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Design and Force Analysis of Mechanical Mechanisms of Pedal Powered Hacksaw in Engineering Workshop

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ABSTRACT

The design and force analysis of a mechanical pedal powered hacksaw developed to modernized and less stressful operation for cutting of engineering materials. The machine was tested and found to be very efficient with an ideal mechanical advantage of 1.22, velocity ratio of 1.64m/s, a power output of 0.395kw and an efficiency of 74.4%, which makes it very adequate and capable for cutting. Furthermore, the rotational speed of the flywheel was fond to be 10.3 rad/s. It is very useful for cutting PVC materials (pipes) and can be used widely in lather and in furniture making industries. This 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.

Keywords: Crack Mechanism, Rotary Motion, Machine Cutting, Reciprocating.

Introduction

This article concentrates on mechanical pedal operated hacksaw machine which utilize the energy generated by foot pedaling in metal cutting operations, in which no electrical power is needed. The pedal operated hacksaw was manually fabricated and is mainly used for cutting metals, wood and plastics. The machine is designed to yield a high mechanical advantage to reduce the effort needed to do that work. According to Sivasubramanian et al (2018) the principle of pedal power hacksaw is to change circulatory motion or cycling motion into translator motion with the help of metal cutting rod. Sahu et al (2016) the rotary motion through pedal is transmitted to the crank connecting hacksaw frame which is guided over a circular rod.

Fig. 1: Pictorial view of the fabricated mechanical pedal powered hacksaw

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 consist of a metal arch with a handle, usually a pistol grip, with pins for attaching a narrow disposable blade. A screw or other mechanism is used to put the thin blade under tension. It is a fine tooth hand saw with a blade under tension. It is used to cut metals and PVC pipes (Mukund et al, 2017). Blades of hacksaw are measured in TPI (Tooth per Inch). Different TPI is needed for different jobs of cutting.

The fabrication of a mechanically manual pedal hacksaw was geared towards addressing or solving some technological and economical challenges faced in a mechanical workshop without the application of electricity (Ashok Kumar et al, 2018). The high cost of purchasing and maintaining an electrical power hacksaw. The electric power saw is not useful on work site where there is no power or electricity. The electric power saw is not suit able to be transported from one site location to the other. The price of electricity tariff is so exorbitant that the small scale entrepreneur or a beginner can barely afford to pay (Pratik et al, 2015). Based on these points, it became imperative to analyze the forces and performance output of fabricated mechanical pedal operated hacksaw.

Design Equations and Manipulations

Human energy expended by a 70kg person, for cycling at (16- 24km/hr.). Using an average cycling speed of 15.5km/hr. is equal to 1.62KJ/Kg (Stephen et al, 2014).

The cycling speed in r. p. m = 120 rpm.

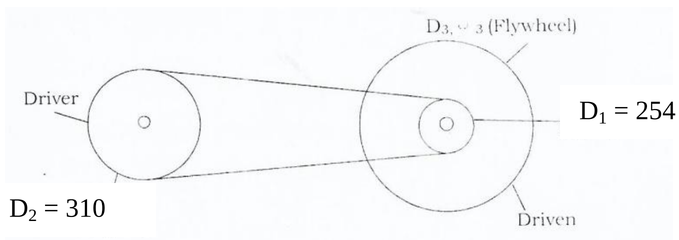


Fig. 2: Driver and Driven assembly

The block diagram representation of speed ratio of the system ω2 = ω3

$$\text{The Ideal Mechanical Advantage (IMA)} = \frac{D\ Driven}{D\ Driver} \quad \ldots\ldots\ldots\ldots 1$$

$$IMA = \frac{D\ Driven}{D\ Driver} = \frac{\omega\ IN}{\omega\ OUT} \quad \ldots\ldots\ldots\ldots 2$$

Where: D Driven = Diameter of driven wheel = D2

D Driver = Diameter of driver wheel = D1

ωIN = Input rotational Velocity of wheel = ω_1

ωOUT = Output rotational velocity of wheel = ω_2

$$\text{And, } IMA_{TOTAL} = IMA \quad \ldots\ldots\ldots\ldots 3$$

$$\text{Also } IMA_{TOTAL} = \frac{\omega IN}{\omega OUT} \quad \ldots\ldots\ldots\ldots 4$$

So using the data below,

Driver (D_1) = 254mm

Driven (D_2) = 310mm

Flywheel diameter D_3 = 310mm

IMA = $\frac{Diameter\ \ of\ the\ Larger\ \ Wheel}{Diameter\ \ of\ the\ smaller\ \ wheel}$ 5

IMA = $\frac{D2}{D1}$ = $\frac{310}{254}$ = 1.22 .... 5a

IMA $_{TOTAL}$ = 1.22

So using N $_{IN}$ = 120rpm

ωIN = $\frac{2\pi Nin}{60} = \frac{2\ x\ 3.142\ x\ 120}{60}$ = 12.568rad/s 6

IMA_{TOTAL} = $\frac{\omega in}{\omega out}$ 7

ω out = $\frac{\omega in}{IMA}$ 8

ω out = $\frac{12.568}{1.22}$ 9

ω out = 10.30rad/s

Therefore, the output rotational speed of the flywheel = 10.30rad/s

The power output, P = F_c x V 10

Where Fc = Centrifugal Force on the flywheel

V = Linear Velocity

r = Radius of flywheel

But, V = ωout x r.. 11

So using the weight of the flywheel as 15kg, the flywheel radius = $\frac{D3}{2}$ = $\frac{310mm}{2}$ = 155mm

= $\frac{155mm}{1000}$ = 0.155m 12

V = ωout x r ....…..... 13

V = 10.30 x 0.155, V = 1.60m/s

And

Fc = $mr\omega^2$ 14

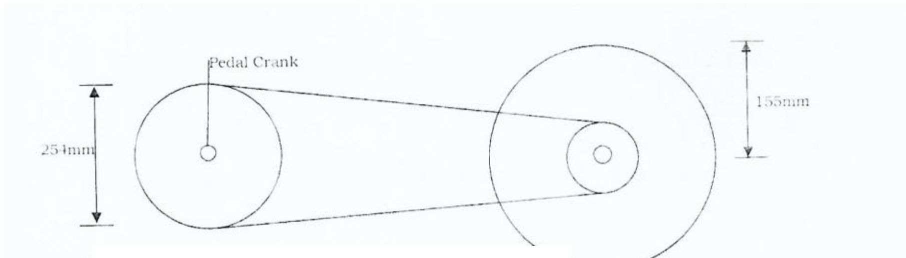
Fc = $15 \times 0.155 \times (10.30)^2$, Fc = 15 x 0.155 x 106.09, Fc = 246.66KN

Therefore, the power, P = Fc x V = 246.66 x 1.60, = 394.656W, = 0.395KW

The Torque, T = $\frac{P}{\omega}$ = $\frac{0.395}{10.30}$= 0.03835KNm…………………………………….. 15

Velocity Ratio

$$V.R = \frac{Effort\ Distance}{\text{Load Distance}} = \frac{Length\ of\ crank\ pedal}{\text{Hacksaw cutting stroke}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 16$$



F Fig. 3: Driver and Driven assembly

$$= \frac{254mm}{\text{Radius of flywheel}} = \frac{254}{155} = 1.64 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 17$$

Therefore V. R. = 1.64

Efficiency of the Machine:

$$\text{Efficiency} = \frac{M.A.}{V.R} = \frac{I\ MA}{V.R} \text{ X } 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 18$$

Recall that IMA = Ideal Mechanical Advantage

= 1.22 (as calculated earlier)

$$\text{Efficiency} = \frac{1.22}{1.64} \text{ X } 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 19$$

= 74.4%

Results and Discussion

1. Force required by the Driver and Driven (Mechanical Advantage)

   Equation 3.1 $\quad IMA = \frac{DDriver}{DDriven} = \frac{Diameter\ \ of\ the\ larger\ \ wheel}{Diameter\ \ of\ the\ Small\ \ wheel}$

   = 1.22

2. However, substituting the values in equation 5a and 9 above the output rotational speed of the flywheel = 10.3rad/s.

3. Power Required to drive the mechanical pedal, P = Fc x V …………..10

   But substituting their values in equ. (12) and (14a) = 394.656W ≈ 0.395Kw

   Similarly the Torque Required T = $\frac{p}{\omega}$ = 0.03835KNm

   Hence the Power Required = 0.395Kw and Torque = 0.03835KNm

4. The velocity of Ratio VR = $dE/_{d}$ = V = dR

$\therefore$ VR = $\frac{Effort\ Distance}{Load\ Distance} = \frac{Length\ of\ crack\ pedal}{Divide\ by\ Hacksaw\ cutting\ stroke}$ ………….. . 16

Substituting the values in equation …………………………………. …17

The VR becomes 1.64m/s

5. The Efficiency η_m = $\frac{MA}{VR} = \frac{IMA}{VR}$ X 100% equation …………………… 18

Substituting the values, η_m = $\frac{1.22}{1.64}$ X 100%, η_m= 74.4%

The Design Equation and Efficiency Analysis of Mechanical Pedal Powered Hacksaw in Engineering Workshop Practice was completed and tested severally using three different materials of mild steel pipe, plastic pipe, thermoplastic and wood. It was discovered that the machine was effective, reliable and efficient with ideal mechanical advantage of Im_A of 1.22 output rotational speed of 10.3rad/s. Similarly, the power required to drive the machine was found to be 0.395Kw. And Torque Required to machine was found to be 0.03835 KNm. The velocity ratio was found to be 1.64m/s. The machine efficiency η_m was found to be 74.4%

Conclusion

The machine was found to be effective and reliable with efficiency of 74.4% and power output of 0.395Kw. Having successfully carried out the fabrication, construction, testing, it satisfactorily showed that the pedal operated hacksaw machine is having an Ideal Mechanical Advantage of 1.22 and a power output of 0.395KW when fabricated using available raw materials and techniques. Metals pipes, plastics and pieces of wood were cut successfully and the overall performance was confirmed to be efficient compared to already existing ones.

Recommendations

This simple cutting machine can be used to solve day today household metal cutting needs and it can be also used in for small entrepreneurial workshops and in industrial applications during power shut down.

It is very useful for cutting PVC materials (pipes) and can be used widely in lather and in furniture making industries.

This 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.

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