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JSMT

http://publisher.uthm.edu.my/ojs/index.php/jsmt

e-ISSN : 2821-2835

Journal of Sustainable and Manufacturing in Transportation

Design and Analysis of Coconut Tree Climbing Bike Using Reverse Engineering Technique

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DOI: https://doi.org/10.30880/jsmt.2023.03.01.004
Received 28 February 2023; Accepted 4 July 2023; Available online 31 July 2023

Abstract: Coconut trees have hard-shelled fruits that grow as high as eight meters to 30m. It is one of the most important crops in the world. Coconut is considered as a healthy food and is used in a various foods and medicine. In this research, a coconut tress climbing bike was designed using reverse engineering technique based on available internet media resources. This research aims to solve the problem faced by most climbers who do not have the complete equipment and technology to climb coconut trees. Throughout the investigation and analysis, references based on Ganapathi Bhat's climbing bike design were studied to obtain the necessary information including load capacity, weight, price, size and estimated speed. Simulation and engineering analysis is made using SolidWorks software to evaluate specification. Based on the analysis and simulation result, this design is able to support and carry a user weighing 80kg to climb a coconut tree. The maximum speed of a coconut tree climbing bike is estimated at 0.6m/s. The coconut tree climbing bike design has a size of 717mm(L) x 539mm(W) x 415mm(H) and its estimated weight is 29.7kg. The selling price of this bike is estimated to be approximate RM 3500. This project is expected to provide information to the readers to obtain the coconut tree climbing bicycle technology that has already been in the small regional market in India. Hence, hopefully this research can help to introduce this technology in more detail to the Malaysia universities and citizens.

Keywords: Reversed engineering, coconut tree, climbing bike

1. Introduction

Coconut trees have hard-shelled fruits that grow as high as eight meters to 30m. Every coconut in an exceedingly bunch is at the identical stage of growth. Rock bottom bunches are the ripest and therefore the upper bunches are tender. Moreover, there's a visual variation of diameter along the peak of each tree. A bunch of coconuts from each tree has five to fifteen nuts. It may be harvested monthly from a coconut tree. To economize, farmers usuallyyield two to three bunches from each tree. This happens every harvest cycle, which ranges between 45-60, or 75-90 days. On average, 10-45 nuts are collected from each coconut tree at various maturity stages every harvest cycle [1]. In Malaysia, coconut is the fourth largest industrial crop behind oil palm, rubber, and rice with most of the plantations found in Sabah and Sarawak. According to a report by the Malaysian Agricultural Research and Development Institute (MARDI), the country is among the top 10 coconut producers in the world, although production fell between 2014 to 2016. The total acreage of coconut plantations had fallen from about 120,000 hectares in 2005 to 85,000 hectares [2]. There are mainly coconut trees-tall and dwarf. The tall grows up to 50-90 feet and starts bearing fruits after 7-10 years. Whereas, the dwarf grows up to 20-60 feet and begins fruiting after 4-5 years. Dwarf varieties have an average life spanof 40-50 years, while tall varieties live up to 90-100 years. Also, the tall varieties are cross-pollinated, and the dwarf ones are self-pollinated [3]. In India, one of the innovations that is extremely unique and useful for workers. As technology evolved, machines are widely used in projects to help others to improve their quality and

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production. In India, Ganapathi Bhat from Komale village of Mangaluru, Karnataka, completed his graduation in agriculture science and started practicing areca nut and coconut farming on his 14-acre ancestral land in 1991 [4]. Ganapathi and Sharvin worked for two more years and came up with a unique machine in 2020 that could carry a person weighing up to 80 kilos. The bike weighing 28 kilos came with multiple features and advantages. The main problem nowadays most human activities are either replaced by the employment of machines or other equipment. A coconut tree climber may bea machine that climb on a coconut palm without much human effort. Because of the constant cylindrical structure and single stem manually climbing on coconut is incredibly difficult. There aren't any branches for holding and supporting coconut trees like other trees. The recent times there is a shortage of coconut tree climbers, which has adversely affected the cutting of coconuts throughout the country. The objective of this project is to do a modelling and proper engineering analysis of the coconut tree climbing machine that has been invented and widely shared in internet media as a new technology in India by using reverse engineering techniques. This project is more focusing on the reverse engineering technique that basically based on available medium internet source. This report learns all the components and the process that are related. At the end of this project, it is hoped that this report will provide readers to gain the information to create the real product of the Coconut Tree Climbing Machine in Malaysia.

2. Literature Review

The literature review is the method of collecting information on all relevant subjects or requirement of the project. It is carried out by collecting data through patent analysis, books, journals and current products that would be comparable and used for product design. One of the new technologies that have been introduced in the market is the Coconut tree climbing bike. This coconut tree climbing bike comes in two varieties, each with the identical function of weight capacity but slightly different size. This 28kg bike can carry a person weighing up to 80 kilograms and comes with a variety of features and benefits. It has a two-stroke motor, pressure driven circles brakes and two-fold safeguards.This bike also climbs 90 trees in one liter of petrol. At the same time, it can save money. Besides, this bike also very easy to carry and it costs Rs59,000 (RM 3,278) with offering one-year warranty [4].

The bike has two tires and a roller that interlocks to grasp the tree's smooth trunk as shown in Figure 1 below. The user has a small seat with a petrol engine fitted below it. The bike has a handle to control the acceleration and braking. Other than that, this bike enables one to hold the trunk without using their hand. The hydraulic brakes serve as an additional safety feature. Moreover, while using this bike, a person takes about five to eight minutes to climb the coconut tree but the bike does itin seconds, without tiring the climber. Moreover, it is safe and can move around the tree. This reduces the effort and time drastically [4].

Fig. 1 - Overall view of climbing bike [5]

To get a clearer result, all points of view should be recorded and translated. The reader will have greater understanding and clarity of all the positions and diagrams with the help of this information. So, in Figure 2 below, show some examples of the product in other different kind of view. Every piece of machinery and equipment needed routine maintenance to function properly when needed as shown in Figure 2(A) and for Figure 2(B) shows the way of coconut tree climbing bike attached to the tree. Next in Figure 2(C) and 2(D) shows the bottom view and the side view of the bike during climbing a tree and the last Figure 2(E) show the proper way of seating at climbing bike.

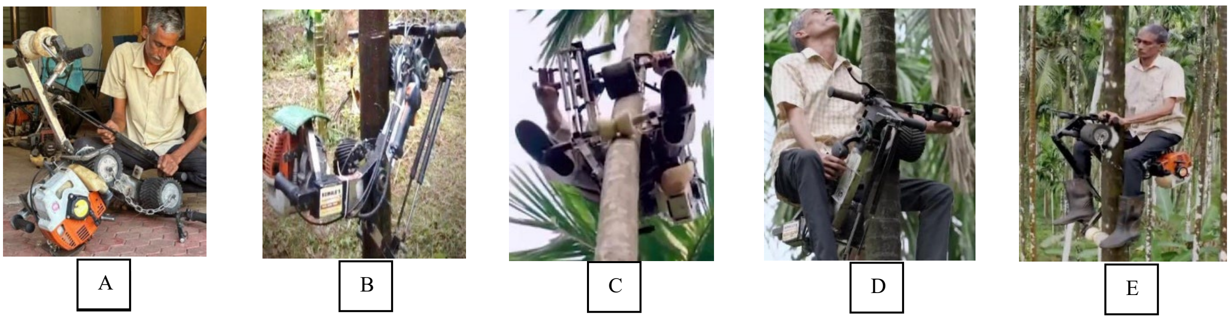


Fig. 2 - Different view of climbing bike [5]

3. Design Process

3.1 Methodology

By the application of reverse engineering (RE) aspect, this project is under reproduction of an existing component [6]. So, the RE process for this study begins with obtaining all of the product detail information that has been selected as a subject for the RE process. There are many different ways can be used to find the information that used in this project. For example, the reading material from internet, patent or technical articles. The full steps in order to complete this project is shown in the process flow on Figure 3. Based on the overall process flow of project, analysis of selected component coconut tree climbing bike photo was the second starting design process of this project. The next part was transferring all estimate dimension and size of climbing bike to sketching. The need for transferring can be crucial at many steps for a reversed engineering. After transferring all estimate dimension and size of climbing bike of sketching was being complete, the project was continuing with creating of 3D CAD Model design by SolidWorks. Lastly, the detail product specification was prepared and the result and discussion we recorded for product research.

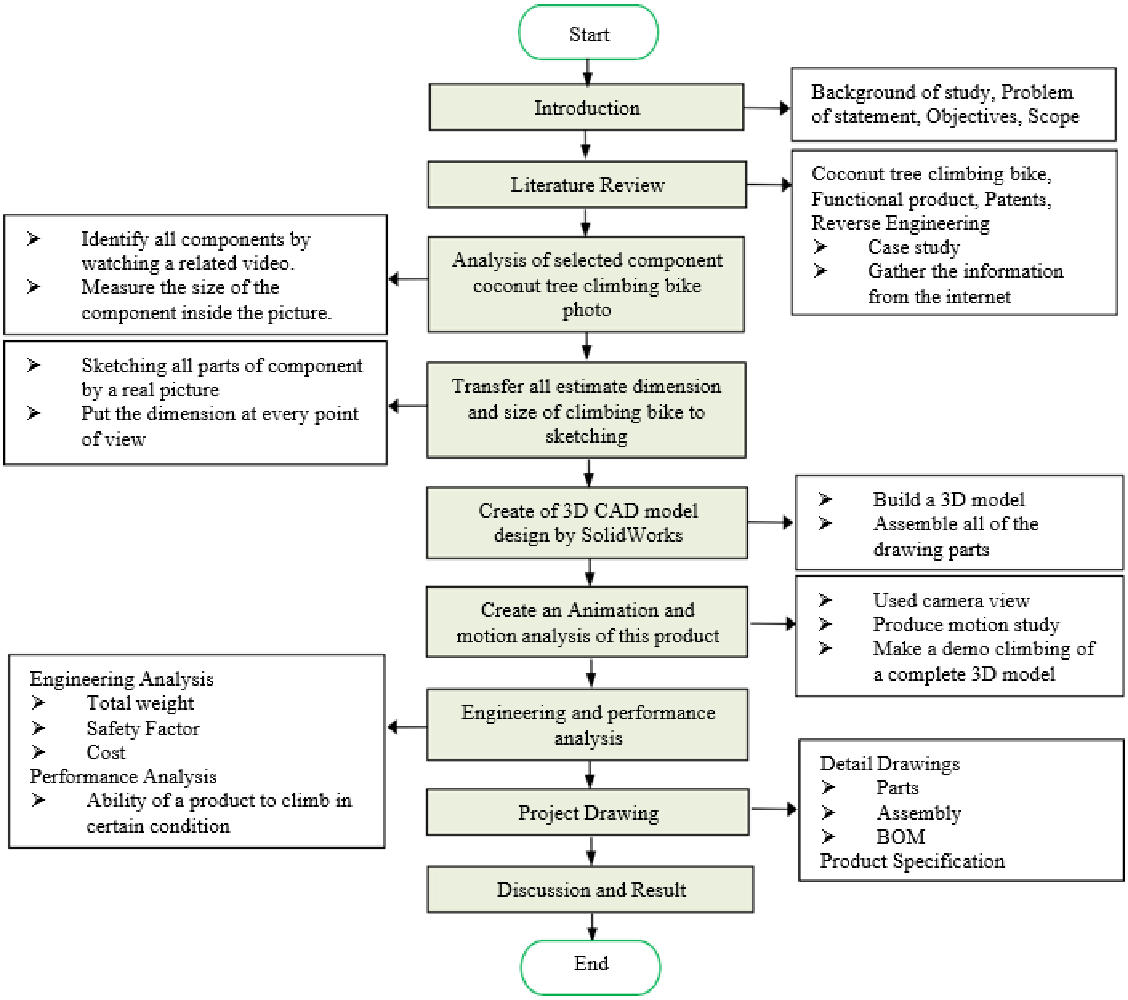


Fig. 3 - Overall process flow of the project

3.2 Analysis of Selected Component

This study began by collecting and searching for all the pictures and info related to climbing bikes. With the info obtained, each component can be compared and the climbing bike system can also be explained. Several techniques have been used in gathering the information such as watching the video on you tube and also by internet web [7]. The key components of the product are then identified from the image before being brought in for further investigation. Figure 4 show the main part of the climbing bike.

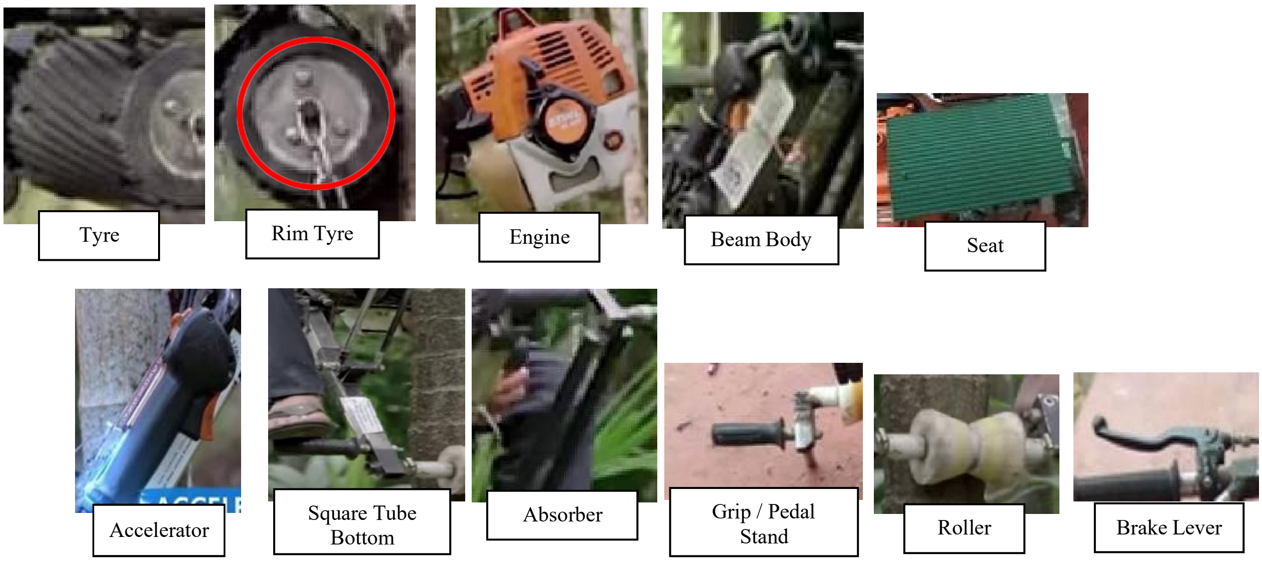
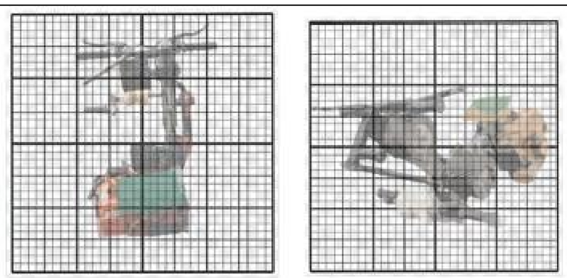
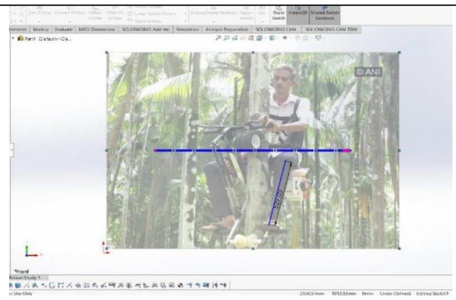


Fig. 4 - The main parts of climbing bike

3.3 Determination of Size

The graph method of measurement must be used as Table 1 (A). Putting a photo of the climbing bike on grid paper is one approach to measure the size of these components. The resulting box size aids in determining the project's total size. Other than that, the attachment of climbing bike photo in SolidWorks also being a part of the method in measurement the dimension as shown in Table 1 (B). The procedure is carried out using SolidWorks software, which use a logical approximate size such as a human foot. A line of the same dimension is calculated from the measured distance and used as a reference to begin estimating the size of the coconut tree climbing bike.

Table 1 - The method of measurement products

 (A)	 (B)

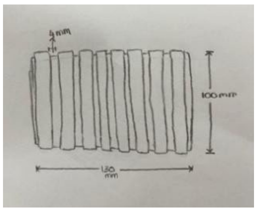
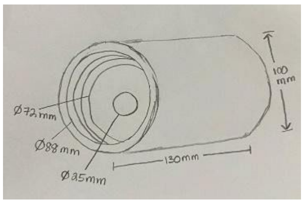
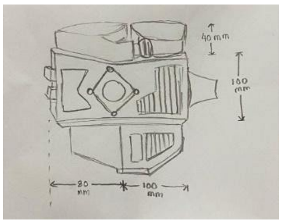
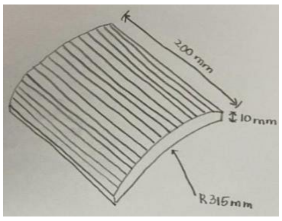
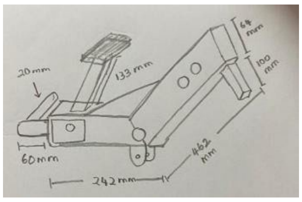
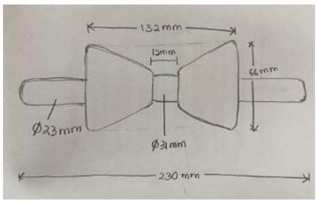
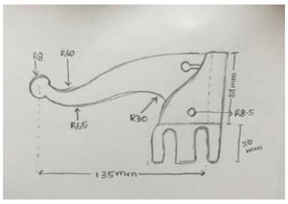
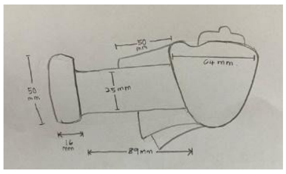
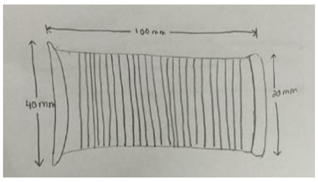
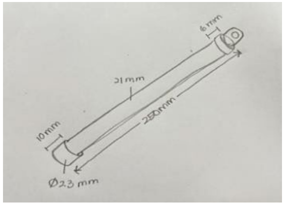
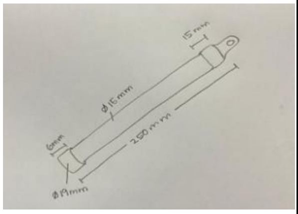
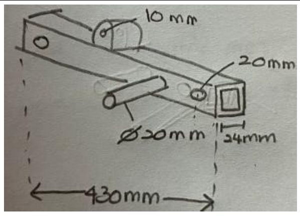
3.4 Estimation Dimension Sketching by Parts

Through information obtained from determination of size, then the measurement was recorded in a components sketches. Table 2 displays the sketching of all sections for the coconut tree climbing bike, which was measured using SolidWorks and graph paper.

3.5 Modelling

Then from the sketches, concept of the coconut tree climbing bike was drawn by using SolidWorks Software. All component that had been drawn were assembled to form the overall structure of coconut tree climbing bike. Figure 5 shows complete assembly of the coconut tree climbing bike

Table 2 - Sketching of the selected parts

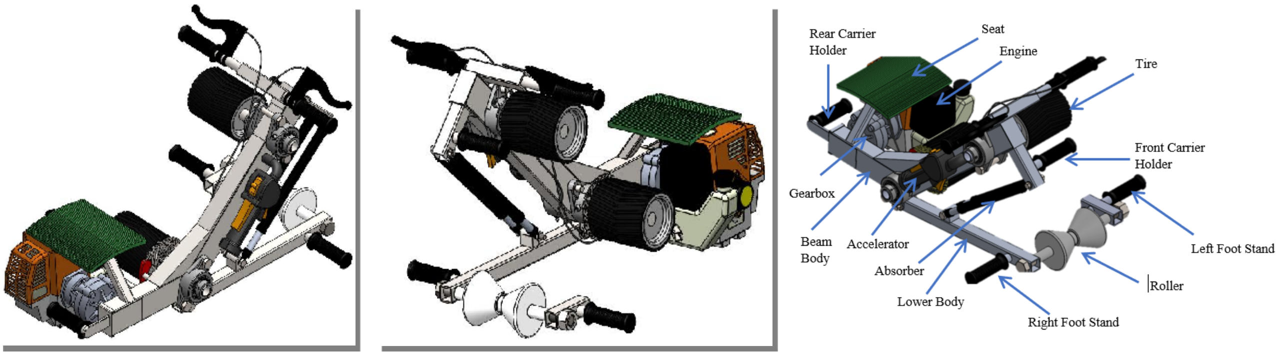


Fig. 5 - Full assembly of coconut tree climbing bike

3.6 Motion Study and Analysis

Gears, sprocket and chain are selected as the bike mechanism for the coconut tree climbing bike. When the accelerator is pressed, the force is transmitted through the gearbox that connected to the sprocket. The chain and sprocket were then transferred the power to the middle gear that rotates to the other gear to reversed the rotation direction. Finally, the rotation is transmitted to the shaft tire through the chain. Figure 6 shows the bike mechanism of coconut tree climbing bike while Figure 7 depicts the position of the tire shaft with sprocket that transmits power to the gear to rotate the tire through chain

Rotation speed is depended on the engine used. The selected engine is a two strokes engine where it working cycle is completed within one revolution. To ensure that the motionrotate continuously, the engine is attached to gearbox and shaft where the shaft is rotate only in one direction. Then the motion is transfer to the sprocket as shown in Figure 8 below.

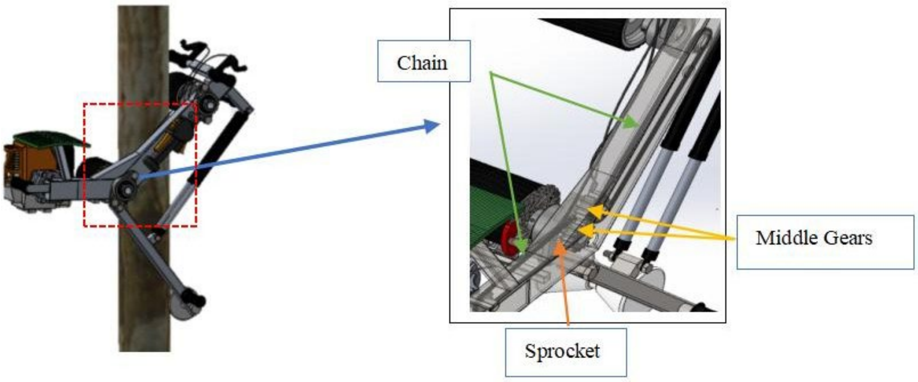


Fig. 6 - The bike mechanism of coconut tree climbing bike

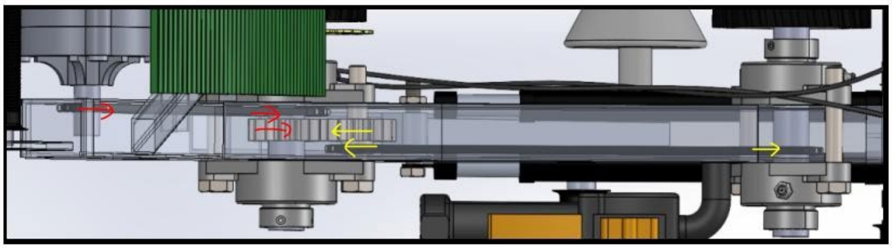


Fig. 7 - Rotation of gears and sprocket

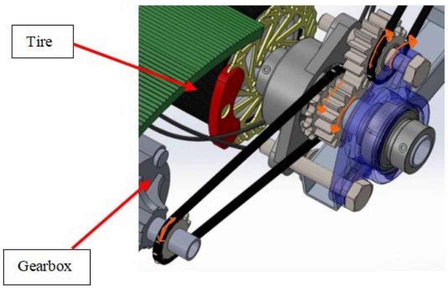
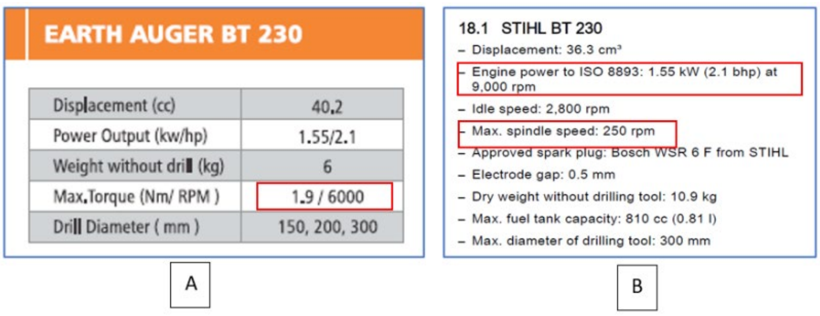


Fig. 8 - Motion transfer

3.7 Engineering and Performance Analysis

In this analysis, calculation of the related parameter such as torque, power, and limit capacity were calculated. Based on the calculation it helps to choose a suitable specification of component that can avoid the failure of the product and reduce the overall cost of the product. Power from the engine is transmitted to the tire via two set of sprockets and the kinetic energy produces by the engine require in order to operate the bike. Figure 9 below shows the detail of engine that this bike used.



EARTH AUGER BT 230

Displacement (cc)	40.2
Power Output (kw/hp)	1.55/2.1
Weight without drill (kg)	6
Max.Torque (Nm/ RPM)	1.9 / 6000
Drill Diameter (mm)	150, 200, 300

A

18.1 STIHL BT 230

- Displacement: 36.3 cm³
- Engine power to ISO 8893: 1.55 kW (2.1 bhp) at 9,000 rpm
- Idle speed: 2,800 rpm
- Max. spindle speed: 250 rpm
- Approved spark plug: Bosch WSR 6 F from STIHL
- Electrode gap: 0.5 mm
- Dry weight without drilling tool: 10.9 kg
- Max. fuel tank capacity: 810 cc (0.81 l)
- Max. diameter of drilling tool: 300 mm

B

Fig. 9 - The detail of engine [8]

Torque is the rotational force of an electric motor, whereas speed is the pace at which the motor can revolve. As mention before, all the information speed and torque at a maximum supplied by the engine is already known. So, to know the output speed and torque *(attach to a sprocket)*, the gear ratio is required to calculate the speed and torque produced by a certain sprocket or gear.

$$Gear\ ratio = \frac{(Speed\ of\ engine)}{(Maximum\ spindle\ speed)} = \frac{9000}{250} = 36$$

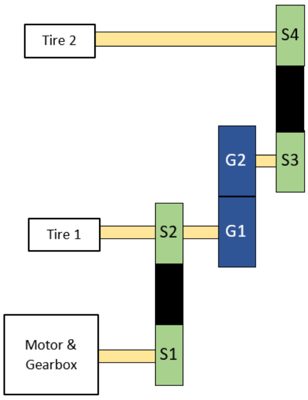
Speed of engine at maximum torque, N_m = 6000 rpm

$$n_{provided} = \frac{\mathrm{N_m}}{\mathrm{M_g}} = \frac{6000}{36} = 166.67\ rpm$$

Maximum output torque at gearbox, N_m

$$T_{max} = T_m \times M_g = 1.9 \times 36 = 68.4\ Nm$$

Figure 10 shows the gear set arrangement used in this bike and by that, the torque and speed produce at the tire can be determined.



Name of component	Symbol	No of teeth, N	Torque, (Nm)	Speed, (rpm)
Sprocket 1	S1	12	68.4	166.67
Sprocket 2	S2	18	102.6	111.11
Gear 1	G1	16	102.6	111.11
Gear 2	G2	16	102.6	111.11
Sprocket 3	S3	13	102.6	111.11
Sprocket 4	S4	13	102.6	111.11

Fig. 10 - Gear set arrangement

Total estimate weight from rider and bike is assumed to be applied at the product's centroid as a downward force as shown Figure 11 where user is targeted less than 80kg and the bike weight is 38kg (17kg for the engine and 19kg for the frame). Total torque required is the sum of torque required at tire 1 and tire 2.

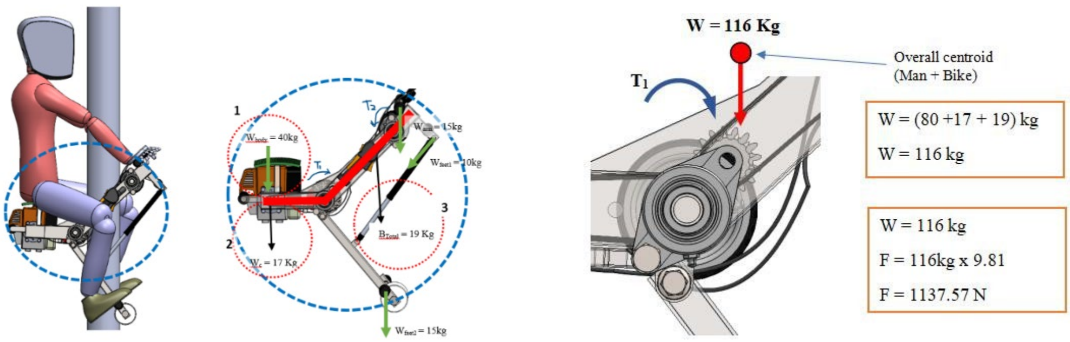


Fig. 11 - The weight at centroid

If the assumption that had been made is tire 1 and tire 2 required the same torque because it rotate with the same speed, so torque needed to move the bike to climb up the coconut tree at each tire1 and tire 2 is around 30 Nm as calculated below.

$$T = F\ x\ r_{tire} = 1137.57\ x\ 0.05 = 56.88\ Nm \approx 60\ Nm$$

As mentioned before, this bike was being design with the ability for handle 80 kg of weight user or load and the velocity is approximate 0.6 m/s (111.11 rpm at 50mm tire) at maximum torque. Hence, engine is a main part that change the power according to the load and the velocity supplied. Table 3 shown the data and graph for the power required by the engine in order to operate this bike with difference load/weight and speed.

Table 3 - The data of power required by engine

Product weight + Fuel Weight (kg) [*W1*]	Weight of user (kg) [*W2*]	Total Force (N) [*F*]	Speed (m/s) [*V*]	Power (W) [*P*]	Rotational Speed (rad/s)	Torque (Nm) [*T*]	RPM [*N*]
30 kg + 6 kg = 36 kg	60	941.76	0.50	570.88	10	47.088	95.492
			0.75	706.32	15		143.239
			1.00	941.76	20		190.986
			1.25	1177.20	25		238.732
	80	1137.96	0.50	568.98	10	56.898	95.492
			0.75	853.47	15		143.239
			1.00	1137.96	20		190.986
			1.25	1422.45	25		238.732
	100	1334.16	0.50	667.08	10	66.708	95.492
			0.75	1000.62	15		143.239
			1.00	1334.16	20		190.986
			1.25	1667.70	25		238.732

The engine power is limited to 1.55KW. It is obvious that if the total force is 1334.16N, which is carrying a 136kg of totalweight with the speed of 1.25m/s, the bike would fail to manage and support. Figure 12 shown the graph for the power required by the engine.

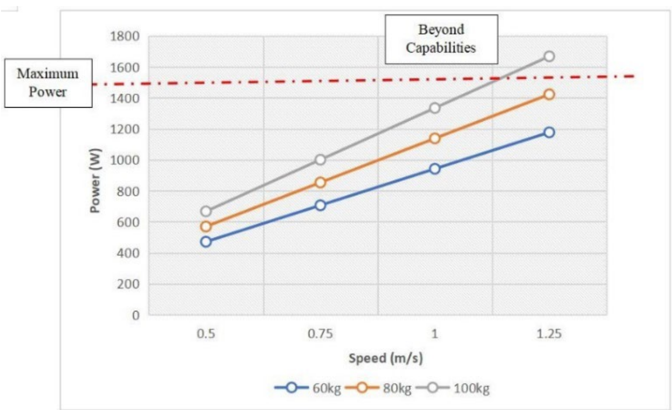


Fig. 12 - The graph of power against speed for the different load

For the structural analysis, there are two analyses have been done to the beam body of the bike. It was stress analysis and factor of safety. As the analysis run, the result that the beam body carried is stronger enough to handling the process but at the certain point,it shown the unsafe part that need to analyze again to improve the condition and safety. As per Figure 13 below, the maximum Von Mises stress is 307.6 MPa. It also stated that the material yield strength is 220.6MPa.

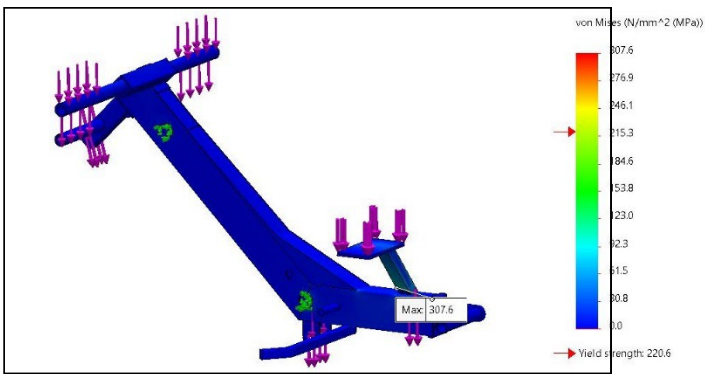


Fig. 13 - Von Mises analysis of beam body

In this instance, it is clear that some stresses in the model exceed the material yield strength while a factor of safety less than 1.0 indicates that the material has failed like the green region as shown in Figure 14. Since the min FOSis 0.7, it is not safe. So, the next analysis had been made for getting a good result and safe.

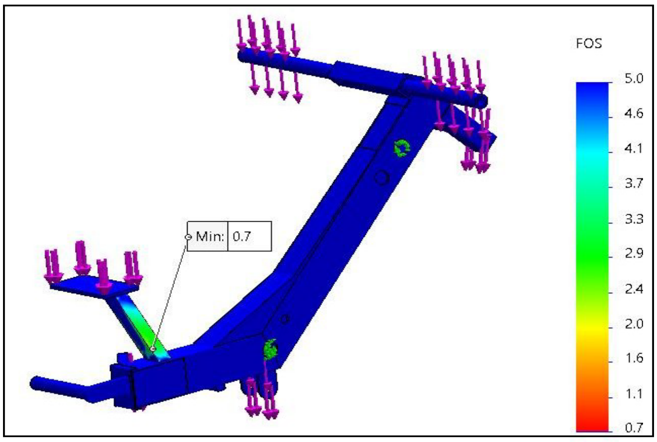


Fig. 14 - Factor of safety of beam body

The second trial of simulation had been done after improvement on critical part has been made. Size of green region part had been increased from the 25 mm to 34 mm so that the beam body are stronger and safe to support the force applied. As the result, the maximum Von Mises stress is 80.8 MPa. Since the maximum Von Mises stress is not exceeded the yield strength, the part will not break under the force load, 400N. In conclusion, the minimum factor of safety is 2.7 and it is safe to use. Figure 15 and Figure 16 shows the detail new result for beam body.

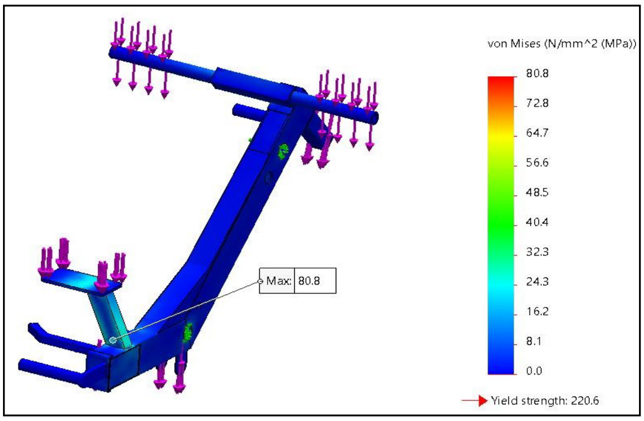


Fig. 15 - New result of Von Mises analysis

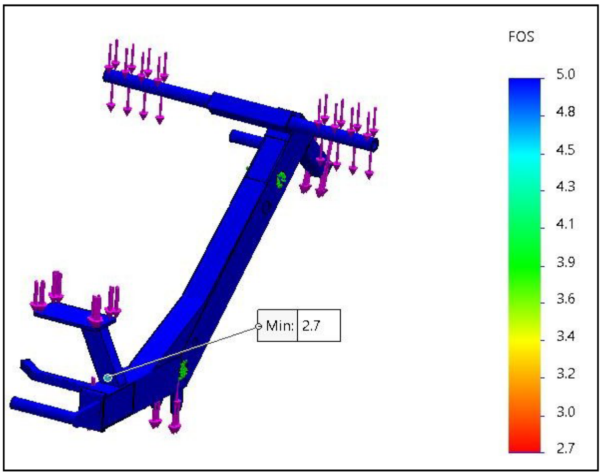


Fig. 16 - New result of factor of safety

From all the analysis that have been done, the final product design specification can be obtained. Table 4 show the Final Product Design Specification for customer information.

Table 4 - Final product design specification

Product Specification	Description
Engine Specification [8]	Power: 1.55 kW / 2.1 hp Weight: 6kg Maximum Torque: 1.9 Nm / 6000 rpm
Weight of bike	29.7 kg
Average Climbing Speed	0.6 m/s
Limit Capacity (Max rider weight)	80 kg
Dimension	717mm(L) x 539mm(W) x 415mm(H).

4. Conclusion

After completing this project, it can be concluded that this project is seen to have been successful by meeting all the objectives that have been set. The objective of this project has been achieved which is to design the coconut tree climbing bike using a reversed engineering technique. This project meant to solve the problem that being face by most of the climber that did not have a complete equipment and technology to climb the coconut tree. With the help of this bike, climber can easily climb the tree with minimize the risk. By using the SolidWorks software, each of the component was being simulated, analyse and come out with the detail project drawing. Based on the result from the analysis and simulation, this design is strong enough for support 80kg of weight user with the rotational speed of 238.7rpm. The overall dimension for this bike will be 717mm(L) x 539mm(W) x 415mm(H) and the total weight is 29.7kg. The selling price for this bike is estimated approximate RM 3532.15. This design is expected to be more efficient when compared to the traditional method or process and will be supported by the market.

Acknowledgement

The authors fully acknowledged the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for supporting this work.

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