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Pedal Operated Hacksaw Machine for PVC Pipes and Wood

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ABSTRACT: Pedal operated hacksaw machine which can be used for small-scale industrial applications and Household needs in which no specific input energy or power is needed in both rural and urban area where there is no adequate supply of electricity was developed, the machine consists of a sprocket arrangement, the crank and slider mechanism, the chain drive etc. In the mechanism, chain drive is directly connected to the hacksaw for cutting of woods and PVC pipes. The material selection was carried out which is mainly mild steel and rectangular iron pipes to carry the weight of the machine. Performance evaluation was carried out on the machine to ascertain its effectiveness. A Polyvinylchloride (PVC) pipe of diameter 30 mm and a thickness of 3 mm were cut at various trials; the depth of cut and time used in cutting the pipe were recorded. Time taken to achieve several cutting depths on a wood of thickness 45 mm were recorded which shown high efficiency of the machine developed. The cost of production of the machine was ₦27,784 Naira and efficiency of 50% was achieved.

KEYWORDS: Hacksaw,Poly Vinyl Chloride (PVC) pipe, horsepower, pedal, sprocket.

I. INTRODUCTION

Pedal power is the transfer of energy from human source through the use of a foot pedal and crank system. This technology is commonly used for transportation and has been used to propel bicycles for over hundred years. Less commonly, pedal power is used to power agricultural and hand tools and even to generate electricity. Some applications include, pedal power washing machine, pedal powered grinders and pedal powered water wells. Some third world development projects currently transform used bicycles into pedal powered tools for sustainable development [1]. Pedal power is the transfer of energy from human source through the use of a foot pedal and crank system. This technology is commonly used for transportation and has been used to propel bicycles for over hundred years. Less commonly, pedal power is used to power agricultural and hand tools and even to generate electricity. Some applications include, pedal power washing machine, pedal powered grinders and pedal powered water wells.

Some third world development projects currently transform used bicycles into pedal powered tools for sustainable development [1]. This project concentrates on pedal powered hacksaw machining. An individual can generate four times more power (1/4 HP) by pedalling than by hand-cranking. At the rate of ¼ HP, continuous pedalling can be served for only short periods, approximately 10 minutes, however, pedalling at half this power (1/8 HP) can be sustained for close to 60 minutes but power capability depends upon age. Many devices can be run right away with mechanical energy. A saw is a tool that uses a hard blade or wire with an abrasive edge to cut through softer materials. The cutting edge of a saw is either a serrated blade or an abrasive. A saw may be worked by hand, or powered by steam, water, electric or other power. An abrasive saw uses an abrasive disc or band for cutting, rather than a serrated blade. A serrated blade is a type of blade used on saws, some knives or scissors. It is also known as dentate, saw tooth or toothed blade.

The principle of pedal power hacksaw is to change circulatory motion or cyclic motion into translational motion with the help of a metal rod. This is mainly used for cutting metals and plastics. It is a manually pedal operated system. A hacksaw is a fine-tooth saw with a blade under tension in a frame, used for cutting materials such as metal or plastics. Hand-held hacksaw consists of a metal arch with a handle, usually a pistol grip, with pins for

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attaching a narrow disposable blade. A screw or other mechanism is used to put the thin blade under tension. It is used to cut metals and Polyvinylchloride (PVC) pipes. Blades of hacksaw are measured in tooth per Inch (TPI). Different TPI is needed for different jobs of cutting.

II. RELATED WORKS

The problem of cutting-off material to size is common to practically every industry. Often, sawing is the first operation carried out on bar stock. Therefore, it is surprising that so little work has been done to understand the problems of this common operation.

The system in as proposed in [1] designed and constructed apedal 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 crank and slider mechanism. In the mechanism, pedal is directly connected to the hacksaw through crank and slider mechanism for the processing of cutting the wooden blocks, metal bars and materials. The objective of the modal is using the conventional mechanical process which plays a vital role. The main aim is to reduce the human effort for machining various materials such as PVC pipes, wooden blocks, steel, etc. The power hacksaw machine, which runs on human power works on the principle of the conversion of rotational motion to oscillatory motion.

However, available literatures on pedal operated hacksaw revealed that the designers of pedal operated hacksaw did not put to consideration the height and comfort of the operator. Consequently, a short person may find it difficult to drive the pedal operated hacksaw compare to taller person. It is based on this limitation the project under review deem it fit to address the issue by designing an ergonomically friendly pedal operated hacksaw machine with adjustable seat and handle arrangement to suit any intending operator of the machine for balance and comfort.

Another system, [2], also designed a pedal system to power a low-cost washing machine made out of readily available materials. The machine generates power through human pedalling to drive the rotary motion of the installed drum. Its innovation lies in its simple design, use of inexpensive parts, very low repairing and maintenance cost, affordability to each member of the society and it does not affect the environment. Intends to directly address the problems faced in washing clothes, and thus have developed a new design for easy effort in washing, rinsing and drying clothes. PPWM is a completely new concept, which in its one laundry cycle does washing, rinsing and drying of clothes similar to that of an automatic washing machine available in the market.

PEDAL OPERATED WASHING MACHINE.

A similar system in [3] designed a system to generate electricity by pedalling a regular gymnasium bicycle. The system converts kinetic energy to electrical energy through an alternator and taps it using a battery.

The system in [4] provided an alternative means of powering a washing machine, using a simple pedal system. The system consisting of a pulley system for increasing its speed has an efficiency of 84.98% and was costed to be 123.80USD.

The system developed in [5] focuses on fabrication of a pedal powered hacksaw for cutting PVC materials. The fabricated system was tested to be efficient with an ideal mechanical advantage of 0.5, velocity ratio of 0.65, power output of 5.72KW, and an efficiency 76.9%.

A similar system developed in [6] implemented a pedal powered hacksaw for specifically light duty operations of plywood, soft bamboo, and iron rod. The implemented system uses the crank and slider mechanism and results showed that a cutting depth of approximately 10mm could be achieved with 60 cutting strokes for around 60rpm.

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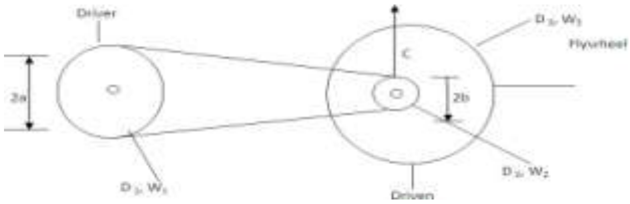
III. METHODOLOGY

Design Data

Human energy expended say 70Kg (150 1b) person, for cycling at 15Km/hr (16- 24Km/h)=1.62KJ/Kg, the average cycling speed = 15.5km/h. The cycling speed in r. p. m = 120 rpm



BLOCK DIAGRAM REPRESENTATION OF SPEED RATIO OF THE SYSTEM.

Ideal Mechanical Advantage (IMA)

IMA = $D_{Driven} = W_{IN}\, D_{Driver} W_{Out}$

where:

D_{Driven} = Diameter of driven sprocket = D_2

D_{Driver} = Diameter of driver sprocket = D_1

W_{IN} = Input rotational velocity of wheel = W_1

W_{out} = Output rotational velocity of wheel = W_2

$IMA_{Total} = IMA_1$

Also,

$IMA_{Total} = \frac{W_{IN}}{W_{Out}}$

So, using the data below:

D_1 = 170mm

D_2 = 80mm

Eccentric disc diameter, D_3 =220 mm

No. of Teeth of $D_1 = T_{n1}$ =38

No. of Teeth of $D_2 = T_{n2}$ = 14

$IMA_1 \frac{D_2}{D_1} = \frac{14}{38} = 0.4 = IMA_{Total}$ which is less than 1

So, using N_{IN} = 120 RPM (Faruk Yildiz, 2009)

$W_{IN} = \frac{2\pi N_{in}}{60}$

$= \frac{02\ x\ 3.142\ x\ 120}{60} = 12.568$rad/s

$IMA_{Total} = \frac{W_{IN}}{W_{Out}}$

$W_{Out} = \frac{W_{IN}}{IMA_{Total}} = \frac{12.568}{0.36} = 34.9$rad/s

The power output, $P = F_c \times V$

where:

Fc = centrifugal force on the eccentric disc

V = Linear Velocity

But V = W_{out} r

Where r = radius of eccentric disc

So, using the weight of an average man say 60-75kg and 0.5kg mass of eccentric disc,

But eccentric disc radius, r = $\frac{D_3}{2 \times 1000} = \frac{220}{2000}$

= 0.11m

V = 34.9 × 0.11

= 3.8 m/s

Fc = mrw^2

=0.5 × 0.11 ×34.92

= 3.84 N

= 0.0038 kN

:. The power, P = FC x V = 3.84 × 3.8
= 14.59 W
= 0.01459 kW

:. The Torque, T = FC x r = 14.59 x 3.8
= 55.4 Nm
= 0.0554 kNm

Design of Eccentric Disc

The crank length is given by the equation L = 2r
Where r = radius of the disc
L = 2 × 110 = 220mm

Velocity Ratio

V.R. $=\frac{effort\ \ distance}{load\ \ distance} = \frac{length\ of\ crank\ \ pedal}{hacksaw\ \ cutting\ \ stroke}$

$\frac{80}{100} = 0.8$

Sprocket Design

The number of teeth on each sprocket can be determined based on the transmission ratio between the bigger and the smaller sprocket/pinion given by;

$i = \frac{Z_2}{Z_1}$

where:

i = transmission ratio,
Z_1 = number of teeth on the driven sprocket or pinion
Z_2 = number of teeth on driving sprocket-bigger sprocket.

$$i = \frac{44}{18} = 2.4$$

Chain Design

$L_{CD} = \left[\frac{2a}{p} + \frac{Z_1 + Z_2}{2} + \left(\frac{Z_2 + Z_1}{2\pi}\right)^2 \frac{p}{a}\right] p$

Where L_{CD} Is the length of chain, a is the centre distance between axes of bigger sprocket and pinion while p is the chain pitch

$L_{CD} = \left[\frac{2 \times 200}{2} + \frac{44 + 18}{2} + \left(\frac{18 + 44}{2 \times 3.142}\right)^2 \frac{2}{200}\right] 2$
= 460mm

Design of Frame

Electric arc welding will be used to obtain a permanent joint. The effective weld force is given by;

$W_c = \frac{\sigma TL}{2S_{cf}}$

Where;
W_c =The effective weld force
σ = Allowable tensile stress for welded metal (N/m^2)
L = length of weld (m)
S_{cf} = Stress concentration factor
T = thickness of weld (m)

$W_c = \frac{32 \times (6 \times 10^{-3})(4 \times 10^{-3})}{2 \times 2} = 0.000192N$

Design of Compressive Load or Dead Load on the Hacksaw Frame

Density of cast iron; $\rho = 7207\ kg/m^3$
Volume of solid cylinder $v = \pi \times r^2 \times l$
$v = 3.142 \times 0.05^2 \times 0.04$
$v = 0.0003142\ m^3 = 0.3142\ \ mm^3$
The mass of the solid cylinder can be obtained as;
Mass, $m = \rho v\ \ kg$
$m = 7207 \times 0.0003142 = 2.26\ kg$

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Therefore, the dead load or self-weight W is given as;

$$W = mg$$

$$W = 2.26 \times 9.81 = 22.17\ N$$

Parts Assembly

The assembly is the putting together of all the fabricated parts to form the complete pedal operated hacksaw machine. This was done by putting in place few methods of joining. The assembly of the pedal operated hacksaw machine involves a lot of welding operations. After the component parts where constructed, the parts where coupled together to form the complete machine. The components where coupled as follows; the pedal crank setup was mounted by the means of electric arc welding, in a similar manner, the stand setup was fixed to the base frame and properly supported. Furthermore, the slider crank mechanism was then fixed and connected to the hacksaw frame via the sliding rod, and finally, the vice was mounted on the base frame.

The whole assembled components were mounted on the base frame and welded for stability. The handle of the hacksaw machine was erected to give comfort and balance to the operator without fear of falling off the machine. This was thoroughly done with all precautions observed to achieve certain reliability of the machine.

Finishing Processes

The finishing processes employed are grinding, cleaning, filling and lastly coating. Grinding was done to achieve good smoothening the surfaces. The unwanted dirt's and other foreign materials were removed by cleaning while the shape edges were removed by filling.

Finally, the painting gave the machine the desired aesthetic and corrosion resistance.

IV. RESULTS

A PVC pipe of diameter 30 mm and a thickness of 3mm was cut at various trials. The cutting depth and time taken in cutting the pipe completely were recorded as shown in Table 1. While the time taken to achieve several cutting depths on a wood of thickness 45 mm were recorded as shown below

Cutting Depth and Time Taken to Cut 30 mm PVC Pipe

Parameter	No Trial	Trial 1	Trial 2	Trial 3	Trial 4
Cutting depth (mm)	0	16	22	26	30
Time (second)	0	4.0	6.0	8.0	10

Cutting Depth and Time Taken to Cut 30 mm PVC Pipe

Parameter	No Trial	Trial 1	Trial 2	Trial 3	Trial 4
Cutting depth (mm)	0	12	18	26	40
Time (second)	0	4.0	6.0	8.0	10

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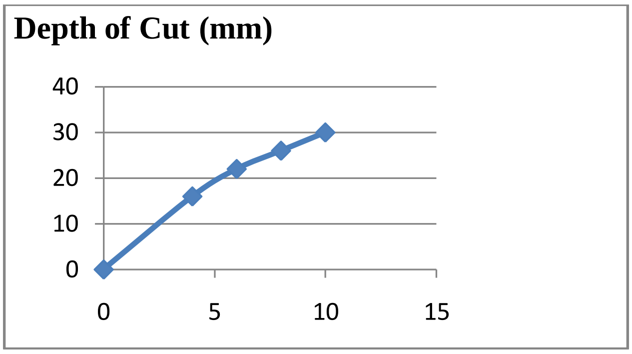
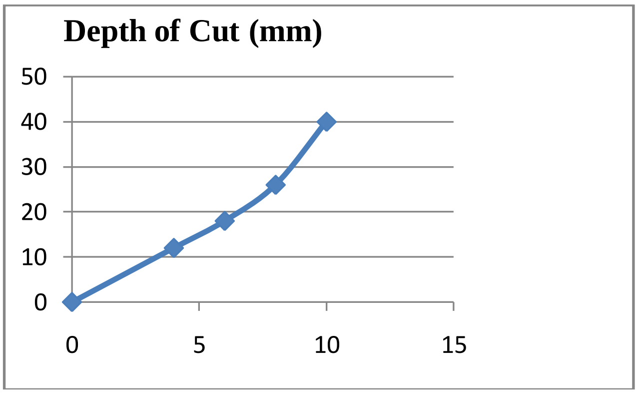


GRAPH OF CUTTING DEPTH AGAINST TIMEFOR PVC PIPE.



GRAPH OF CUTTING DEPTH AGAINST TIMEFOR WOOD.

The slope of graph of wood

$$S_w = \frac{\Delta(\text{Cutting depth of wood})\ \text{mm}}{\Delta(\text{time})\text{sec.}}$$

$$S_w = \frac{26-16}{8-6} = 5\ {}^{\text{mm}}/_{\text{sec.}}$$

The slope of graph of PVC pipe

$$S_p = \frac{\Delta(\text{cutting depth of PVC pipe})\text{mm}}{\Delta(\text{time})\text{sec.}}$$

$$S_p = \frac{26-12}{8-4} = 3.5\ {}^{\text{mm}}/_{\text{sec.}}$$

Slope Ratio

$$= \frac{S_w}{S_p} = \frac{5\ {}^{\text{mm}}/_{\text{sec.}}}{3.5\ {}^{\text{mm}}/_{\text{sec.}}} = 1.43$$

The slope of the two graphs represents the cutting speed of both materials that was tested. The values of the slope of the graphs in Fig. 3 and 4 respectively represent the cutting speeds for PVC pipe and wooden material using the pedal powered hacksaw machine. It can also be deduced from these figures that, the cutting speed of the hacksaw while cutting a wooden material is 1.43 times the cutting speed of the hacksaw while cutting PVC pipe. Therefore, it indicates that it takes more time to cut PVC materials than wooden materials. The two values obtained for the cutting speed indicates that the machine is economically okay for small scale industries. From the evaluation processes carried out on PVC pipe and wood, it was seen that the machine is highly efficient as shown below.

Efficiency of the Machine

Efficiency = $\frac{M.A}{V.R} = \frac{IMA}{V.R}$ x 100%

Recall that;

IMA = Ideal Mechanical Advantage = 0.4
(as calculate earlier)

Efficiency = $\frac{0.4}{0.8}$ x100% = 50%

V. CONCLUSION

The pedal operated hacksaw machine with adjustable seat and handle arrangement was designed and fabricated using locally available materials. The machine is being powered by the operator who pedals the machine by means of bicycle pedal. The power is transmitted to the hacksaw frame with the aid of the slider crank mechanism which causes the reciprocating motion of the hacksaw which cuts the PVC pipes and wood. After due testing of the machine, the performance analysis revealed that the efficiency of the machine was found to be 50% and having a productivity of 3.5 mm/sec for PVC pipes and 5 mm/sec for wood.

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