International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 05 May 2024, pp: 1059-1065 www.ijaem.net ISSN: 2395-5252

Design and Fabrication of a Pedal Driven Hacksaw Machine

Lawal A. S[1]

[1] *Department of Mechanical Engineering, Ekiti State University Ado Ekiti, Nigeria,*

Date of Submission: 18-05-2024 Date of Acceptance: 28-05-2024

ABSTRACT

Metal fabrication is a value added process that involves the construction of machines and structures from various raw materials. This study involved a larger sprocket which rotates with help of human powered pedal. The smaller sprocket is connected to the plane which is mutually perpendicular to the axis of the larger sprocket is made to rotated by using chain drive. The smaller sprocket is rigidly supported by means of shaft and bearing support. The circular frame is mounted on the same shaft where the smaller sprocket is mounted. When the pedal is operated, circular frame rotated which in turn cuts the mild steel, copper and Poly Vinyl Chloride material. The main aim is to reduce the human effort for machining various materials such as mild steel, copper and Poly Vinyl Chloride etc. The pedal powered machine which runs on human power, works on the principle of the conversion of rotational motion in a mutually perpendicular axis (Crank and Slider Mechanism). The Pedal operated hacksaw machine was successfully tested after development for the speed of 50, 70 and 90 rpm and its shows cutting time of 70% less than that of human time. The machine is cost effective compared to electrically powered hacksaw machine. Also, the machine consumes no electricity at all, which is a major plus and it has simple design, reliable, and can be used where electric supply is not available, particularly in rural areas. The machine operates with the mechanical efficiency of 72.9% and mechanical advantage of 0.47.

Keywords: machine, sprocket, pedal, hacksaw, mechanical efficiency, mechanical advantage.

I. INTRODUCTION

Hand-powered devices have been used for millennia, but during the last quarter of the 19th century a radically improved generation of tools appeared, taking advantage of modern mass production machinery and processes (like interchangeable parts) and an increased availability in superior material (metal instead of wood). One of the outcomes included an array of new drilling machines, but their heydays were over fast. These human-powered tools were not only a vast improvement over those that came before them; they also had many advantages in comparison to the power drills that we use today (Khope et.al., 2013).Human powered tools and machines have been viewed as an obsolete technology ever since the arrival of fossil fuels and electricity. This makes it easy to forget that there has been a great deal of progress in their design, largely improving their productivity.

The most efficient mechanism to harvest human energy appeared in the late 19th century: pedaling. Stationary pedal powered machines went through a boom at the turn of the 20th century, but the arrival of cheap electricity and fossil fuels abruptly stopped all further development (Gite et.al., 2011).The cleverest innovation in applying human power to rotary motion only appeared in the 1870s. Some of us still use it as a means of transportation, but it is rarely applied to stationary machines anymore: pedal power. Initially, pedals and cranks were connected directly to the front (or sometimes rear) wheel. With the arrival of the 'safety bicycle' shortly afterwards, this direct power transmission was replaced by a chain drive and sprockets still the basics of most present day bicycles. Pedal power did not come out of the blue because some of the first bicycles were equipped with treadles, which could be considered the predecessor of the pedal.

Pedal power 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. Less commonly pedal power is used to power agricultural and hand tools and even to generate electricity. Some applications including pedal powered laptops, pedal powered grinders and pedal powered water wells. Some third world development projects currently transform used bicycles into pedal powered tools for sustainable development

(Chaudhary et.al., 1986).On their own, pedals and cranks did not offer a better mechanical advantage than the hand crank, let alone the capstan or the tread wheel. What made pedal power so revolutionary was that it offered the possibility to use the stronger leg muscles in a continuous motion while at the same time offering a much more compact mechanism than the capstan or the tread wheel. Moreover, using the appropriate gear ratio a mechanical advantage similar to that of a capstan or a tread wheel could be achieved by multiplying torque at the expense of speed or vice versa. This made pedal power suitable for a much larger variety of applications.

In the world of pedal-power devices, most devices fall into two categories: Electrical devices and mechanical devices. Electrical devices often have limited input current tolerance. Consequently Electrical elements (such as diodes and inverters - available to purchase at a local electronic store or online) are necessary to convert the current created into a current that your device can use. If these elements are left out there is a good chance that you will damage your device. The other consequence is that this configuration loses more energy in translation than a mechanical device, especially if a battery is needed between the generator that creates your energy and your device. In other words, these systems are less efficient as pedal-power devices than mechanical devices. Mechanical devices typically have to be modified, possibly to the point that it may be impossible to return it to its original condition. These devices include blenders, drills, washing machines, etc. All of the energy put into pedaling is translated directly into the action the device's motor would have performed.

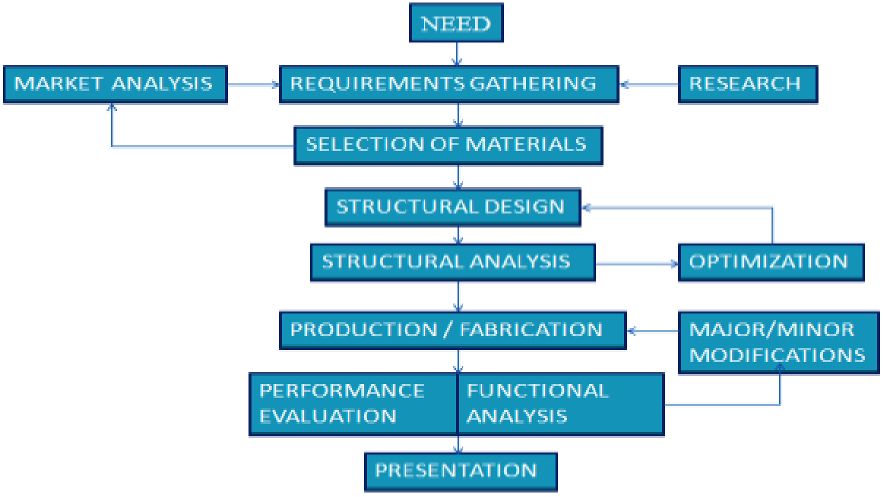
The Pedal driven hacksaw works on slider crank mechanism. The Pedal driven hacksaw is used to cut ply wood in small scales. Pedal driven hacksaw helps to obtain a less effort uniform cutting. It can be used in places where electricity is not available. It is designed as a portable one which can be used for cutting in various places. The main parts of Pedal driven hacksaw are hack saw, reciprocating rod welded to the pedal of a bicycle, flywheel, sprocket and chain drive. The hack saw is connected with the reciprocating rod. By pedaling the bicycle the reciprocating rod moves to and fro, the hack saw will be moving with the rod. The plywood to be cut is placed under the hack saw on a work piece holder. Thus the plywood can be cut without any external energy like fuel or current. Since this uses no electric power and fuel, this is very cheap and best.

II. METHODOLOGY

The study entails selecting of some suitable fabrication materials such as round galvanized iron pipe and mild steel and also developed a concept design of the structure. Analysis of the design (design calculations) was carried out, after which the production and fabrication process commences. Finally, the machine was tested and overall performance evaluations were also performed.

Design and Fabrication Procedure

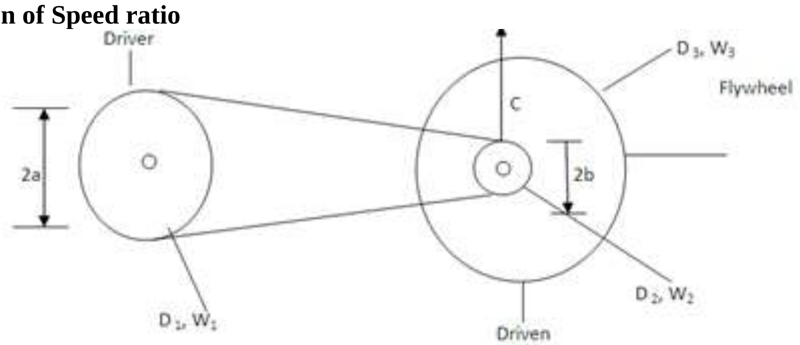
The design and fabrication procedures followed in this project are structured as below:



Source: Khurmi,2014.

Figure 1: Design and Fabrication Procedure

Step1: Calculation of Speed ratio



The block diagram representation of speed ratio(i) of the system.

$\omega_2 = \omega_1$

Speed ratio i = Maximum Speed/Minimum Speed

$i = N_1 / N_2$

$= 3000/1500$

$i = 2$

Step2: Calculation of Number of Teeth

$Z_1 = 14$

$Z_2 = 42$

Step3: Calculation of Pitch Value P

$A = 30 * P$ (Kalaikathir, 2014)

$560 = 30 * P$

Pitch P = 18.67 mm

$A = 50 * P$

$560 = 50 * P$

Pitch P = 11.2 mm

Ranges from 11.2 to 18.67

Step4: Selection of Chain

Based on Pitch Value we selected **‘R50’** (Kalaikathir, 2014)

Step5: Calculation of Total Load

Total Load $\sum P = P_t + P_c + P_s$ (Kalaikathir, 2014)

Tangential Force $P_t = 10^\wedge 2 * N / V$

Power N = $\sigma AV / 10^\wedge 2 * KS$ (Kalaikathir, 2014)

Stress = $1.85 * 9.81 / 10^{\wedge -} 6$

Stress = $18.15 * 10^\wedge 6 N / mm^2$

Bearing Area $A = 0.7 cm^2$ (Kalaikathir, 2014)

$= 0.7 * 10^{\wedge -} 4$

$A = 7 * 10^{\wedge -} 5 m^2$

Chain Velocity $V = P * Z_1 * N_1 / 60$ (Khurmi, 2014)

$= 15.875 * 10^{\wedge -} 3 * 25 * 3000 / 60$

V = 19.84 m/s

Service Factor $K_S = K_1 * K_2 * K_3 * K_4 * K_5 * K_6$ (Khurmi, 2014)

Constant Load $K_1 = 1.0$

Fixed Centre Distance

$K_2 = 1.25$

$a_p = 30 to 50 P$

$K_3 = 1$

Position up to 60

$K_4 = 1$

Drop Lubrication

$K_5 = 1.0$

Single Shift $K_6 = 1.0$

$K_s = 1.25$

Power N = $(18.56 * 10^\wedge 6) * (7 * 10^{\wedge -} 5) * 19.84 / 10^\wedge 2 * 1.25$

Power N = 988 kW

Tangential Force $P_t = 10^\wedge 2 * 988 / 19.84$

= 5079.43 kgf

P_t = 49.82 kN

Tension due to Sagging of Chain

$P_s = K * W * a$

Coefficient of Sag K= 6 (Kalaikathir, 2014)

Weight per meter W= 1.01 kgf (Kalaikathir, 2014)

W = 9.91 N

Tension due to Sagging

$$P_s = 6*9.91*0.56$$

= 33.29 kgf

P_s= 326.64 N

Centrifugal Tension

$$P_c = W*V^2/g$$

$=9.91*19.84^2/9.81$

= 397.63 kgf

P_c = 3.9 kN

Total Load $\sum P = P_t + P_s + P_c$

$=(49.82*10\hat{}3)+326.64+(3.9*10\hat{}3)$

Σ_P= 54.05 kN

Step6: Calculation of Design Load

Design Load = $\sum P * K_s$

$=(54.05*10\hat{}3)*1.25$

Design load = 67.56 kN

Step7: Calculation of Factor of Safety FSw

FSw = Breaking Load/Design Load

Breaking Load

Q = 2220 kgf (Kalaikathir, 2014)

= 2220*9.81

= 21.77 kN

FSw = 21.77/67.56

FSw = 0.32

Step8: Calculation of Chain Length

Length of Chain = $l_p * P$

(Kalaikathir, 2014)

Length of Continuous Chain in Multiple of Pitches

$$l_p = 2a_p + (Z_1 + Z_2/2) + [(Z_2 - Z_1/2JI)2/a_p]$$

(Kalaikathir, 2014)

Approximate Centre Distance

$$a_p = a^*/P$$

(Kalaikathir, 2014)

= 560/15.875

a_p = 35.27

l_p= (2*35.27) + (25+50/2) + [(50-25/2Л)2/35.27]

l_p = 108.05 mm

Length of Chain L = 108.05*15.875

L =$1.72*m$

Step9: Exact Centre Distance

Centre Distance $a = [e + \sqrt{(e^2 - 8m)} * P/4]$

$$e = l_p - (Z_1 + Z_2)/2$$

= 108.05-(25+50)/2

e = 70.55 mm

m = (Z_2-Z_1/2Л) 2

= (50-25/2Л) 2

m = 15.83

Centre Distance

$$a = 70.55 + [\sqrt{70.55^2 - (8*15.85)}]*15.875/4$$

a = 557.93 mm

Step10: Calculation of Sprocket Diameter

$d_1 = P/\sin(180/Z_1)$ (Khurmi, 2014)

$=15.875/\sin(180/25)$

d_1 = 126.66 mm

$$d_{01} = d_1 + 0.8d_r$$

(Khurmi, 2014)

$=126.66+(0.8*10.16)$

d_{01}= 134.78 mm

$$d_2 = P/(180/Z_2)$$

$=15.875/\sin(180/50)$

d_2 = 252.82 mm

$$d_{02} = d_2 + 0.8d_r$$

$=252.82+(0.8*10.16)$

d_{02}=260.94 mm

3.2.3.2 Design of Ball Bearing

Axial Load F_a = 1000 N

Radial Load F_r = 1500 N

Speed N = 1500 rpm

Life in hours = 15000 hrs

Calculation of Radial and Axial Force

Step1: Axial Load F_a = 1000 N

Radial Load F_r = 1500 N

Step2: Calculation of F_a/F_r

Axial Load/Radial Load

= F_a/F_r

= 1000/1500

= 0.667

Step3: Selection of Bearing

Speed N = 1500 rpm (Kalaikathir, 2014)

Bearing of Basic Dimension, 'SKF 6236'

Step4: Calculation of Static and Dynamic Load Carrying Capacity
For ‘SKF 6236’
Static Load Rating = 204000 N
(Kalaikathir, 2014)
Dynamic Load Rating C^* = 76000 N
(Kalaikathir, 2014)

Step5: Calculation of F_a / C^* ratio
Axial Load /Static Load Rating
= F_a/C*
= 1000/204000
= 0.0049
Step6: Selection of e Value
e = 0.22 (Kalaikathir, 2014)
Step7: Selection of Radial Load Factor and Thrust Load Factor
Radial Load Factor X = 0.56
(Kalaikathir, 2014)
Thrust Load FactorY = 2
(Kalaikathir, 2014)
Step8: Selection of Service Factor
Rotatory Machine with No Impact
(Kalaikathir, 2014)
Service Factor S = 1.5
Step9: Calculation of Equivalent Load P
Load P =$[(X * F)+(Y * F)]S$
(Kalaikathir, 2014)
= [(0.56*1500) + (2*1000)] 1.5
Load P = 4260 N
Step10: Selection of C/Pratio
C/P = 11.5(Kalaikathir, 2014)
C =$11.5 * P$
= 11.5 * 4260
C = 48990 N
Step11: Check for Selected Bearing
Calculated C Value= 48990N
Standard C Value = 176000N
Selected Bearing ‘SKF 6236’
Design is Safe
Step12: Calculated of Expected Life in hours
Expected Life $L = (60 n L_n)/10\verb|^|6$
= (60 * 1500 * 15000)/10 ^ 6
L = 1350 million revolution

3.2.3.3 Torque and Power Calculations

Design Data: Human energy expended say $70kg$ person: for cycling at $15km/hr$ ($16-24km/hr$) =$1.62kJ/kg$, the average cycling speed =$15.5km/hr$ (Stephen et al., 2015) the cycling speed in rpm = $120rpm$ (Stephen et al., 2015).

Ideal Mechanical Advantage (I.M.A.) of the machine

$$= \frac{\text{Diameter of the driven sprocket}}{\text{Diameter of the driver sprocket}}$$

$$= \frac{\omega_{in}}{\omega_{out}}$$

So, using $N_{in} = 120\,rpm$ (Stephen et al., 2015)

$$\omega_{in} = \frac{2\pi N_{in}}{60}$$

$$\omega_{in} = \frac{2 * 3.142 * 120}{60}$$

= 12.568rad/s

$$\text{I.M.A} = \frac{\omega_{in}}{\omega_{out}}$$

$$\Rightarrow \omega_{out} = \frac{\omega_{in}}{IMA}$$

$$\text{IMA}= \frac{70}{150} = 0.47$$

$$\omega_{out} = \frac{12.568}{0.47} = 26.74 rad/s$$

The output rotational speed of the flywheel=26.74rad/s

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

Where F_c =centrifugal force on the flywheel

V=linear velocity

ButV = ω_{out} x r

Where r = radius of flywheel.
So, using the weight of an average man say 60-75kg and 15kg mass of flywheel

But flywheel radius(r) = $\dfrac{D_3}{2 \times 1000}$

$$= \frac{160}{2 \times 1000} = 0.08\text{m}$$

$$\Rightarrow V = 26.74 \times 0.08$$
$$V = 2.14 m/s$$

And $F_c = m\omega^2 r$

$$= 15 \times 26.74^2 \times 0.08$$

=858.03N

$\therefore$ The Power, $P = F_c \times V$

$$= 858.03 \times 2.14 = 1836.19W$$

$\therefore$ The Torque, $T = F_c \times r$

$$= 858.03 \times 0.08 = 68.64Nm$$

3.2.3.4 Efficiency

Ideal Mechanical Advantage (I.M.A.) of the machine =

$$\frac{\text{Diameter of the driven sprocket}}{\text{Diameter of the driver sprocket}}$$

$$= \frac{70}{150}$$

I.M.A. =0.47

$$\text{Velocity Ratio }(V.R) = \frac{\text{Effort distance}}{\text{Load distance}} =$$

$$= \frac{100}{155}$$

V.R= 0.645

The Mechanical Efficiency of the machine=

$$\frac{IMA}{V.R} \times 100\%$$

=

$$\frac{0.47}{0.645} \times 100\%$$

= 72.9%

Performance Evaluation

The machine was tested for three different materials (mild steel pipes, wood and PVC pipes). The ideal mechanical advantage of 0.47, power output of 1836.19W and efficiency of 72.9% makes it very adequate and efficient as a useful machine for exercise and as a cutting machined compared to the existing ones.

Table 4.1: Comparison of cutting time of different materials of 16mm diameter shaft

Speed(rpm)	Time(in seconds)		
	Mild Steel	Wood	PVC Pipe
50	76	57	46
70	62	43	33
90	53	38	25

Mild Steel: Density; Hardness= 120 BHN

PVC pipe: $1467\ kg/m^3$; Hardness= 80 BHN

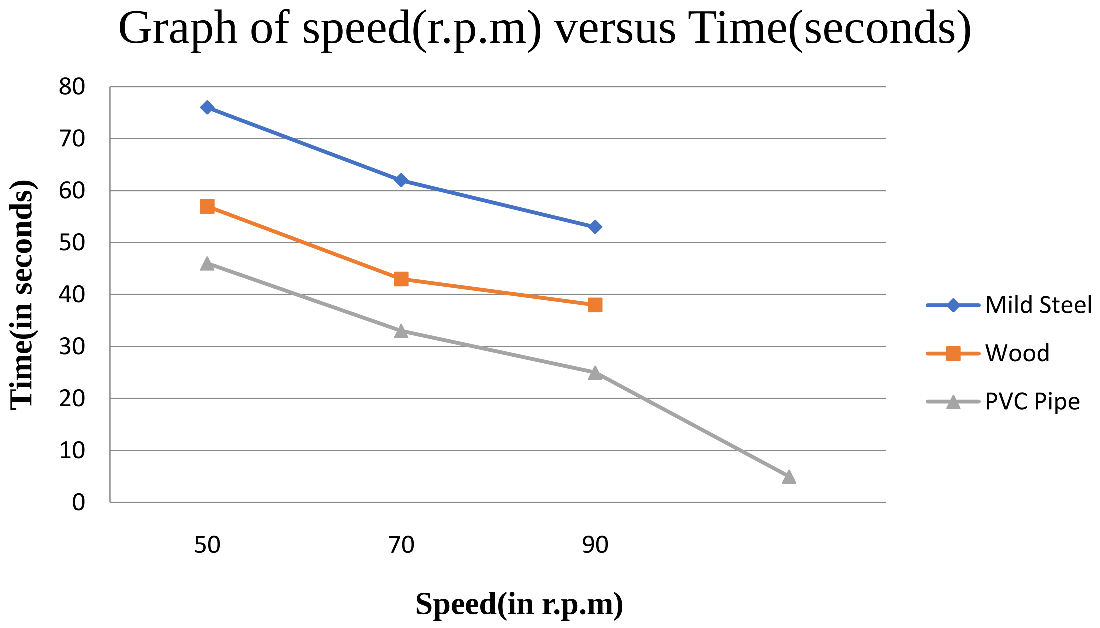


Figure 2: the graph of speed versus Time

It can be observed from the graph that as the speed (in r.p.m) increases from 50 r.p.m to 70 r.p.m the cutting time decreases (fig 2).This is because as the hardness of the material increases the time required to cut the work piece increases. The time required to cut the same work piece with hacksaw machine is less than half of that time required to cut directly by hacksaw

III. CONCLUSIONS

The Pedal operated hacksaw machine was successfully tested for the speed of 50,70 and 90 rpm and shows cutting time 70% less than that of human time. The machine is cost effective compared to electrically powered hacksaw machine. Also, the machine consumes no electricity at all, which is a major plus point. The machine is simple in design, reliable, and can be used where electric supply is not available, particularly in rural areas. The machine operates with the mechanical efficiency of 72.9% and mechanical advantage of 0.47.

REFERENCES

[1]. Adarsh, R., Kushagra, S. and Sudeep, M. (2014).”Design and construction of a Pedal Powered Washing Machine (PPWM)”, International Journal of Scientific & Technology Research (Volume 3, Issue 11 ISSN 2277-8616).

[2]. Amos, W. (2015). “Design of A Bicycle Peddle Operated Grain Mill”.

[3]. Bahaley,S.G., Awate,A.U. andSaharkar,S.V. (2012). “Performance Analysis of Pedal Powered Multipurpose Machine”, International Journal of Engineering Research and Development (IJERD) (Vol.1, Issue.5, e-ISSN: 2278-0181).

[4]. Carlos, M., Henry G. and Maya, P. (2010).“Design & Realisation of a pedal powered mill”.

[5]. Chaudhary,P. (1986). “Understanding pedal power” ISBN: 0-86619268-9 [C], Volunteers in Technical Assistance Technical paper 51 VITA 1600 Wilson Boulevard USA.

[6]. Gite, L.P., Pandey, M.M., Shrivastav, A.K. and Tiwari, P.S. (2011). “Pedal power for occupational activities: Effect of power output &pedaling rate on physiological responses”. International journal of Industrial Ergonomics; pp. 261-267.

[7]. Kalaikathir, A. (2014). Design Data, Data book of Engineers, (ISBN 978-81-927355-0-4, Compiled by PSG College of Engineering and Published in Coimbatore, India).

[8]. Khope, P.B. andModak J.P. (2013). “Development and Performance Evaluation of a Human Powered Flywheel Motor Operated Forge Cutter.” international journal of scientific & technology research (volume 2, issue 3, March).

[9]. Khurmi, R.S. and Gupta J.K. (2004). Machine Design, 4th Edition.

[10]. Khurmi, R.S. (2014). “Design of Machine Elements”, (Eurasnia publishing house 3 Pvt Ltd, 14th revised edition).

[11]. 111

[12]. Kirthikumar,D.C. (2013). “A Research on Multi-Purpose Machine”, International Journal for Technological Research in Engineering (Vol.1, Issue.1, ISSN: 2347-4718).

[13]. Linxu, W., Jingyu R., and Qiang L.(2011). “Design and Implementaion of the Reciprocating Pedal Powered Electricity Generating Device”, Advanced Materials Research (Vol.282-283 pp 735-738).

[14]. Prasad, A., Hatwalne, Sushil T., Ambadkar, Vivek R. and Wankhade, A.M.(2011). “Design and development of Pedal operated flour mill.” New York Science Journal.

[15]. Stephen, Tambari, Dan O.G., Ruene W. and Ayejah V. (2015).IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684 P -ISSN: 2320-334X, Volume 12, Issue 4, PP 48-52 www.iosrjournals.org.

[16]. Vishal, G., Neelesh K. and Gautam Y. (2013). “An Experimental Setup and Design of Pedal Powered Water Pump”, International Journal of Engineering Research and Technology (Vol.2, Issue.1).