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ANALYSIS THE STRENGTH OF MILD STEEL MATERIAL ON A HANDCYCLE BIKE FRAME

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Abstract. The frame is one of the most important parts in a series of constituents of a bicycle. The materials for making bicycle frames usually use tight and strong materials such as stainless steel, carbon and titanium. Mild steel is steel with low carbon, which is about 0.05-0.30%. After conducting a tensile test on the mild steel material used on the handcycle bicycle frame, the highest stress results were 1,093.87 N/mm² and the highest strain was 0.167%. For the results of stress analysis contained in the autodesk inverter, the von mesess results are obtained for men weighing 70 kg von mesess maximum 1400 mpa and women weighing 60 kg 1200 mpa. The maximum displacement generated for men weighing 70 kg 96.63 mm and women weighing 60 kg 82.83 mm. For the safety factor obtained based on the safety number from Dobrovolsky for static loads, the safety number is 1.25-2; dynamic load 2-3 shock load 3-5 while the safety rate that occurs in the load is 0.15 for men weighing 70 kg and 0.16 for women weighing 60 kg. So the handcycle bikes that we made are safe to ride because the results obtained are still below existing standards.

Keywords :Mild-steel, Handcycle frame, Tensile test, Stress analysis.

1. INTRODUCTION

In today's era, with the increasing need for transportation and causing a lot of pollution, bicycles are still the favorite mode of transportation because, apart from causing no air pollution, bicycles are also healthy for riders who use them [1]. However, not everyone can ride a bicycle, especially those who have physical limitations on their feet. Peoples with disabilities make up 2.45% of the population in Indonesia About 10.26% of them have had a limb defect. Handcycling is a combination of handbikes and bikes that has been used since around the year 1900 [2]. This is a form of alternative transport for those who have a missing limb [3]. Para-athletics handcycle has begun to be disputed as one of the paralympic sports since 2004 [4]. Hand movement is the most common method of propulsion, but alternatives do exist. Over the last two decades, several forms of handcycles have been developed. This mode of propulsion is used for people with limited mobility in hand therapy as well as in competition in the games, this year's Paralympic discipline. It uses a pedaling system that resembles a normal bike with “chain wheel sprockets”. A 3D analysis was made using a Vicon system (Vicon 370). A kinematic inverse model of seven degrees of freedom was deduced. The model input is the user's upper arm length, the user's shoulder joint location, and the user's crank size. The initial position (synchronous mode and a backrest angle close to 901), like the ‘‘downward’’ and the ‘‘backward’’ positions, seems to generate a lower joint range of motion than other position adjustments [5].

Functionally, the casual model handcycle is very comfortable to make daily. Even though the race model handcycle is not as comfortable as the casual model, we will create a racing handcycle model that is as comfortable as the casual model and can be made daily in addition to sports for people with disabilities. One of the main components in handcycle construction is the frame. This frame is a support for the entire bicycle construction. For this reason, the design of frame strength is very important. In this project, we use mild steel metal, which is one of the non-ferrous metals which is very much used in everyday life, both in large and small industries as well as in households [6]. A biomechanical analysis of handcycling performed 1-min exercise test on a handcycle at 70 revolutions per minute. This article proposes an original data collection and analysis methodology that gathers synchronized kinematics, kinetics, and electromyography. Such data, which most often appear complex, are easily summarized using this methodology [4]. Autodesk Inventor is a CAD (Computer Aided Design) program with solid three-dimensional modeling capabilities for the process of creating 3D prototype objects visually, simulating and drafting along with documentation of the data. In Inventor, a designer can make a 2D sketch of a product, model it into 3D to be followed by the process of making a visual prototype or even more complex simulation. Autodesk is a 3D design mechanical CAD software for creating 3D digital prototypes used in product design, visualization and simulation [7]. The frame is a very calculated component because it has the heaviest mass compared to other components and affects the efficiency of a bicycle [8].

Therefore, many tools for people with physical disabilities have been developed, one of which is a handcycle. This handcycle helps people with disabilities to do activities outside the room, such as sports, shopping, and other outdoor activities. Hand bikes often too. It is often also intended that handcycle be used to increase mobility for people who have physical disabilities or for people who do not have physical disabilities. In making a bicycle frame, the thing that must be considered is the selection of materials. Here we choose mild steel material as a material for making handcycle bicycle frames. In terms of design, the mechanical properties of a metal must be considered. Mechanical properties are defined as a measure of a material's ability to accept a force. Construction design is an important part of designing a vehicle, in this case a handcycle. The construction of the vehicle frame needs to be designed so that it can withstand loads and support the various components contained in the vehicle [9]. The design of this handcycle construction focuses on the design of vehicle construction on flat road conditions, without holes, and without inclines. The focus of the problem is on determination analysis the strength of the mild steel material for handcycle construction using tensile test and stress analysis with Autodesk Inventor Professional software.

2. METHODS

2.1. Stress Analysis Testing

Simulations were carried out using Autodesk Inventor software. The handcycle frame material is mild steel with a thickness of 4 mm and the simulation analysis carried out is a static load analysis or stress analysis, namely by making a 2D and 3D frame model or frame, verifying the material or filling in the material properties table (Table 1), determining the constrains, gravitational force, applied load, so that the results are considered for the construction of a planned tool or product [10].

Table 1. Material Properties Mild-Steel

Variable	Mild Steel	Value
General	Mass density	3.54303 g/cm^3
	Yield strength	219.94 MPa
	Ultimate tensile strength	430 MPa
Stress	Young's modulus	200 Gpa
	Poisson's ratio	0.29 ul
	Shear modulus	77.5 Gpa

Meshing is a structural analysis stage using the finite element method by breaking down the tested structural objects into finite elements which are connected to each other [11]. Analysis of the strength of the frame is carried out during static conditions, namely when the rider is riding the bicycle in a stationary position [12]. The analysis is carried out on the handcycle frames.

2.2. Tensile Test

Tensile testing of materials using Universal Testing Machine to determine the value of the maximum fracture stress and strain data [13]. This tensile test aims to determine the strength and level of elasticity of the mild steel material used on the bicycle frame. The tensile test uses the ASTM E-8 standard. The next test is testing the composition of the material to find out the composition of the material used on the handcycle bicycle frame.

$$\sigma = \frac{F}{A} \tag{1}$$

$$\varepsilon = \frac{\Delta L}{L_0} \tag{2}$$

Refer to the equation (1) and (2), that σ is the stress (N / mm2), F is the force (N) and A is the cross-sectional area (mm2). The strain (ε) is the difference between the length of the extension divided by the initial length (Lo) and the unit%.

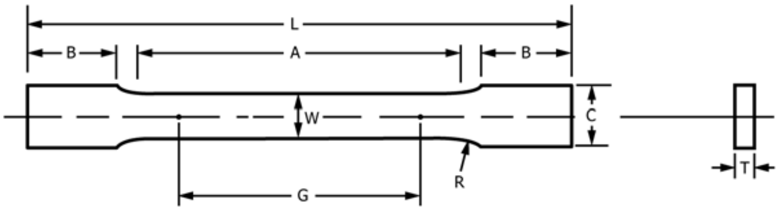

Figure 1. Tensile Test Specimen Standard ASTM E8/E 8M-08 [14]

Table 2. Specification Tensile Test Material [14]

Specification	Value
Specimen width (W)	12.5 mm
Gauge length (G)	92 + 0.1 mm
Specimen thickness (T)	10 mm
Fillet radius (R)	12.5 mm
Overall length (L)	200 mm
Clamping length by grips (B)	50 mm
The width of the clamped part of the grips (C)	20 mm

3. RESULTS AND DISCUSSION

3.1. Stress Analysis using Autodesk Inventor.

Stress analysis is one of the applications contained in the Autodesk Inventor which is useful for simulating material testing which is useful for reducing losses in the material processing process.

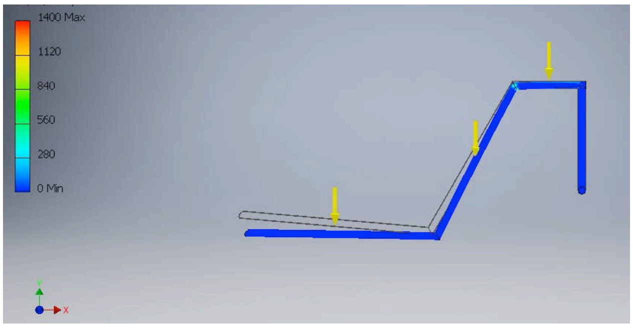

Figure 2. Von-Meses Male Rider Weighing 70 Kg

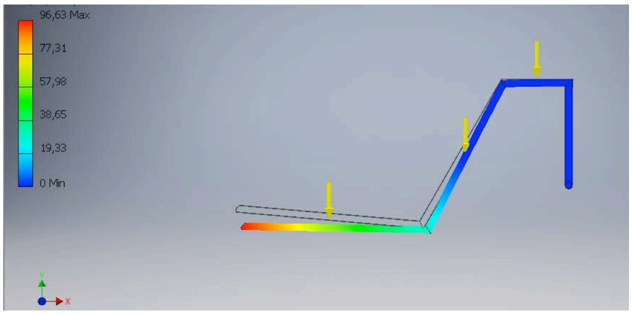

Figure 3. Displacement Male Weighing 70 Kg

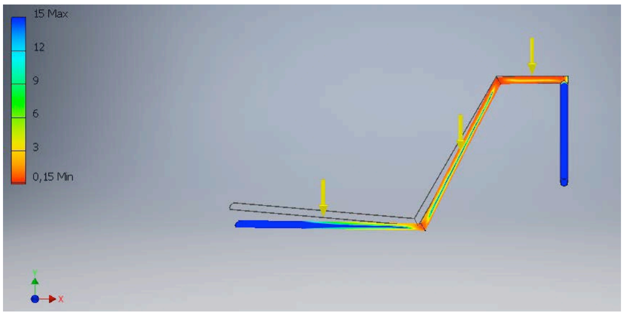

Figure 4. Safety Factor for Male Riders Weighing 70 Kg

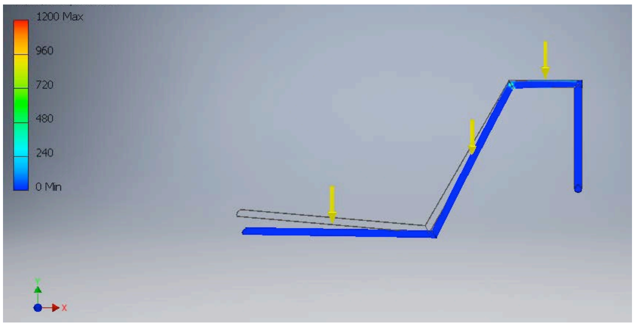

Figure 5. Von-Meses Female Rider Weighing 60 Kg

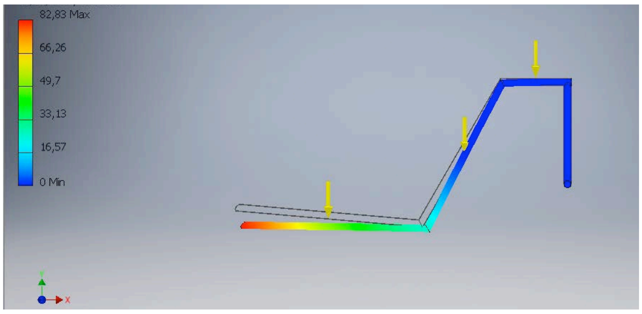

Figure 6. Displacement Female Weighing 60 Kg

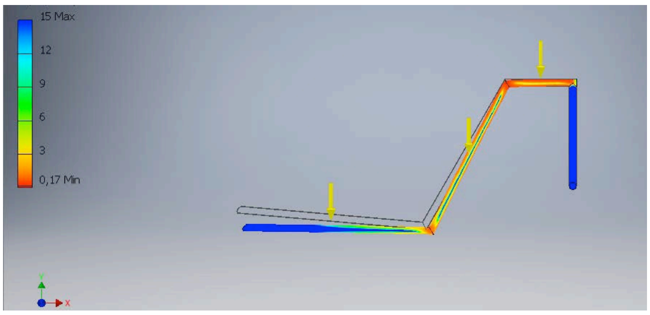

Figure 7. Safety Factor for Female Riders Weighing 60 Kg

Based on the results of stress analysis on the autodesk inventor with a driver's weight of 70kg and 60 kg, it was found that the frame that received the most force was in the lower frame where the driver's seat was place and the largest displacement occurred in the lower frame. The safety factor based on the safety numbers from Dobrovolsky for the static load the safety number is 1.25-2, dynamic load 2-3, shock load 3-5 [15], while the safety rate that occurs in the load is 0.15 for men weighing 70kg and 0.16 for women weighing 60 kg. The safety factor (SF) is an important parameter in determining a construction. Construction is said to be safe if the value of SF ≥ 1

Table 3. Analysis Results using Stress Analysis on Autodesk Inventor Software

Simulation result	Achievement limit	Value	
		Male	Female
Von Misses	Maximum	1400 MPa	1200 MPa
	Minimum	0 MPa	0 MPa
Displacement	Maximum	96.63 mm	82.83 mm
	Minimum	0 mm	0 mm
Safety Factor	Maximum	15 ul	15 ul
	Minimum	0.15 ul	0.17 ul

The simulation results for all frame designs obtained that the largest maximum displacement of 96.63 mm occurs on a frame with a male rider specification and a maximum displacement of 82.83 mm occurs on a frame with a female rider specification. The results of displacement for all bicycle frames can be seen that it does not cause changes to the structure so that the bicycle frame is considered able to withstand the load that occurs. The stress of one of the post-proccessors is the result of calculating the stress-strain relationship in the object model, the strain is obtained from the deformation experienced by the model. The equivalent voltage used in the Von-Mises method with varying driver weights

3.2. Tensile Test Result.

Tensile strength is the ability of a material to accept tensile loads. The test is carried out using a tensile testing machine, by clamping the sample firmly and the load is applied continuously until the sample breaks. The mechanical properties that are expected to be known are tensile strength, yield strength and tensile strength [16]. The results of the tensile test on the handcycle frame are obtained in the following table:

Table 4. The Result of Tensile Test

Specimen	Lo (mm)	Max. Load (KN)	Lf (mm)	ΔL (mm)	P max (KN)	ε(%)	σ(N/mm)
1	50	40	58.35	8.35	12.3	16.7	635.26
2	50	40	57.85	7.85	12.9	15.7	684.40
3	50	40	56.7	6.7	11.7	13.4	621.21

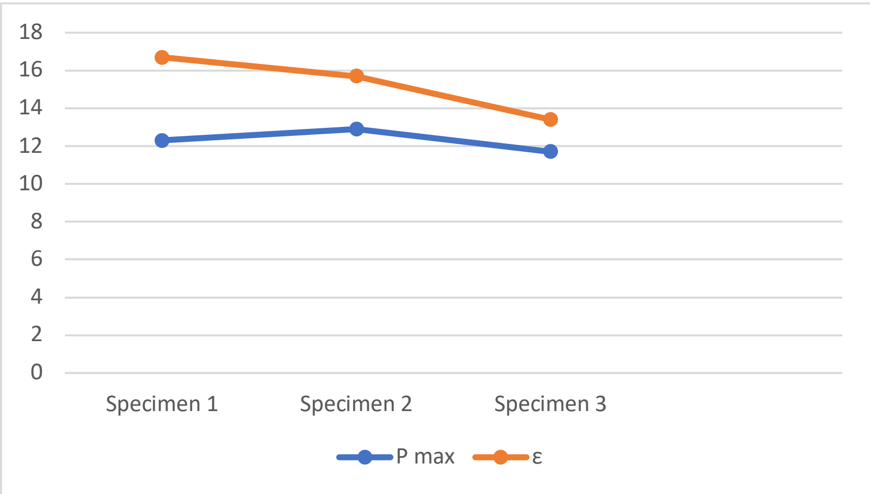

Figure 8. P max and Elongation value.

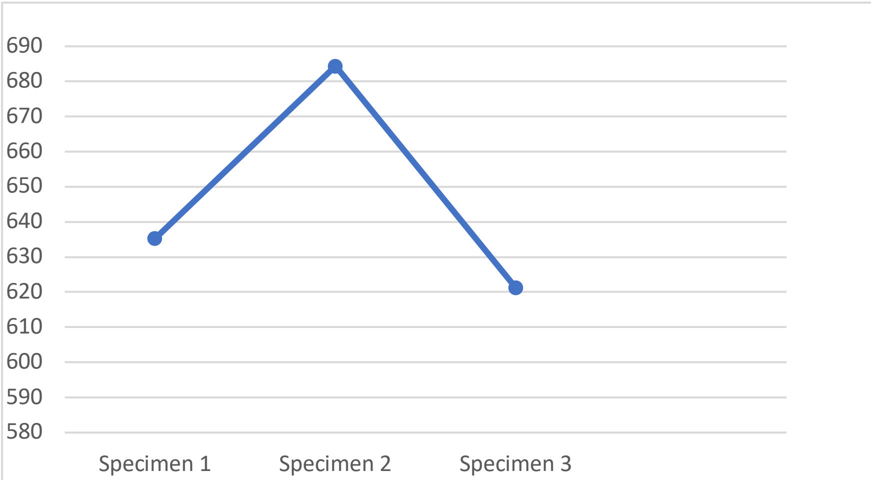

Figure 9. The maximum stress value of the tensile test

Based on the results of the tensile test research conducted by the author, it was found that the highest strain was obtained by specimen no.1 with a value of 16.7% and the lowest strain was obtained by specimen no.3 with a value of 13.4% while the average strain was 15.1%. For the greatest stress obtained by specimen no.2 with a value of 684.4 N/mm and the lowest stress obtained by specimen no.3 with a value of 621.218 N/mm while the average stress is 646.95 N/mm.

4. CONCLUSION

The conclusions from the research results are obtained as follows:

1) The results of the tensile test carried out on mild steel specimens, the highest strain results were 16.7% and the highest stress was 684.4 N / mm². Even though with the same specimen material, the results of the tensile test that came out were different between the 3 specimens tested. In my opinion this can happen because of several factors that occur when conducting testing such as mounting clasps on specimens with different positions, secondly, when cutting specimens, there is a difference in size between specimens.
2) After using stress analysis on the autodesk inventor, the results show that the largest displacement occurs on the part of the frame that supports the driver's seat and for the largest equivalent stress occurs at the connection between the seat back and the upper frame. The greater the load received affects the amount of displacement that occurs in the bicycle frame.
3) For the safety factor that is obtained based on the safety number from Dobrovolsky for static load, the safety number is 1.25-2; dynamic load 2 - 3; the shock load is 3-5, while the safety rate that occurs in this load is 0.15 for men weighing 70 kg and 0.16 for women weighing 60 kg. So the handcycle bikes that we made are safe to ride because the results obtained are still below existing standards.

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