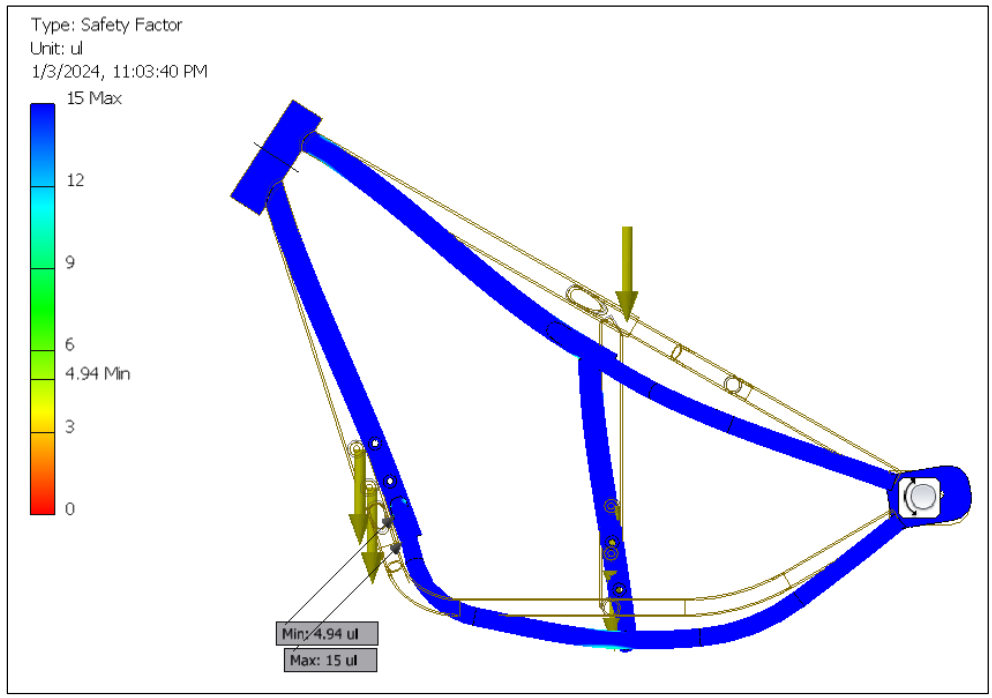

Figure 12. Safety Factor on Chopper Frame, 90 kg Rider Weight

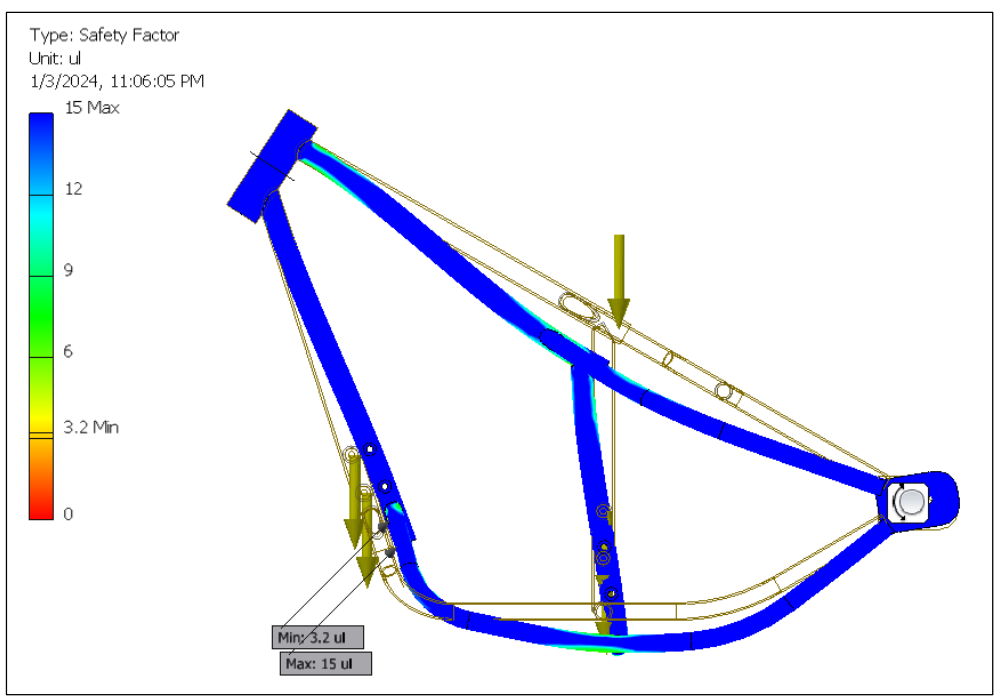

Figure 13. Safety Factor on Chopper Frame, 140 kg Rider Weight

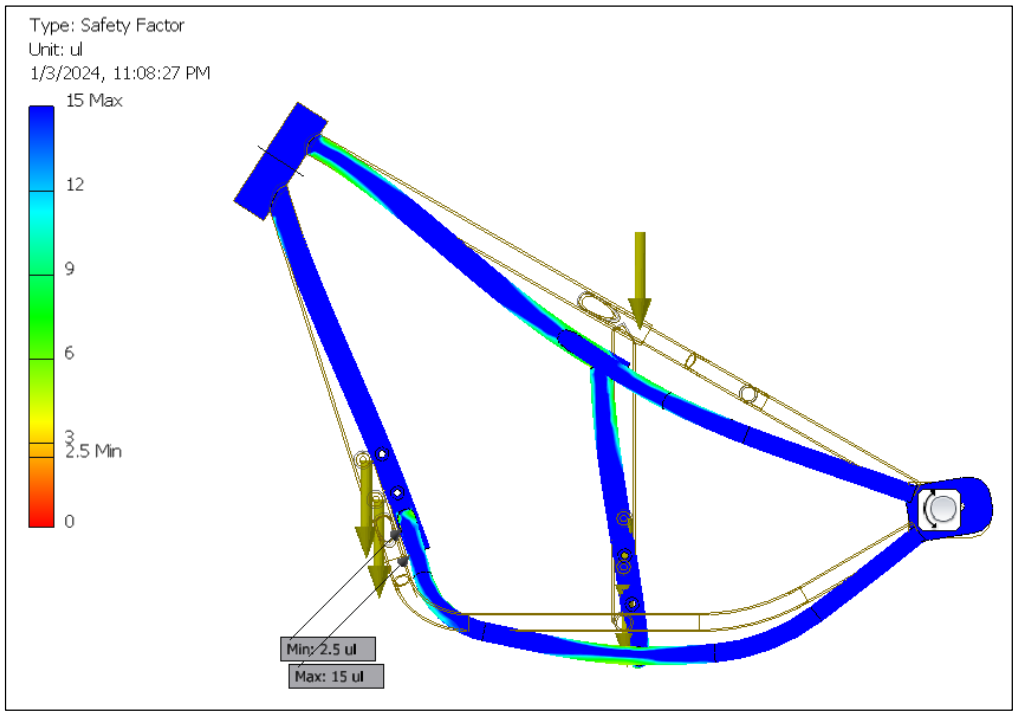

Figure 14. Safety Factor on Chopper Frame, 180 kg Rider Weight

The Von Mises stress that occurs in the chopper-style motorcycle frame increases as the load supported by the frame increases. The Von Mises stress that occurs when supporting loads of a rider weighing 70 kg, 90 kg, 140 kg, and 180 kg are 32.83 MPa, 41.91 MPa, 64.59 MPa, and 82.76 MPa respectively.

The maximum von Mises stress occurs in the area near the connection between the lower subframe and the main lower frame. This happens because the rider's load and the engine's load are supported by that particular section. The loading applied to the chopper-style motorcycle frame results in displacement, with the magnitude of displacement occurring at rider weights of 70 kg, 90 kg, 140 kg, and 180 kg being 0.27 mm, 0.35 mm, 0.53 mm, and 0.68 mm respectively. The safety factor for the chopper-style motorcycle frame with rider weights of 70 kg, 90 kg, 140 kg, and 180 kg are 6.30, 4.94, 3.20, and 2.50 respectively. From that safety factor value, when compared to the permissible safety factor for automobiles, which is 3 [25], the designed chopper frame is sufficiently safe to support a rider's load of up to 140 kg. However, it becomes unsafe with a load of 180 kg. The safety factor value suitable for the vehicle also aligns with what was previously disclosed by earlier researchers [26].

4. CONCLUSION

This research has produced a chopper-style motorcycle frame design made of steel with a mass of 11.74 kg. Assuming an engine load of 30 kg, this chopper-style motorcycle frame is capable of being used for riding with a total rider weight of 140 kg, as the safety factor remains at 3.20. The maximum Von Mises stress recorded is 64.59 MPa, and the displacement is 0.53 mm.

This study only utilized static analysis. Therefore, in subsequent research, dynamic analysis could be conducted along with various other factors such as different shapes and materials. This approach aims to achieve a better design and analysis for the chopper-style motorcycle frame.

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