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A Study on Design of Frame Tube Bike Composite for Reducing Stress and Deformation Based on CEN 14766 Standards Test Methodology

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ABSTRACT

In the previous study, frame tube design analysis is developed to provide a significant reduction in stress and deformation. This study aims to analyze the frame tube composite design. The design analysis by using FEM software is used to model frame tubes with shell elements. The layer angle orientation is set as design parameters. Material is carbon fiber composite (epoxy E-glass UD). Dimension thickness is 2 mm. Seat tube angle 74.5^o and head tube angle 70.5^o. Load is applied in static condition with weight loading on 80 Kg. Based on the simulation results, the smallest deformation and stress values occur in the model with a layer orientation angle of [45^o, 90^o, 90^o, 45^o] with a deformation value of 0.099556 mm and a stress of 10.016 MPa.

Key words: frame tube, stress, deformation, composite, carbon fiber, static, layer orientation angel.

1. INTRODUCTION

All terrain bikes (ATB) or mountain bikes (MTB) are bikes that are used on extreme terrain. In 1970, MTB bikes were first introduced in the hills of San Francisco. In 1981 exhibited at the New York Bike Show, the mountain bike inventor said that this type of bicycle would never be popular. However, approximately 80% of the bicycles sold in the United States are MTB type bikes. The ATB / MTB bicycle is the first bicycle to be ridden to the top of Mount Kilimanjaro, the highest point on the African continent, 5,895 m [1]. Since then, MTB bikes have become known to the world. Currently bicycles are becoming a means of transportation and sport which is again popularly used by many people.

Especially since the Covid-19 pandemic, bicycle users have increased. The needs for the bicycle market need to be increased with safety considerations. To design a bicycle, we should test the bicycle frame by paying attention to several standards that must be owned, one of which is the research method by varying the material and thickness of the frame compiler pipe and simulating [2]. The optimum design conditions for a bicycle for an angel of seat tube frame are 72^o and the rider load is approximately 90 kg based on the results of the analysis conducted by [3]. Optimization of the modification of head tube angle 69^o - 76^o and top tube angle 70^o - 86^o resulted in a change, namely reducing the stress on the bicycle frame structure [4].

In this study, we will modify the angle of the head tube (70.5^o) and seat tube (74.5^o) with other angles being freed to fit the bicycle frame model [5]. In the use of carbon fiber materials, it is preferable to obtain stiffness with a lighter mass in a special frame [6], so that if it is used on a bicycle frame it will be lighter and stronger with carbon fiber composite material to obtain comfort and safety while driving.

Analysis of the finite element method by [7] on simulating the stress strength of a bicycle frame in the ANSYS FEM software using various boundary conditions and the results were compared with the theoretical results in the literature analysis. All stresses were found to be well below the maximum material stress limits and the results were found to be in agreement with the theoretical results. They suggested that the design can be developed with composite materials for further analysis. Composite is a new material trend in demand for structural design because it has the advantage of high strength and stiffness to weight ratio [8]. Therefore, it is a challenge for modification of the frame tube using composite materials. According to o, increasing the thickness of the tube wall alone, does not lead to problem solving [9]. Currently carbon is increasingly being used and developed to achieve good strength and lightness [10]. Based on the above background, this study will be conducted to design a frame tube bike composite for reducing stress and deformation based on CEN 14766 standards test methodology [2].

2. METHODOLOGY

The design analysis by using FEM software is used to model frame tubes with shell elements. Figure 1 shows the frame tube model. Dimension thickness is 2 mm. Seat tube angle 74.5° and head tube angle 70.5°. Load is applied in static start up condition with weight loading on 80 Kg.

Table 1 denotes the material properties of composite epoxy e-glass o.

Property	Value	Unit
Density	2000	$Kg.m^{-3}$
Orthotropic Elasticity		
Young's Modulus X direction	45000	MPa
Young's Modulus Y direction	10000	MPa
Young's Modulus Z direction	10000	MPa
Poisson's Ratio XY	0.3	
Poisson's Ratio YZ	0.4	
Poisson's Ratio XZ	0.3	
Shear Modulus XY	5000	MPa
Shear Modulus YZ	3846.2	MPa
Shear Modulus XZ	5000	MPa
Orthotropic Stress Limits		
Tensile X direction	1100	MPa
Tensile Y direction	35	MPa
Tensile Z direction	35	MPa
Compressive X direction	-675	MPa
Compressive Y direction	-120	MPa
Compressive Z direction	-120	MPa
Shear XY	80	MPa
Shear YZ	46.154	MPa
Shear XZ	80	MPa

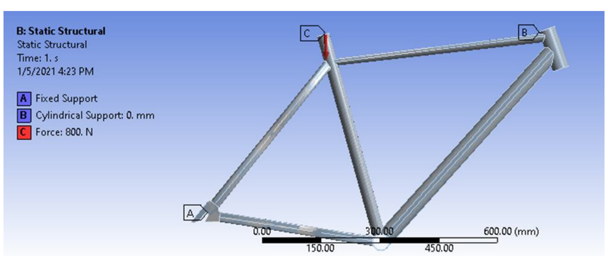


Figure 1. Modeling Frame Tube

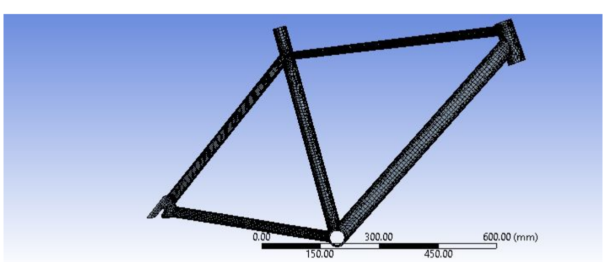


Figure 2. Meshing of model

Table 1. Material properties of composite epoxy E-glass

The layer angle orientation is set as design parameters as shown in Table 2.

Table 2. Five model of orientation angle

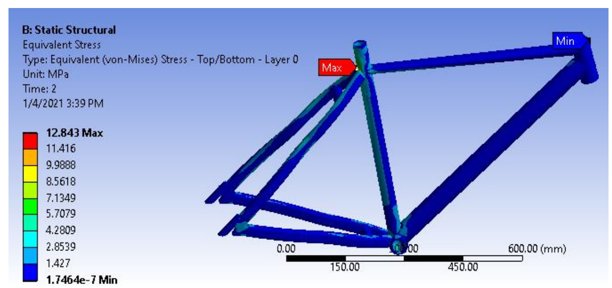
Model	Orientation Angle
1	0^o, 90^o, 0^o, 90^o
2	0^o, 45^o, 0^o, 45^o
3	90^o, 45^o, 45^o, 90^o
4	45^o, 90^o, 90^o, 45^o
5	0^o, 30^o, 45^o, 90^o

The observed values are stress and deformation on the frame tube.

3. RESULTS AND DISCUSSION

From simulation results, it can be determined the stress and deformation from five models as shown in Figure 3 – 4.

a)



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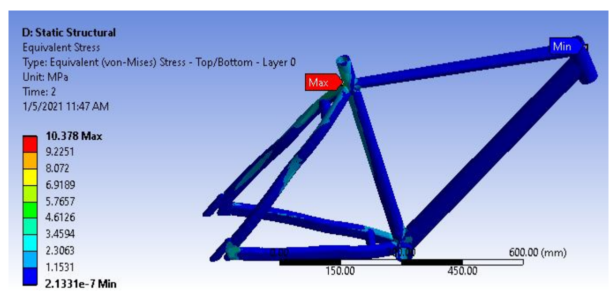

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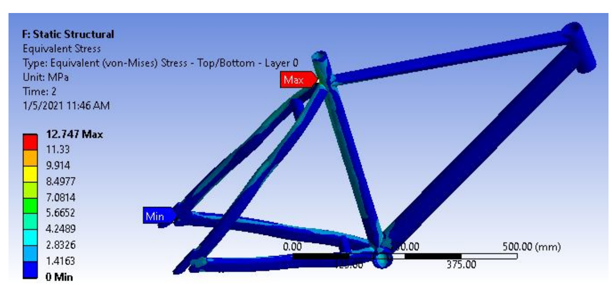

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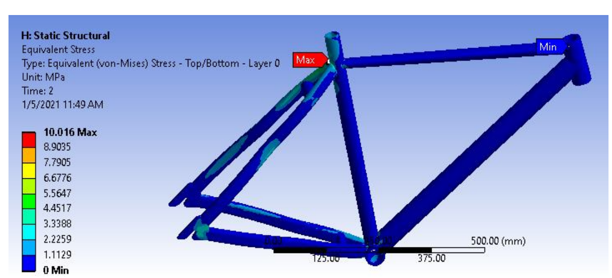

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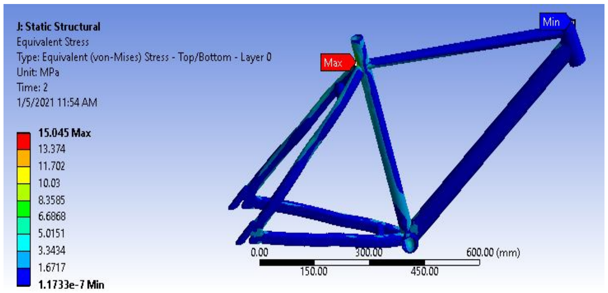
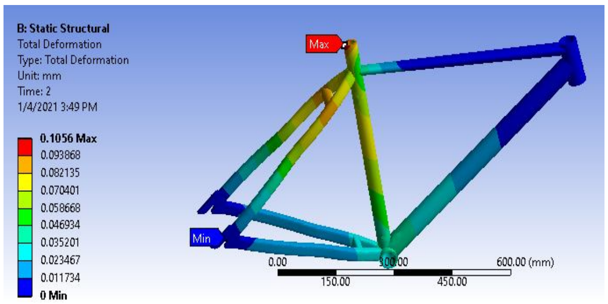


Figure 3. Stress distribution on all models (a) Model 1 (b) Model 2 (c) Model 3 (d) Model 4 (e) Model 5

a)



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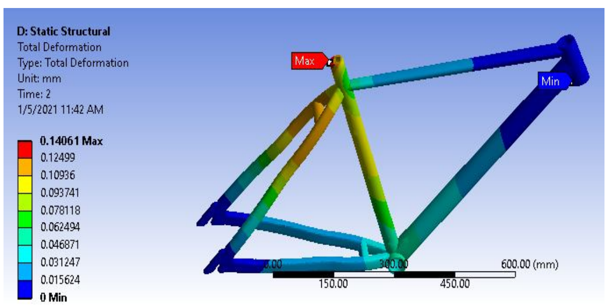

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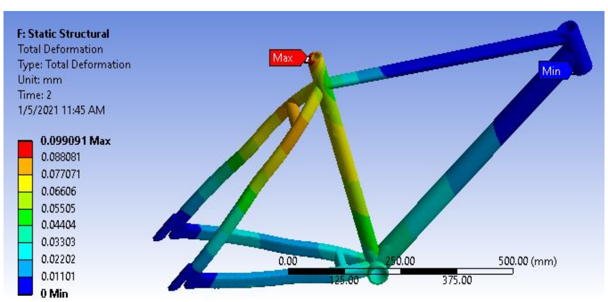

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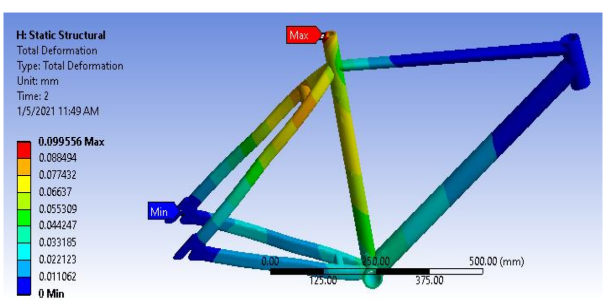

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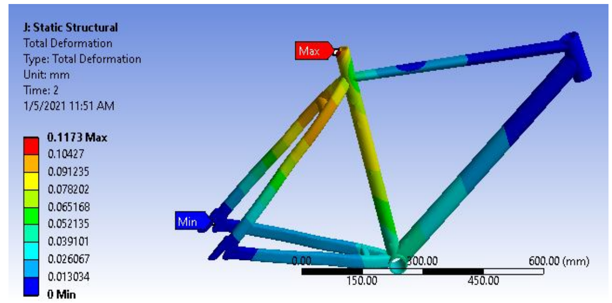

Figure 4. Deformation distribution on all models (a) Model 1 (b) Model 2 (c) Model 3 (d) Model 4 (e) Model 5

From the simulation results, the largest von-Mises stress at the orientation angle [0°, 30°, 45°, 90°] is 15.045 MPa and the largest maximum deformation value at the layer orientation angle [0°, 45°, 0°, 45°] is 0.14061 mm. The results of the smallest deformation at the layer orientation angle [90°, 45°, 45°, 90°] are 0.099091 mm, the smallest von-Mises stress at the layer orientation angle [45°, 90°, 90°, 45°] is 10.016 MPa. The best deformation and stress values with the smallest expectations are at the orientation angle [45°, 90°, 90°, 45°] with a deformation value of 0.099556 mm and a stress of 10.016 MPa.

Figure 3 shows the maximum stress value and the results of the deformation for each model. There are significant differences between one model and another. It can be seen that the layer orientation angle that can reduce deformation and stress convergently is in the third angle model. The orientation angle of the third layer model benefits more because it has the result of reducing deformation and stress. In the other layer orientation angle model, it has nothing in common with reducing the deformation and stress values. This is because when the properties for deformation decrease the stress properties increase, and vice versa.

It can be seen that the deformation area due to maximum loading is at the end of the seat tube, while the minimum deformation condition occurs around the fixed support area. The area of maximum stress due to loading is the connection (node) of the seat tube to the seat stays. This is because the loading angle follows the direction of gravity and in the static start up condition of the bicycle towards the rider.

The results of the stress area and deformation of each layer orientation angle model for the maximum value show the similarity in position. Thus, the deflection is thought to occur in the area around the seat tube stem which is directly connected to the bicycle saddle connector. Similar conditions were carried out by previous researcher with the load on the saddle used the direction of gravity which had a minimum von-Mises stress value [11].

The minimum stress and deformation values in the figure 3 and 4 shows that the fixed support area is safer from stress and deformation due to loading. It is necessary to pay attention to the area of maximum stress and deformation for periodic loading. The loading conditions on the seat tube will affect the stress relationship with each tube, namely the down tube, top tube, chain stays, seat stays [7]. In the simulation they produced the highest seat stay stress value (6,2 MPa) and the seat tube has the lowest stress value (1,01 MPa) of that condition.

The layer orientation angle model used in this simulation uses a general model. It can be seen in models 1, 2, and 5 that the angles are sequential, but in models 3 and 4 the angles used can reduce the stress and deformation values.

At different layer orientation angles carried out by Qiwei Guo, it will increase the tensile strength and do not decrease the stress value, although this rarely happens. However, it will be different if the treatment of the layer orientation angle is included in the composite treatment on the bicycle frame which has an effect on reducing stress and deformation [12].

The planned geometry design has a thickness of 2 mm for each model, and has 4 layers with different orientation angles. It is obvious in the figure 3, the fourth model has the lowest stress value, compared to the simulation geometry model with a thickness of 1.8 mm [2]. At different angles of layer orientation with different number of layers, the layer model in boundary conditions can further reduce the stress [13].

4. EDITORIAL POLICY

The submitting author grants that this manuscript has been agreed by all of the authors. The submitting author also has checked that citation has properly been made.

5. CONCLUSION

The consecutive orientation angle at each layer is not sufficient to affect the stress value and deformation. However, the random orientation angle at each layer affects the stress and deformation values of the composite material used. It would be a good idea to develop more simulations about the random differences in the orientation of the layers in order to maximize the stress and deformation values. A functional change in the type of composite material is required at each different angle of orientation.

The geometry model by the author is a general and simple model. It is better to do some development on the geometry model used. The geometry model used can vary in shape, size and volume. Beyond carbon fibers are expected to be applied in this simulation.

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