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Design and Construction of Mountain Bike Frame Using Solidworks Software and Matlab Simulink

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Abstract: This paper discusses the application of generative design of mountain bike frames using Solidworks and MATLAB Simulink software. The topic is taken from the problem of the value of the inertial force that occurs in the mountain bike structure due to the dynamic force acting. The mountain bike in this study was made of epoxy carbon composite material in order to get a rigid, strong and light frame. The process is carried out using Solidworks software and analysis using MATLAB Simulink software. This article is an explanation of the bicycle frame design process that occurs due to the assumption of a wavy track. Based on computational studies conducted on MATLAB Simulik, for a load of 90 kg it can be seen that a static load is 1659.1 N and a dynamic load is 36.78 N with a gravity of 9.8 N/m2. Based on the simulation on the track model, it is known that there is a factor of safety of 5.8 with a deflection of less than 1 mm (ie 0.126 mm). The frame of this bike is made of wet laminated composite material made of epoxy composite fiber. Modeling a bicycle frame and how it is used is a major factor in determining the deflection of a bicycle structure.

Keywords: Matlab Simulink, Solidworks, Bicycle Frame Deflection, Composite Materials, Wet Lamination

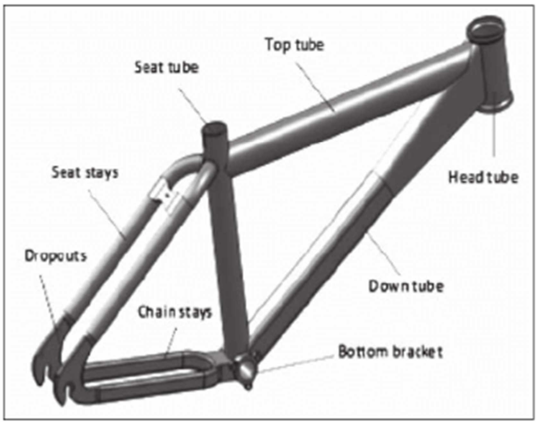
1. Introduction

Based on some of the literature on the bicycle, it has been defined as a simple dispositive that allows more efficient personal movement than walking, but only requires muscles to perform this translational motion. The history of cycling is a challenge that evolves with the advent of technology. More relevant to the purposes of this article, however, is the role the bicycle played in social movements in the United States and around the world in the last century. [1] However, much time has been spent reinventing the bicycle with a different design and better materials. The purpose of this brief historical introduction is to give aspiring discoverers a glimpse of some of their predecessors.

Researchers have been experimenting with the possibilities of human-powered two-wheeled transportation since the early 19th century. With the passage of time, many researchers are making bicycles lighter by using composite materials, which transmit power with the help of internal gears, and use electricity as a substitute for human power. This evolution is very interesting, especially at the dispositive of highly efficient transportation and recreation. The evolution process takes place slowly or quickly, where each development leads to a better product. [2]

Bicycle frames' track record has gone from wood, steel, aluminum, light alloys, to composites in the last century and a half. Cycling research itself has gone from a curiosity to a mode of transportation in developing countries and a tool of sport and recreation in developed countries. [3] Recent advances in the bicycle industry occurred almost simultaneously with developments in the automotive and aerospace industries. As the cost of aerospace materials has fallen, they have gone from the most basic to the most advanced. Likewise, mass production techniques for the automotive industry have helped lower costs. However, the original materials and production processes only enhance the precision and quality of the product.

Fiber is combined with resin to become a composite (FRC) which is widely used in the aerospace or automotive industry which later also developed in the sports performance industry. [4] The manufacture of bicycle parts from composite materials has increased significantly in the last 20 years. Based on the point of view of obtaining tubular sections from fiber reinforced plastics, it has been studied for a long time in various technical aspects and is applied. Bike frames are mostly made up of tubes but in composite frames more attractive designs can be used as shown in Figure 1. [5]



(a)

(b)

Figure 1. *Comparison of conventional and current designs.*

Mountain bike frames must be designed in such a way to be able to pass through rough and bumpy terrain. This situation has the potential to cause an additional innesia moment which causes an increase in the bicycle load, especially on the frame. If the bicycle frame experiences an increase in acceleration, an inertial force arises on the entire frame. By considering the finite element, the increase in the moment of inertia will cause an additional reaction force which causes an additional deviation in the structure. [6]

2. Research Methodology

Several researchers have developed lightweight carbon fiber materials that are used in aircraft structures and have been used in automotive structures, as well as mountain bike frames. This material is very light and has high strength, so that the bicycle frame that uses it will perform optimally. So in this research a Solidworks mountain bike frame was developed which was then simulated using MATLAB Simulink. [7]

2.1. Solidworks

The software used is a computer-aided design tool, so it will be easier for product design and simple calculations. The tools are widely used globally by engineering professionals, engineering students, simulation experts, and research and development professionals from various industries to perform the following CAD operations in relatively minimum time. [8] Simulink Matlab takes advantage of problem solving block diagrams that are handled to a multi-domain model, to other devices without writing code. In the case of mountain bike system design, the track model must be made, and of course the dynamic characteristics are the main reference. After that mountain bikes become easy to simulate, and get the tension that happens to a mountain bike frame.

By referring to various literatures and as an initial design, the initial quantities are used as listed in Table 1. [8]

Table 1. *Table of bicycle dynamics specifications.*

No	Description	Values	Units
1	Mass and Rider Mass	85	kg
2	Front Stiffness	18,87	kN/m
3	Rear Stiffness	22.64	kN/m
4	Front Wheel Stiffness	30.60	kN/m
5	Rear Wheel Stiffness	67.56	kN/m
6	CG distance forward	0.4	m
7	CG distance backwards	0.6	m

Panji Abdillah Khoerul Azmi, (2017) designs and manufactures precision frames (jigs) intended for further design processes. Figure 2 shows a jig that has been realized so that it can be used in the design process. The loading application on the solidworks software itself begins with a load of 60 kg, and the safety factor obtained is 3.8. In this case, it is necessary to iterate so that the safety score increases, and the minimum is 6. Therefore, the design process is reworked to meet the standard.

Figure 2. *Bike frame jigs.*

Referring to the implementation of this research, the methodology for implementing this research can be completed in several stages as shown in Figure 3.

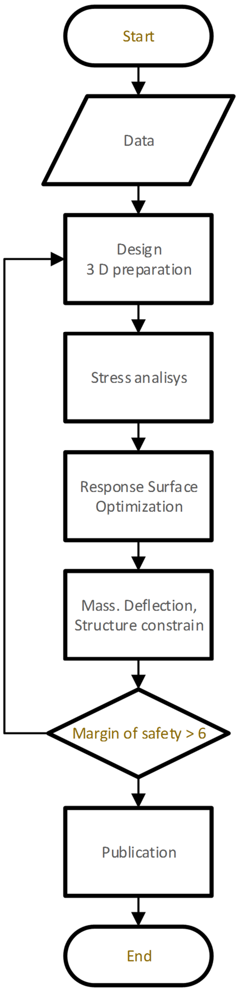


Figure 3. *Flow chart of the implementation of research.*

2.2. Vibration Respons

In the process of determining the deflection of a bicycle structure, a simulation is carried out on the final design to justify the dynamic loads and deflections that occur in the mountain bike frame. Because the track of a mountain bike fluctuates as shown in the curve in Figure 4. The dynamic load caused by the track is a combination of the excitation response of the front and rear wheels. The front and rear wheel tracks can be simulated on a curve as shown in Figure 3.

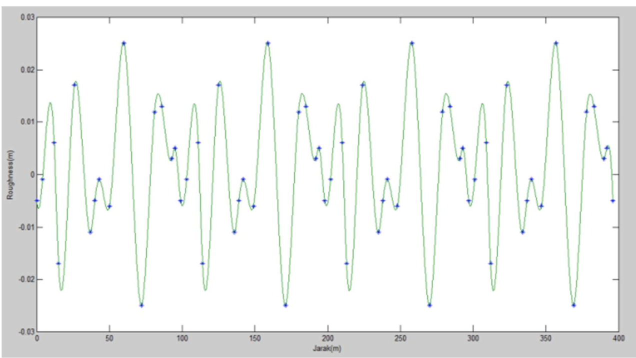


Figure 4. *Mountain bike track model in this study.*

Mountain bike frame vibration when an object moves on its track, as shown in Figure 3, has always been a topic of interest in engineering. This is in accordance with the analysis of vehicle vibration so that it can explain the comfort and performance of mountain biking, and needs to be displayed in the frequency domain. In this study Newton's second law method is applied to model and analyze vibrations in an object, as has been applied by many researchers.

The 5 dof model is used to model the movement of the mountain bike frame due to the movement of the front and rear wheels due to the track. [9] In general, these coordinates are independent geometric bounds that are measured by position rather than the object being vibrated. Figure 4 shows the size that is the reference for this study. [10]

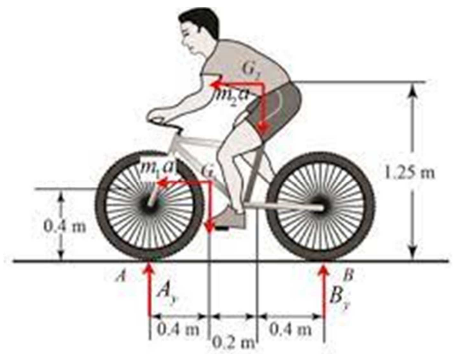


Figure 5. *Mountain bike geometry and dimensions.*

3. Result and Discussion

Referring to the geometry and dimensions of the mountain bike frame, the method for making a 5 dof bicycle model is as shown in Figure 5. Based on this figure, the dynamics of the motion of the mountain bike system can be arranged and its response at the point cg is known. This is because only the up-and-down movements and throws are referenced. In this study, study parameters are used and represented: front wheel mass (m_f), rear wheel mass (m_r), seat and rider mass (m_c), frame mass (m_s), distance between front and rear axles (l_s), the distance from the front support to the cg point (l_1), the distance behind the cg point (l_2), and the gyration radius (r). Modeling the movement of the bicycle frame structure (5 dof) as shown in Figure 6. [11]

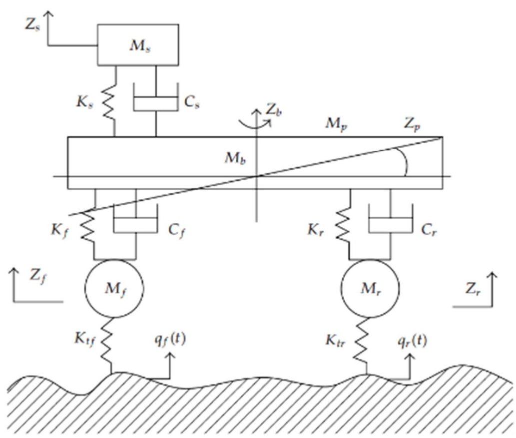


Figure 6. *Mountain bike dynamics model.*

The mechanical vibration of the mountain bike frame structure modeled as Figure 5, in general can be solved with a matrix. By using Newton's second law, you can arrange a matrix based on the deviations that occur. By using the lathe model, the dynamic system can be modeled as shown in Figure 7.

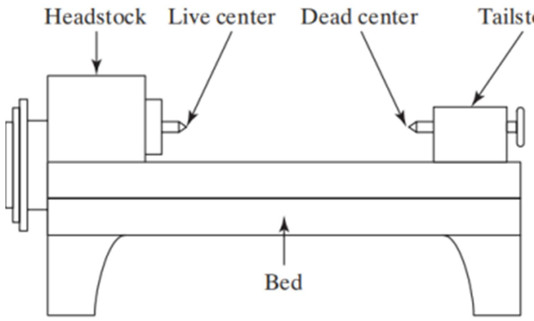


Figure 7. *Simulink Matlab model base of mountain bike models.*

Based on the lathe in Figure 7, then the structural can be modeled as can be seen in Figure 8.

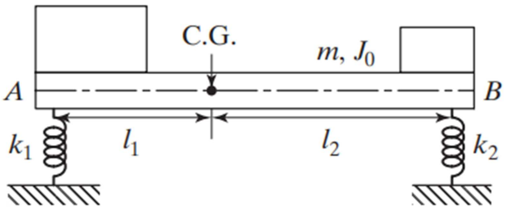


Figure 8. *Model dynamics of the lathe due to vibration.*

The dynamic model of the lathe as shown in Figure 8, in this study it can be modeled and simulated as shown in Figure 9.

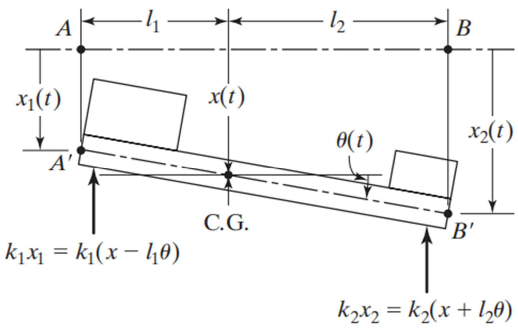


Figure 9. *Deviation in the lathe structure that can compose the equation of motion.*

The procedure for making the equation of motion is carried out by giving the deviation as shown in Figure 8. Referring to Figure 9, can be arranged equations of motion in the vertical and rotational directions. The equation of motion of the lathe frame is written in Eq. (1-2).

$$m\ddot{x} = k_1(x - l_1\theta) - k_2(x + l_2\theta) \quad (1)$$

$$J_0\ddot{\theta} = k_1(x - l_1\theta)l_1 - k_2(x + l_2\theta)l_2 \quad (2)$$

According to the press. (1) and (2), can be arranged in the form of a matrix as written in press (3),

$$\begin{bmatrix} m & 0 \\ 0 & J_0 \end{bmatrix}\begin{Bmatrix} \ddot{x} \\ J_0 \end{Bmatrix} + \begin{bmatrix} (k_1 + k_2) & -[k_1l_1 - k_2l_2] \\ -[k_1l_1 - k_2l_2] & (k_1l_1^2 + k_2l_2^2) \end{bmatrix}\begin{Bmatrix} x \\ \theta \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \quad (3)$$

Based on the simulation with the modeled trajectory, the deflection for varying loads is [13 – 15].

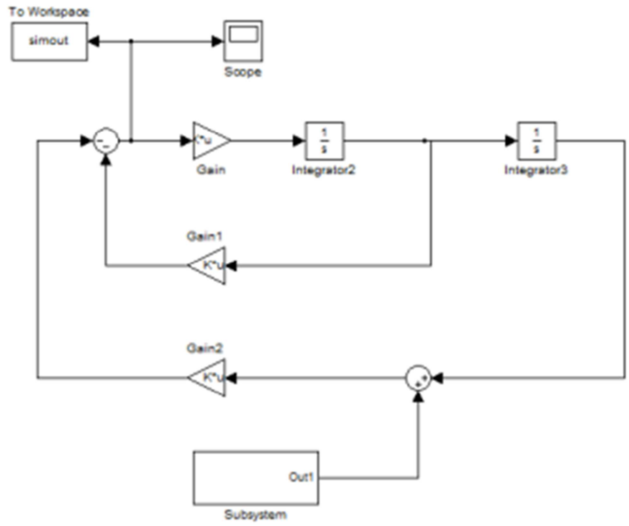
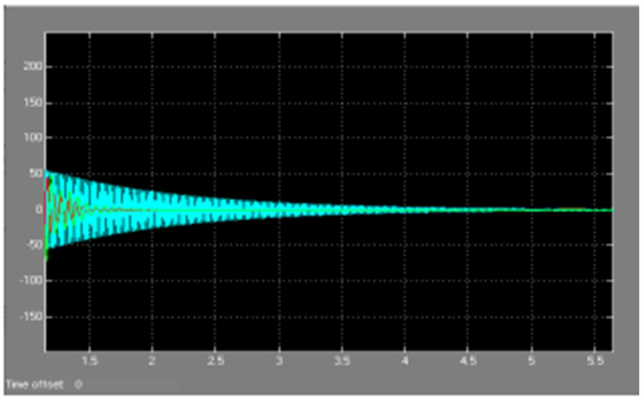


Figure 10. *Simulink dynamic force equation.*

Based on the Simulink circuit above, and by varying the workload, the dynamic load acting on the cg point of the mountain bike frame is obtained. The dynamic disturbance that causes the additional deflection is closely related to the bumpy road profile. The road waves in this mountain bike study are represented in Figure 3. The simulation results from the Matlab Simulink circuit refer to the load, resulting in an inertial force at the cg point as shown in Figure 11.



Figur 11. *Inertial force value.*

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Table 2. Max von mises stress on mass riders.

Raider Mass (kg)	Max Von Midrd (Mpa)
60	44.61
70	52.11
80	59.47
90	66.88

Demikian pula dengan hasil deviasi rangka sepeda gunung seperti yang tertulis pada Tabel 3.

Table 3. Max displacement against rider Mass.

Raider Mass (kg)	Maximum Displacement (mm)
60	0.084
70	0.098
80	0.112
90	0.126

Similarly, the results of the safety margin of bike frame as written in Table 4.

Table 4. Safety of factor in every rider's mass loading.

Raider mass (kg)	Safety Factor
60	8.7
70	7.5
80	6.6
90	8.8

4. Conclusion

Penggunaan Solid works dan software Simulink Matlab telah mendukung generatif desain rangka sepeda gunung dengan menggunakan material Bio-composite dan telah dilakukan lebih dari 2 kali dengan material konvensional.

Referring to Tables 2, 3, 4, it can be seen that the design of these bicycles is getting better and these mountain bikes are quite safe for the people of Indonesia. If there is a desire to use it in other areas, it is necessary to review its relation to the mass of the rider and the environment which will increase the inertia of the mass acting on the bicycle structure, as well as the usage factor.

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