[1.]Kolawole Adesola OLADEJO, [2.]Olawale Waheed AJAYI, [3.]Anthony Izuchnkwu ANANTI, [4.]Babafemi Olamide MALOMO, [5.]Dare Aderibigbe ADETAN

PERFORMANCE ANALYSIS OF A FOOT PEDAL OPERATED HACKSAW

[1-5.]Department of Mechanical Engineering, Obafemi Awolowo University, Ile–Ife, Osun State, 220282, NIGERIA

Abstract: Interrupted power is a major problem faced by most Nigerians, and it has a lot of effect on how machining operations are carried out. The method used to cut engineering materials in Nigeria involve the use of manual equipment, such as the hand operated hack saw, which is tedious to use and not that effective considering the amount of human effort put in during the cutting process. The electrically operated hacksaw is not a suitable option to use in most areas, because of the interrupted power supply, hence the need to develop an alternative means of cutting with an improved efficiency, this motivated the development of the pedal operated hacksaw described in this report. The objective of this is to develop a mechanical device that would be easily fabricated and maintained, and still be able to cut engineering materials with an efficiency higher than that of the hand operated hacksaw and will require only human effort to operate. The device uses the pedaling action from the operator and converts it to rotating motion of the crank through a system of chain drive and sprockets and then this motion is converted into the reciprocating motion of the hacksaw, which in turn is used to cut the required material. This report contains the design concept, principle of operation and the fabrication method used in developing the pedal powered hacksaw.
Keywords: hacksaw, foot pedal,crank system, flywheel, saw cutting

1. INTRODUCTION

Pedal power hacksaw is the transfer of energy from a human source through the use of a foot pedal and crank system. This technology is most commonly used for transportation and has been used to propel bicycles for over a hundred years. Pedal power is used to power agricultural and hand tool and even to generate electricity. Some applications include pedal powered laptops, pedal powered grinders and pedal powered water wells. *Abu, et al., (2019);Adekunle et al., (2020).,*this study was planned to design, model, fabricate and evaluate a pedal powered hacksaw using recycled bicycle. Standard design procedures were used to design and fabricate scrap bicycle, base, vice, hacksaw and link mechanism for the pedal powered hacksaw. Autodesk Inventor Professional software was used to model the fabricated machine to carry out its stress analysis. Performance evaluation of the pedal powered hacksaw was carried out on various engineering materials and the results were compared to hand-held hacksaw. It was established that the pedal powered hacksaw saved significant time in cutting and less tedious with fewer cutting strokes. The pedal powered hacksaw, a technological innovation, will save the environment from dumping of scrap bicycles and give the operator on-the-job benefit of a cycling exercise for physical and mental fitnesses.

Subash, et al, (2014); Dharwa, (2013);Oladejo, et al., (2024);pedal operated hacksaw machine which can be used for industrial applications and Household needs in which no specific input energy or power is needed. This project consists of a sprocket arrangement, the crank and slider mechanism, the chain drive. In the mechanism, chain drive is directly connected to the hacksaw for the processing of cutting the wooden blocks. *Sreejith, et al, (2014); Dharwa, (2013); Bahaley, et al, (2012); Linxu, et al, (2011);* performance of the *Pedal Driven Hacksaw*, was compared with Hand Hacksaw at different rpm. He had given better, accurate and faster cuts when compared with hand hacksaw at different rpm. He reduces the effort of cutting plywood to a great extent. When compared to the Power Saw the requires only manual power thereby reducing the utility bill considerably.

*Stephen, et al, (2015); Bamiro, (2014);*work can also serve as an exercising machine for fitness while cutting, it uses the principle of a slider crank mechanism which converts the rotary motion of the flywheel to the reciprocating motion of the hacksaw during pedaling. *Sahu, et al, (2016),* objective behind this machine to reduce both cutting time and energy in which no external power is required for cutting operation, it also available in affordable cost. The peddle power two-way hacksaw machine, which runs on human power, works on the principle of the conversion of rotational motion to oscillatory motion. This is a green project which saves our electricity need

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and can be easily applicable in day today's life. *Jagadeeswara and Hemachandra, (2017);Bahaley, et al, (2012);Oladejo, et al,. (2024);*concept is to cut wood work pieces by pedaling operation with less human effort and comparatively in less time. The principle involved in this equipment is the Rotary motion of pedaling operation will be converted to the Reciprocatory motion of the shaft attachment. This attachment shaft will be bolted with a hacksaw frame fixed with wood cutting blade. There will be a provision on the work table to measure the length of the work piece to be cut or retained.
*Sandeep, et al, (2017); Linxu, et al, (2011);Oriolowo, et al, (2019);*consists of eccentric disc mechanism and gear mechanism. For cutting operation the eccentric disc mechanism is used i.e., the pedal is directly connected to the hacksaw through processing of cutting the wooden blocks, metal bars, materials. For wet grinding and washing machine the bevel gear mechanism is used. The cam is used for striking operation. For cell phone components are charger. The objective of the modal is to use the conventional mechanical process which plays a vital role. Riding a cycle helps in main gives us its power to reduce our efforts and save our time some useful applications. *Rahul, (2017); Oladejo, et al, (2023);*used for cutting of wood, plywood, thin metals (<2mm), and pipes. The material can be cut without any external energy like fuel or current. As machine uses no electric power and fuel, this will help to maintain green environment.
The observations show that power required for pedaling is well below the capacity of an average healthy human being. This study is aimed at developing a hacksaw for the cutting of engineering materials for rural and urban areas where there is lack of constant power supply. Objectives:
- design a foot pedal operated hacksawing machine,
- fabricate the machine developed in (a) above, and
- evaluate the performance of the machine.

2. MATERIALS AND METHOD
The design of the pedal powered hacksaw, involved the initial stages of conceptual design and specifying the purpose of each part of the proposed model, which was then followed by the fabrication. After considering the simplicity of the design, availability of materials and ease of fabrication, the design concept was developed, the machine was fabricated and presented in this report using a Computer Aided Design software.

Design Consideration
When fabricating the pedal powered hacksaw, the following considerations were taken into account:
- The power stroke which is the backstroke should be more efficient than that of a normal manual hacksaw.
- The device should be suitable for local manufacturing capabilities and the machine should employ low-cost materials and manufacturing methods.
- It should be accessible and affordable by low-income groups, and should fulfill their basic need for mechanical power
- It should be simple to manufacture, operate, maintain and repair.
- It should be as multi-purpose as possible, in its ability to cut different engineering materials like PVC pipes, steel rods and steel pipes and is expected to be able to cut PVC pipes and steel pipes of *12mm-50mm* thickness.
- It should make use of locally available materials and skills in its construction. Standard steel pieces such as steel plates, iron rods and angle iron that are locally available should be used. Standard tools used in machine shop such as hack saw, files, punches, medium duty welder, drill press, small lathe and milling machine should be adequate to fabricate the parts needed for the construction of the pedal powered hacksaw machine.
- It should make use of standard bicycle parts wherever possible and power is intended to be supplied to the shaft by means of a chain from the bike's chain wheel to a ratcheted sprocket on the shaft.
- The vice used to hold the materials being cut should be strong enough to withstand the force and heat involved during the cutting process. In that regard a u-channel of would be used as the external frame of the vice and would be used as the internal frame of the vice.
- The pedal powered hacksaw machine should be comfortable for a man or woman of average height to pedal.

Fabrication

During the fabrication process, the pedal powered hacksaw fabrication started with the base stand, then the seat and handle bar for the operator was fabricated, the foot pedal the was welded in place for propulsion, two sprockets of different sizes were used and they were combined such that, they allows minimal effort from the operator and it delivers maximal torque for cutting engineering materials. The flywheel was added after the sprockets to help store energy during redundant strokes, it also include bearings for pedal propulsion and for the linkage between flywheel and crank, basically the pillow bearings and the ball bearings were used for more efficient energy transfer and reduced frictional losses, *Sahu, et al, (2016); Dharwa, (2013)*. The hacksaw fitted with High Speed Steel *(HSS)* serrated saw blade was fitted in the front section of the machine, with a connecting rod between the hack saw and the crank mechanism; for the purpose of holding the work piece in place, a form of holding vice was included in the fabrication and it was made from the locally available material to reduce overall cost.

Design Analysis

— Pitch Circle Diameter of the Sprocket

Therefore,

$$P = AB = 2AO\sin\left(\frac{\theta}{2}\right) = 2\cdot\frac{d}{2}\sin\left(\frac{\theta}{2}\right)$$

$$P = d\sin\left(\frac{\theta}{2}\right) \qquad (1)$$

Let d = pitch circle diameter of the sprocket
T = number of teeth on sprocket
P = pitch of the chain

Thus, the diameter, d, can be evaluated from: $d = P\,\mathrm{cosec}\left(\frac{\theta}{2}\right)$

$$\theta = \frac{360}{T} \qquad (2)$$

Substituting the value of θ from we get:

$$d = P\,\mathrm{cosec}\left(\frac{180}{T}\right) \qquad (3)$$

$$R = \frac{P}{2}\mathrm{cosec}\left(\frac{180}{T}\right)$$

Where, R = radius of the sprocket

— The Length of the Transmission Chain

From belt drive theory, Length of belt (L) is given as, Khurmi, (2000); Bamiro, (2014); Oladejo, et al., (2023):

$$L = \pi(R_1 + R_2) + 2x + \frac{(R_1 - R_2)^2}{x} \qquad (4)$$

where,

R_1	radius of the smaller sprocket
R_2	radius of the bigger sprocket
x	center distance between the sprockets

Comparing the parameters of the pulley of a belt drive with the sprocket of chain drive,

$$R_1 = \frac{P}{2}\mathrm{cosec}\left(\frac{180}{T_1}\right) \qquad (5)$$

$$R_2 = \frac{P}{2}\mathrm{cosec}\left(\frac{180}{T_2}\right) \qquad (6)$$

$$\pi(R_1 + R_2) = \frac{P}{2}(T_1 + T_2). \qquad (7)$$

From equation, R_1 and R_2 can be evaluated as:

$$R_1 = \frac{P(T_1 + T_2)}{2\pi} - R_2 \qquad (8)$$

$$R_2 = \frac{P(T_1 + T_2)}{2\pi} - R_1 \qquad (9)$$

$$m = \frac{\text{centre distance}}{\text{pitch}} = \frac{x}{P};$$

m = the number link on the chain

Replacing these parameters, gives;

$$L = P\left[\left(\frac{T_1 + T_2}{2}\right) + 2m + \left[\frac{\left(\mathrm{cosec}\left(\frac{180}{T_1}\right) - \mathrm{cosec}\left(\frac{180}{T_2}\right)\right)^2}{4m}\right]\right] \qquad (10)$$

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— **Speed of the drive**

Using the gear system of the sprocket,

$$N_1T_1 = T_2N_2. \tag{11}$$

where,

N = Number of revolutions made per minute by sprocket.

For a compound chain drive where d_1, d_2, d_3, d_4 are the pitch circle diameter of the sprockets, N_1, N_2, N_3, N_4 are the speed measured in revolution per minute and T_1, T_2, T_3, T_4, are the numbers of teeth on the sprockets. The relationship between the input and the output speed (N_1 and N_4) is given as:

$$\frac{\text{speed of last driven}}{\text{speed of first driver}} = \frac{\text{product of diameter of drivers}}{\text{product of diameter of drivens}}$$

$$\frac{N_4}{N_1} = \frac{d_1d_3}{d_2d_4} \tag{13}$$

Therefore,

$$\frac{\text{speed of last driven}}{\text{speed of first driver}} = \frac{\text{product of numbers of teeth of drivers}}{\text{product of numbers of teeth of drivens}}$$

$$\frac{N_4}{N_1} = \frac{T_1T_3}{T_2T_4} \tag{14}$$

— **Velocity of the sprocket, V**

V = wr(15)

where:

$$\text{w = angular velocity; w} = \frac{2\pi N}{60} \tag{16}$$

r = radius of pitch circle diameter of sprocket; $r = \frac{d}{2}$

d = pitch circle diameter of sprocket

Design Calculations

Calculating the Pitch circle diameter of sprocket using:

- Having a standard chain of 12.7 mm, the sprocket diameters are;
- Sprocket 1 has 44 teeth (44T)
- Therefore the pitch circle diameter "d" of sprocket 1 is;

From equation:

$$d = P \text{ cosec } \left(\frac{180}{T} \right)$$

$$d = 12.7 \text{ x cosec } \left(\frac{180}{44} \right)$$

$$d = 178.02 \text{ mm}$$

Also, sprocket 2 and 3 will both have 18 teeth (18T)

Therefore the pitch center diameter "d" of sprocket 2 is;

From equation:

$$d = P \text{ cosec } \left(\frac{180}{T} \right) = 12.7 \text{ x cosec } \left(\frac{180}{18} \right) = 73.14\text{mm}$$

Sprocket torque was decided to be traded for speed so that it would be suitable for cutting engineering materials faster, so a 18 teeth sprocket was used.

$$L = P\left[\left(\frac{T_1+T_2}{2}\right) + 2m + \left[\frac{\left(\text{cosec}\left(\frac{180}{T_1}\right) - \text{cosec}\left(\frac{180}{T_2}\right)\right)^2}{4m}\right]\right]$$

From equation:

$$m = \frac{\text{center diameter}}{\text{pitch}} = \frac{x}{p}$$

Approximate,center distance x = 610 mm

Therefore,

$$m = \frac{610}{12.7} = 48.03$$

Then, using equation:

$$L = P\left[\left(\frac{44+18}{2}\right) + 2(48.03) + \left[\frac{\left(\text{cosec}\left(\frac{180}{44}\right) - \text{cosec}\left(\frac{180}{18}\right)\right)^2}{4(48.03)}\right]\right] = 1{,}618 \text{ mm}$$

— **Speed transmitted to the hacksaw**

Since multiple chain drive system is being employed, then using equation:

$$\frac{\text{speed of last driven}}{\text{speed of first driver}} = \frac{\text{product of numbers of teeth of drivers}}{\text{product of numbers of teeth of drivens}}$$

From equation:

An average man produces a pedaling speed of 30-80 rpm, our calculation will be based on a speed of 30 rpm

$$\frac{N_2}{N_1} = \frac{T_1}{T_2}$$

$$N_2 = \frac{T_1}{T_2} \times N_1 = \frac{44}{18} \times 30 = 70 \text{ RPM}$$

To calculate the angular velocity of the driver, w_{in}

Using equation:

$$w_{in} = \frac{2\pi N_1}{60}$$

where,

w_{in} = angular velocity of the first sprocket, (driver), $w_{in} = \frac{2 \times \pi \times 30}{60} = 3.142$ rad/sec

To get the velocity (v) of the driver,

Standard radius size of a 44 teeth sprocket is 89.01 mm

$$V = w_{in} r = 3.142 \times 89.01 = 279.67 \text{ mm/s}$$

To calculate the angular velocity of the driven, w_{out}

$$w_{out} = \frac{2\pi N_2}{60}$$

where,

w_{out} = angular velocity of the last sprocket, (driven), $= \frac{2 \times \pi \times 70}{60} = 7.33$ rad/sec

To get the velocity, V of the driven,

From equation:

$$V = w_{out}\, r = 7.33 \times 36.57 = 268.06 \text{ mm/s}$$

— **Calculation for Flywheel and the crank velocity**

Distance from the center of the flywheel O to the point A in which the crank is to connected to the flywheel will be (R) = 74 mm. Since the flywheel will be connected to the same shaft as the driven sprocket, then they will have the same angular velocity,

$$w_{flywheel} = 7.33 \text{ rad/s}$$

$$V_{flywheel} = V_A = w_{flywheel} \times R = 7.33 \times 74 = V_A = 542.42 \text{ mm/s}$$

Since the crank was connected to the saw frame through a link which allowed relative movement between them. Then we assumed that the saw frame was another link. Since the length of the crank was 190 mm and that of the saw frame was 320 mm.

Then we calculated the velocity output of the crank:

- Crank AO was the distance between the center of the flywheel and the point at which the crank is connected to the flywheel;
- Crank AB is used to represent the crank that connects the flywheel to the saw frame; and
- Crank BC is used to represent the saw frame that is to be connected to the crank AB.

From:

$$\frac{V_A}{\sin 15.24} = \frac{V_B}{\sin 27.2} = \frac{V_{B/A}}{\sin 137.56}$$

Since, $V_A = 542.42\text{mm/s}$

$$V_B = 942.91\text{mm/s}$$

$$V_{B/A} = 1392\text{mm/s}$$

$$w_{B/A} = \frac{1392}{190} = 7.33 \text{ rad/s}$$

From:

$$\frac{V_B}{\sin 90} = \frac{V_C}{\sin 59.83} = \frac{V_{B/C}}{\sin 30.17}$$

Since, $V_B = 942.91\text{mm/s}$; $V_C = 815.18\text{mm/s}$; $V_{B/C} = 473.60\text{mm/s}$

$$w_{B/C} = \frac{473.60}{320} = 1.48 \text{ rad/s}$$

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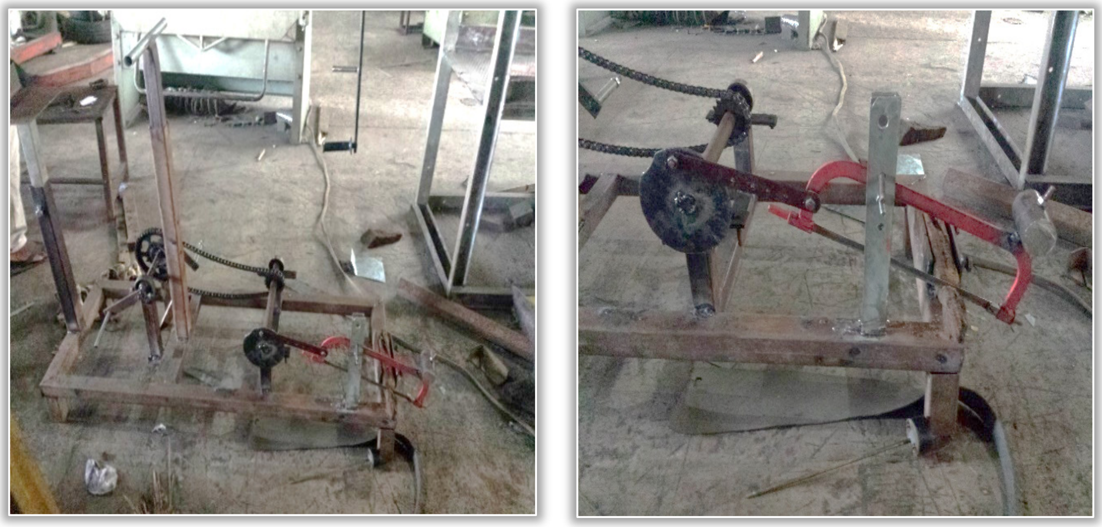
— **Other Dimensions:**

≡ Hacksaw frame: (L×W×H) = (400×25×10) mm
≡ Hacksaw blade (hole to hole): (L) = 400mm
≡ Connecting rod: (L×W×H) = (250×5×5) mm
≡ Circular disc = (200mm diameter)

Performance test on the machine

The weight on top of the hacksaw frame was taken as a variable factor in the design of the Foot Pedal Operated Hacksaw, the weight was varied to know the optimal weight for cutting different engineering materials.



(a) (b)

Figure 1:The finished Pedal Powered Hacksaw Machine.

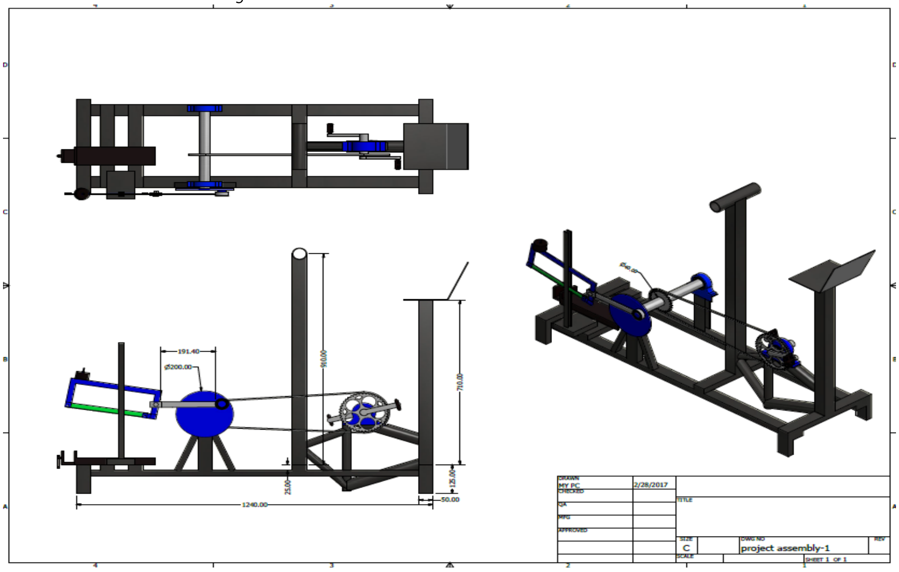


Figure 2: Orthographic and isometric views of the machine.

3. RESULTS AND DISCUSSION

(i) having completed the fabrication of the machine, the hacksaw was attached to the crank or rotating disc through the connecting rod. Two types of engineering materials were then held with the mechanical vice in turns.The machine was tested on two different materials (mild steel pipes, wood). The operator mounted on the bicycle and paddled the pedal.The weight variation has the most effect on the soft wood and is the most effect at the 1.4kg weight range. The Hacksaw was observed to be less effective on the mild steel pipes.

(ii) Since there is the problem of erratic power supply in the country, this pedal driven hacksaw is a reliable alternative to the conventional electric hacksaw when being used to cut soft wood, it has not proven that effective against mild steel. It has to be understood that in rural areas where there is problem of electricity shortage or no electricity, it is a very stressful and laborious task to perform machining operations. So the pedal driven machine, satisfies the need of rural people

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by giving them an alternative way of performing machining operations such as cutting, which cost-effective and eco-friendly. The machine designed has zero operating Cost.

Table 1: Data showing the relationship between the number of strokes and Revolution per minutes

Number of Strokes	Revolution per minute (Rpm)
40	20
60	30
80	40
100	50

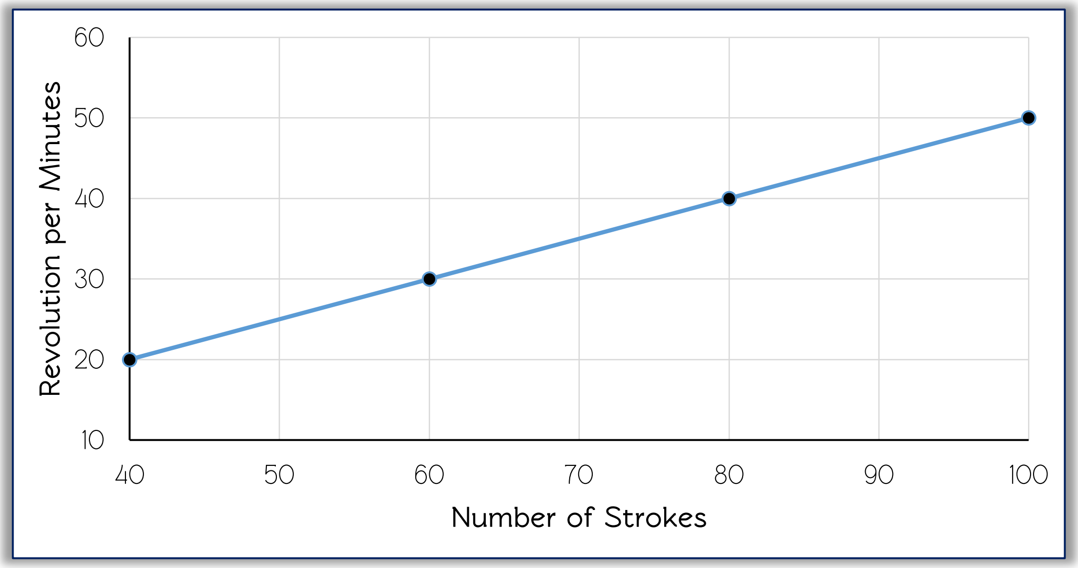

Figure 3: A graph showing the relationship between the number of stroke and speed.

Table 2: The relationship between weight attached on the hacksaw frame and cutting depth on a soft wood and mild steel, while pedaling at 30rpm (60 strokes) for a minute.

Weight in kg	Cutting depth (mm) Soft wood.	Cutting depth(mm) Mild Steel pipes
0.2	15	4
0.5	25	7
1.2	32	8
1.4	36	10

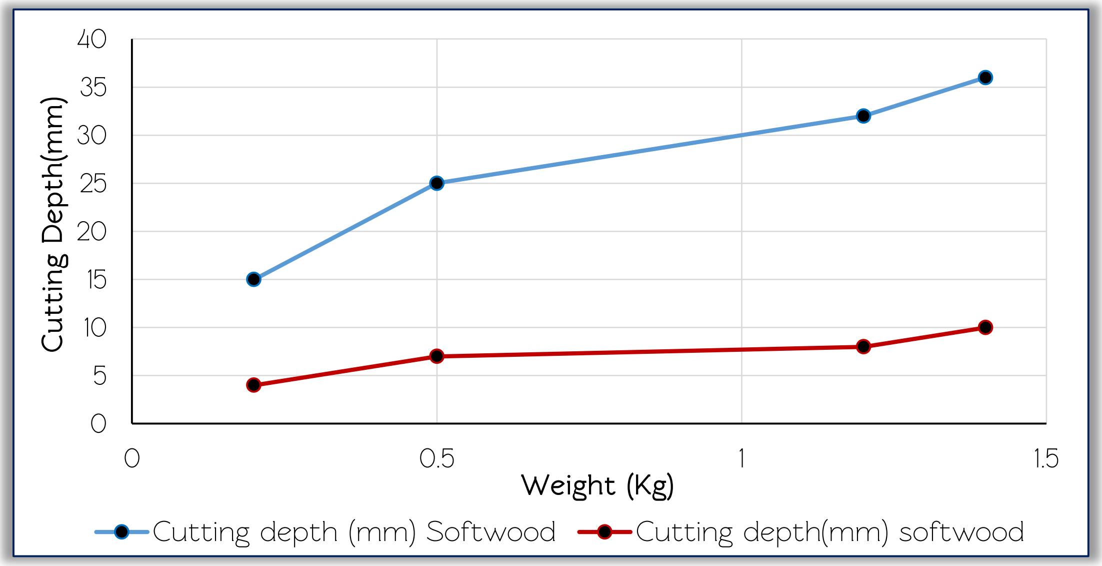

Figure 4: A graph showing the relationship between the Cutting Depth and Weight on the Hacksaw frame.

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4. CONCLUSION

A low cost and simple design pedal operated hacksaw machine is fabricated. This machine reduces the human effort needed to carry out a cutting operation. This machine would be useful in rural workshops in cutting soft woods and some other soft engineering materials like PVC, especially during power shutdown scenarios. This machine would be very useful in saving electrical power and performing work faster. The Pedal Operated hacksaw, has and advantage of using human effort as the fuel and it is quite portable enough for a machine that is pedal powered, since it can easily be carried to its point of operation when needed.

The machine has proven to be quite effective in the cutting of materials like soft wood, but a major drawback is the fact that It performs very poorly against materials like mild steel and iron. It has been observed that for this to be possible a larger saw would be needed and more bearings and bigger sprockets would be needed for this operation to be possible, which in turn raises the cost of fabrication and makes it more bulky, this definitely defies the purpose for which the machine was built, i.e. to be cheap and portable.

The Performance Evaluation shows that at 30rpm a cutting depth of 36mm can be obtained at 60 strokes for softwood, while a cutting depth of 10mm can be obtained for mild steel under the same condition, this goes to prove that for mild steel the effort put into the machine operation is less than the obtained output. The Machine has been observed to give a better, accurate and faster cuts when compared with the hand Hacksaw at different rpm. Part of the aim of the experimental observation of the machine was to determine the appropriate weight to be used on top of the hack saw for maximum cutting effect, in relation to that, the weight range of 1.2 to 1.4kg has been found to be the effective weight range, and all tests were done at around 30rpm (under manual observation).We hope through our research and analysis we have designed or at least helped clarify the design concept of a pedal-powered hacksaw.

Hopefully in the near future, such helpful tools become a common addition to villages or remote areas. The knowledge of fabrication processes, mechanics of machines, and ergonomics were employed in the construction of this project, and a detailed report of this project was developed.

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