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Bicycle Frame Design And Structural Analysis

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Abstract – With the development of technology, human beings, who can easily cover long distances, have not been able to give up bicycles, although they are advancing in the field of transportation every day. The bike is still attractive as it does not require long and costly maintenance, is light and handy. The human-powered bicycle is a nature and environment friendly vehicle in addition to motorized transportation vehicles. In this study, in general a bicycle frame design suitable for daily and mountain roads, ergonomically designed according to human body size was designed and the stresses and elongations that occur in the analysis programs were examined.

Keywords – Bicycle Frame, Design, Structural Analysis, Ansys, Aluminum

I. INTRODUCTION

With the development of technology, human beings, who can easily cover long distances, have not been able to give up bicycles, although they are advancing in the field of transportation every day. The bike is still attractive as it does not require long and costly maintenance, is light and handy. The human-powered bicycle is a nature and environment friendly vehicle in addition to motorized transportation vehicles [1]. The origin of the bicycle dates back to 200 years ago. In 1817, German Baron Karl von Drais invented the two-wheeled vehicle that was the prototype of the modern bicycle [1].

Drais used the vehicle to be able to move faster. The rider was advancing by pushing his foot off the ground in the pre-pedal period [1].

Patented by Von Drais on June 26, 1819, the vehicle became popular in many countries such as Austria, the United Kingdom, Italy, and the United States. Drezin was developed over time and evolved into a bicycle [1].

Pierre and Ernest Michaux designed the first pedal bike. Two French father and son named Pierre and Ernest Michaux put pedals on the front wheel hub of the vehicle built by Drais. So the real bike was invented [1].

After that, the curiosity for cycling started to spread much faster all over Europe. Father-son started mass production by establishing the "Michaux Company" [1].

Today, highly developed bicycles are used in many areas such as mountain bikes, racing bikes, model kids bikes, city and road bikes, fitness bikes, electric bicycles, service bikes [1, 5, 6].

II. MATERIALS AND METHOD

In this study firstly, it was determined the size and weight of the bike user. An individual of 180 cm and 80 kg is approximately 60 cm in arm length and 80 cm in inside leg length. Lifting the handlebar and pedal distances of the bicycle by using these measurements.

Bicycle squad selection has a major impact on cycling comfort. When one of the simplest methods that helps us choose the minimum of the frame is from the seat, the frame deems it appropriate to have a distance of 10 cm between the upper tube and the crotch. But in a more professional sense, all the angles of the cycling frame were important for sportive riding [2].

The dimensions in the Table 1 may vary according to bicycle types and brands [2]. Calculations and measurements are approximate units. The grouping made in the form of XS - S - M - L - XL was made on average dimensions. Each bike should be evaluated according to its own characteristics, your body size and your usage situation. You have to remember that these calculations are very general, given the number of possible bike styles that humanity has invented and the wide variety of human body types.

Table 1. Dimensions according to bicycle types and brands

Boy	Bacak İç Boyu	Kadro Boyu	Ölçü	Frame size
		MTB/CROSS		YOL / ŞEHİR / TREKKİNG
152 cm	71 cm	14" (36cm)	XS	41-43 cm (16-17")
157 cm	72 cm	15" (38 cm)	S	43 cm (17")
162 cm	74 cm	16" (41 cm)		46 cm (18")
167 cm	75 cm	16" (41 cm)	M	48 cm (19")
172 cm	76 cm	17" (43 cm)		51 cm (20")
175 cm	77 cm	17" (43 cm)		53 cm (21")
177 cm	79 cm	18" (46 cm)	L	53 cm (21")
182 cm	82 cm	18" (46 cm)		56 cm (22")
187 cm	86 cm	19" (48 cm)	XL	56 cm (22")
192 cm	89 cm	20" (51 cm)		57 cm (22")
197 cm	92 cm	21" (53 cm)		58 cm (23")

In addition, the calculation becomes more difficult as the bike's length has a decisive effect on your position on the bike. When it comes to classic styles such as mountain biking, road biking or trekking, you can find the general dimensions in the Fig. 1 below [2].

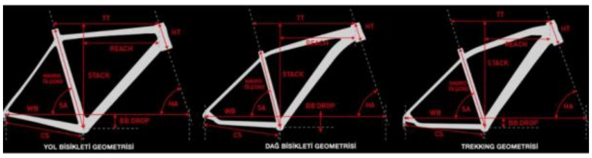

Fig. 1 General dimensions of classic styles

However, it will be different if you want to use the bike for more extreme rides, for example in marathon or XC races, Cross, Enduro or Downhill. In such cases, a smaller frame (at least one or even two sizes smaller) might be a good choice. This is because a smaller bike is easier to maneuver. However, be careful not to overdo it on the small size as it can have a negative effect on the bike's running. Therefore, it is necessary to choose the model that suits you, taking into account the mathematical calculations, bike style and the experiences of other cyclists [2].

Bike tire sizes vary according to bicycles. Children's bicycle tires dimensions are mostly expressed as 16 rims, 20 rims and 24 rims [3]. Mountain bike tire dimensions are mostly expressed as 26 rims, 27.5 rims and 29 rims. 27.5 rim tire size has an outer diameter of 650 mm [3]. Tire sizes in tour bikes are between 35-43 mm and 28 rims are generally used on touring bikes. 28 rim is expressed as 700 [3, 7]. Road bikes are bike models, which are also referred to as racing bikes. These bicycles are thin tires designed for use on asphalt. Usually 700 × 23 tires are used on road bikes [3]. In our design, 27.5 rim tire size will be used and 27.5 rim tire size has an outer diameter of 650 mm. We have designed a bicycle suitable for mountain roads and daily use, taking into account human dimensions. The dimensions of the bike are given in Fig 2.

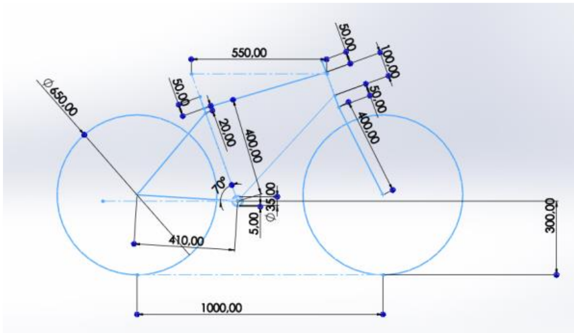

Fig. 2 Dimensions of the bike

The purpose of any bicycle frame is to offer the highest strength to the lowest weight. Bicycle frame strength is determined by many factors.

Carbon steel is the most common material used in steel bicycle frames. Although carbon steel is a strong and long-lasting material, it is not as light as chrome steel [4]. With a smooth shape and good processing, you can get a solid frame that will last for many years with chrome steel [4].

Carbon fiber bicycle frame; Parallel layers of fibers are glued together. This forms a layer. A layered form is created by stacking several layers. If this layered form is designed correctly, a very solid structure emerges and it is very light. So why aren't all bicycles made of carbon? Because this carbon network is prone to brittleness. Metal materials can be bent and recover more easily. However, bicycles made of carbon fiber are prone to brittle behavior, making it difficult to manufacture because they have to be built stronger than they should [4].

Titanium bicycle frame; Lighter than steel and tough as steel, the expensive metal used in mountain and road bikes. This metal, which has an excellent flexibility, is used because it absorbs shocks by itself [4].

Aluminum bicycle frame; Today, aluminum is cheap and it is frequently used in bicycles due to this feature. Aluminum, which can be quite light and robust with a suitable design, is ideal for use [4].

In our design, we will use aluminum alloy metal in the bicycle frame because it is extremely lightweight and cheap but aluminum's mayor disadvantage is that is lacks the durability or damage and fatigue resistance of either steel or titanium. The material properties of the aluminum alloy we use in Fig. 3.

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	2770	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
12	S-N Curve	Tabular	
16	Tensile Yield Strength	2,8E+08	Pa
17	Compressive Yield Strength	2,8E+08	Pa
18	Tensile Ultimate Strength	3,1E+08	Pa
19	Compressive Ultimate Strength	0	Pa

Fig. 3 The material properties of the aluminum alloy

III. RESULTS AND DISCUSSION

Total deformation results when 800 N force is applied from the seat was seen in Fig. 4.

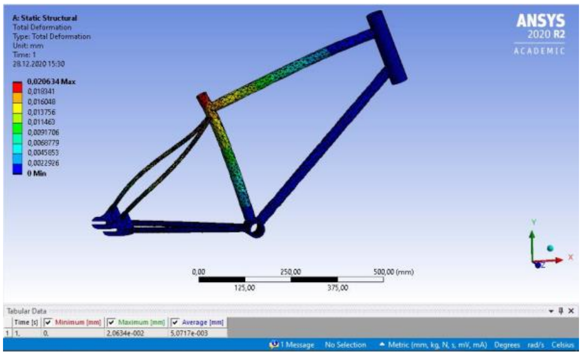

Fig. 4 Total deformation results when 800 N is applied

The maximum total deformation is 0.020634 mm. Total deformation results when 600 N force is applied from the seat part and 200 N force is applied from the handlebar part was seen in Fig. 5.

Fig. 5 Total deformation results when 600 N is applied

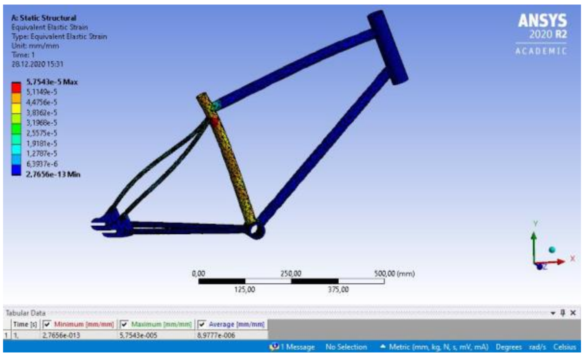

Fig. 6 Equaivalent elastic strain results when 800 N is applied

The maximum total deformation is 0.015475 mm. Equivalent elastic strain results when 800 N force is applied from the seat was seen in Fig. 6. The maximum equivalent elastic strain is 5.7543x10^{-3} mm/mm.

Equivalent elastic strain results when 600 N force is applied from the seat part and 200 N force is applied from the handlebar part was seen in Fig. 7. The maximum equivalent elastic strain is 4.3157x10^{-3} mm/mm.

Fig. 7 Equaivalent elastic strain results when 600 N is applied

Equivalent stress results when 800 N force is applied from the seat was seen in Fig. 8.

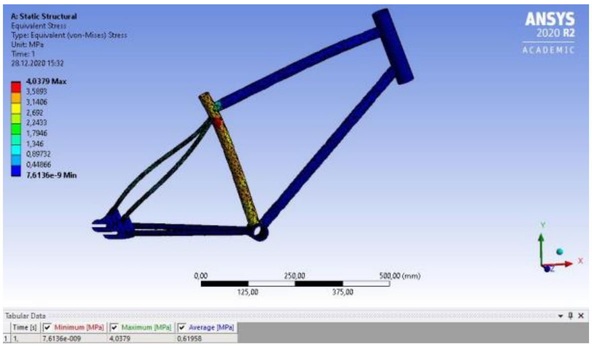

Fig. 8 Equaivalent stress results when 800 N is applied

The maximum equivalent stress is 4.0379 MPa. Equivalent stress results when 600 N force is applied from the seat part and 200 N force is applied from the handlebar part was seen in Fig. 9. The maximum equivalent stress is 3.0285 MPa.

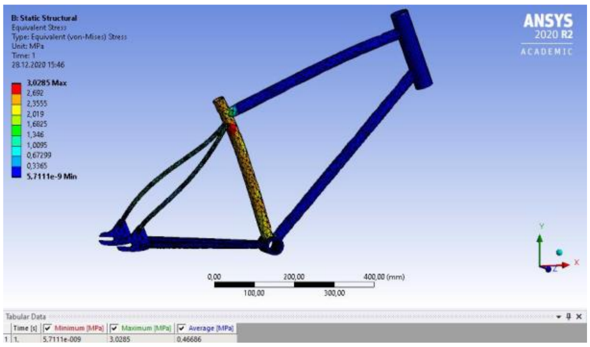

Fig. 9 Equaivalent stress results when 600 N is applied

IV. CONCLUSION

- The maximum total deformation is 0.020634 mm when 800 N force is applied from the seat.
- The maximum total deformation is 0.015475 mm when 600 N force is applied from the seat part and 200 N force is applied from the handlebar part.
- The maximum equivalent elastic strain is $5.7543x10^{-3}$ mm/mm when 800 N force is applied from the seat.
- The maximum equivalent elastic strain is $4.3157x10^{-3}$ mm/mm when 600 N force is applied from the seat part and 200 N force is applied from the handlebar part.
- The maximum equivalent stress is 4.0379 MPa when 800 N force is applied from the seat.
- The maximum equivalent stress is 3.0285 MPa when 600 N force is applied from the seat part and 200 N force is applied from the handlebar part.

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