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Design of Pedal Driven Unit: An unconventional alternative Energy Source

M. S. Giripunje[1], Dr. C. N. Sakhale[2], S. K. Undirwade[3], S. N. Waghamare[4]
[1] Priyadarshini College of Engineering, Mech. Engg. Dept., Nagpur, Maharashtra, INDIA
[2] Priyadarshini College of Engineering, Mech. Engg. Dept., Nagpur, Maharashtra, INDIA
[3] Priyadarshini College of Engineering, Mech. Engg. Dept., Nagpur, Maharashtra, INDIA
[4] Priyadarshini College of Engineering, Mech. Engg. Dept., Nagpur, Maharashtra, INDIA

Abstract
Increasing load shedding, insufficiency of electricity, increase of electricity bill charges & poor people ratio in our country has forced us to think in the direction of utilization of man-power in process machines instead of usual electrically operated machines.

Now-a-day a person has to exercise daily on the exercise machine (to keep himself physically fit) and. So if a person exercise or work out on this pedal driven unit then it can generate Power about 1HP which (if we use heavy Flywheel, power can be amplified up to 5 HP) can run the household machine like water pump, electricity generation machine, washing machine etc.

So, the present work is on Pedal Driven Unit which comprises a Bicycle mechanism, Flywheel, appropriate clutch for transmission & process unit could be any process device such that product quality does not get affected on account of variation in speed of process unit.

Keywords: *Pedal driven unit, Bicycle mechanism, process unit.*

1. Introduction

Today's India is facing tremendous problem of load shedding & power cuts. Many more countries are also facing problem of limited on earth are ending & of course these are out of reach of common man as these are costly. We can't use the energy available in the form of power (electricity) whenever we need due to load shedding.

Generally, A person can generate four times more power by pedaling than by hand-cranking .If a person pedals with his full capacity then continuous pedaling can be done for only short period of about 10min. However pedaling at half power can be sustain for around 60min. Pedal power enable a person to drive device at same rate as that achieved by hand-cranking but with far less effort & fatigue.

So, In this work we use pedaling mechanism to generate the power and store the energy in flywheel by using the proper gear ratio & then flywheel runs any process unit. Fig. describes schematic arrangement of such Pedal Driven unit which comprises a Bicycle mechanism.

2. Objective of the Proposed Work

The energy sources of such types are considered as one form of non- conventional energy source. The importance of this work is for the remote and interior area for energizing process unit in the range up to 5 Hp. For this range, large number of process machines is required to be energized [2].

For small farmers, it is necessary to adopt this concept to small agricultural implements. Accordingly this type of energy source has been adopted for several processes such as keyed bricks, wood turning, algae formation machine, fodder chopper, oilseed presser [3,4,5,6,7]. Such an energy source if developed and utilized, it will be of great help to poor people / people in villages [1], firstly because it does not need conventional energy and it may generate work for one of the family member.

A large area around the vicinity of big cities in Asian countries is a rural area and almost all rural areas in India are affected by load shedding which greatly hampers the daily needs, growth and development of these rural areas. If the society focuses its research work on replacing the electricity driven process units

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by human power, then it will be of great help to such rural areas for the overall growth and development. Also it may generate employment for the poor people/ people in villages for their self dependence.

2.1 Human Power Output

The maximum power output from a human being occurs in a rowing action because most muscle groups in the body are used. However, these outputs are loosely approached by those obtained from the legs applied to moving pedals. Little advantage appeared to be gained from pedal motions other than simple rotating cranks as on a bicycle and use of cranks gives a fairly smooth rotary motion at speeds of 60-80 rpm. Hand cranking is frequently used but as the arm muscles are smaller than the thighs, power output is reduced. The power output to be expected from normal peddlers are around 0.1HP.This output can be maintained for 60 minutes or more. Higher outputs can be produced for shorter periods. In static applications, the outputs available tend to be lower than those measured from the performance of cyclists because of the effect of winds in reducing body temperature. It may prove advantageous to provide fans for peddlers in static situations to improve output.

2.2 Power Levels

The power levels that a human being can produce through pedaling depend on how strong the pedaler is and on how long he or she needs to pedal. If the task to be powered will continue for hours, at a time 75 watts mechanical power is generally considered the limit for a larger, healthy non-athlete. A healthy athletic person of the same build might produce up to twice this amount. A person who is smaller and less well nourished, but not ill, would produce less; the estimate for such a person should probably be 50 watts for the same kind of power production over an extended period. The graph in Fig. 3 shows various record limits for pedaling under optimum conditions. The meaning of these curves is that any point on a curve indicates the maximum time that the appropriate class of person could maintain the given average power level.

2.3 Pedaling Rate

How fast should a person pedal? Human beings are very adaptable and can produce power over a wide range of pedaling speeds. However, people can produce more power--or the same amount of power for a longer time--if they pedal at a certain rate. This rate varies from person to person depending on their physical condition, but for each individual there is a pedaling speed somewhere between straining and flailing that is the most comfortable, and the most efficient in terms of power production. (For centuries, this fact was apparently not recognized.) The predominant method of human power production was to strain with maximum strength against a slowly yielding resistance. This is neither comfortable nor efficient. Neither is the opposite extreme of flailing at full speed against a very small resistance. A simple rule is that most people engaged in delivering power continuously for an hour or more will be most efficient when pedaling in the range of 50 to 70 revolutions per minute (rpm). See Fig. 1, Fig. 2 and Fig. 3. For simplicity's sake, we will use 60 rpm, or one revolution of the pedal crank per second, as an easy reference value for estimates of the gear ratios required to drive a given load.

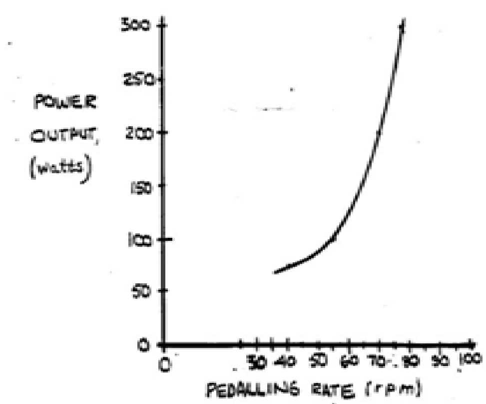

Fig. 1 Variation of optimum pedaling rate with desired power output

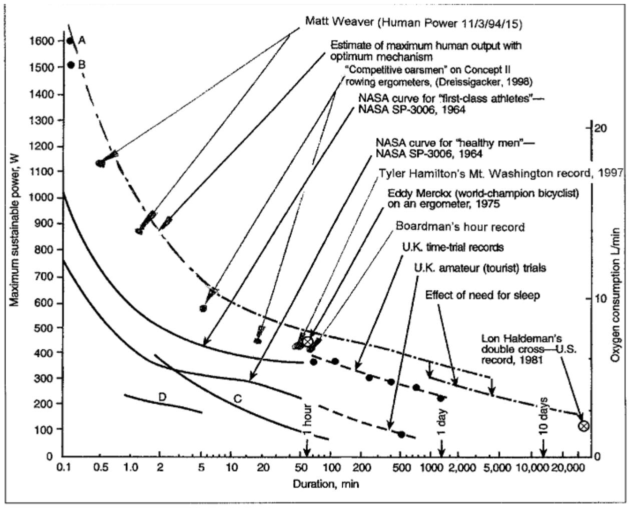

Fig. 2 Human Power Output Peddling (From 'Bicycling Science' II Edition, F. R. Whitt, D. G. Wilson, MIT Press)

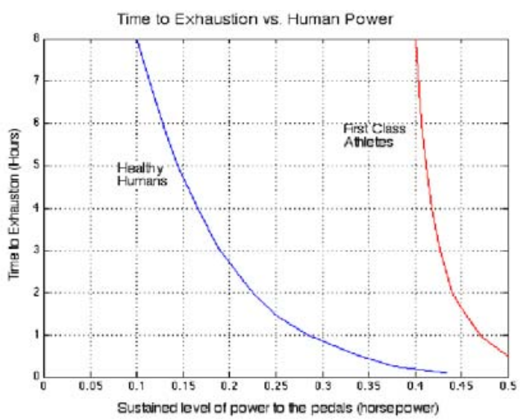

Fig. 3 Variation of sustained level of power with time to exhaust

3. Design of Main Components

3.1 Flywheel

$$\Delta E = \left(\frac{W}{g}k^2\right)K_s\omega_m^{\ 2}$$

Where,
Ks = Coefficient of speed Fluctuation.
ΔE = The maximum fluctuation of energy.
k = Radius of gyration
= {0.12[Do2 + (Do – 2h) 2]} 1/2
ω_m = mean velocity in radians/second
h = rim thickness
b = rim width

Applying Sokolowski's formula to calculate grinding energy per kg of food grain [8, 9, 10, 11, 12, 13, 14], Energy required for grinding (E) is given as:

$$E = K\left[\frac{1}{\sqrt{d}} - \frac{1}{\sqrt{D}}\right]$$

Where,
d = particle size after grinding,
D = particle size before grinding
K = grinding index

Let us consider one of the hard quality of wheat (Ardente) for which the value of grinding index K = 47KJkg-1mm1/2
Considering the initial size of wheat, D = 5mm
And the minimum flour particle size, d = 0.2mm

$$E = 47\left[\frac{1}{\sqrt{0.2}} - \frac{1}{\sqrt{5}}\right]$$

= 84.07 KJ/kg

Consider that, during one cycle, [utilizing the energy stored in flywheel after one minute of peddling], we have to grind 0.5 kg of wheat. Energy required for grinding 0.5 kg of wheat,
= 84.07/2
=42.035 KJ
= 42035 J
$\therefore \Delta$E = 42,035 J

$$\Delta E = \left[\frac{1}{2}I\omega_{max}^{\ 2} - \frac{1}{2}I\omega_{min}^{\ 2}\right]$$

$$K_s = \frac{N_{max} - N_{min}}{N_{mean}}$$

$$\Delta E = \left(\frac{W}{g}k^2\right)K_s\omega_m^{\ 2}$$

$$= \left(mk^2\right)K_s\omega_m^{\ 2}$$

$$= IK_s\omega_m^{\ 2}$$

Where,
I = Moment Of Inertia of Flywheel.

ΔE = 42,035 J, Ks = 2, ω_m = 41.866 rad/sec
$\therefore \ \Delta E = IK_s\omega_m^{\ 2}$
$\therefore$42,035 = I $\times$2$\times$(41.866)2
$\therefore$ I = 11.99 kg-m2

We consider, I = 12 kg-m2
Assume Dm = flywheel mean diameter = 0.98m
∴ k = 0.49m
Assuming that the rim provides 95 percent of the required moment of inertia,
$mk^2 = 0.95 \times I = 0.95 \times 12 = 11.4$
$m = 11.4/k^2 = 11.4/0.49^2$
∴ m = 47.48 kg
Other dimensions of flywheel:
b = 100 mm, h = 19.7mm, Do = 1000 mm, No. of arms = 6.
Stresses in the flywheel:
Centrifugal stress = 13.53 MPa, Bending stress = 187.21 MPa, resultant stress = 56.79 MPa.

3.2 Chain Drive

Rated Power, PR= 900 W
Design Power (Pd) : Pr × K1
Where,
K1 =Load Factor, from design data book it should be 1.2 for moderate shock and service of 10 hours per day [12, 13, 14].
Pd = 900 × 1.2 =1080 W =1.44 hp
Speed of smaller sprocket = 120 rpm.
From design data book graph, Select chain No. 50 for which Pitch (p) = 15.875.
The chain sprocket with the 24 teeth on the smaller sprocket and 48 teeth on the larger sprocket is available in the market.
Pitch Diameter of smaller Sprocket (Dp2)

$$D_{p2} = \frac{p}{\sin\left[\frac{180}{T_2}\right]}$$

T2 = No. of teeth on smaller sprocket = 24

$$D_{p2} = \frac{1.1875}{\sin\left[\frac{180}{24}\right]} = 106.5 \text{ mm}$$

Pitch Line Velocity (Vp) :
Vp2= (π × Dp2 × N2)/60 = (3.14 × 106.5 × 10-3 × 120)/60
Vp2 = 0.66 m/sec
Power capacity per strand:

$$P = p^2\left[\frac{V}{104} - \frac{V^{1.41}}{526}\left(26 - 25\cos\frac{180}{T}\right)\right]\times 10^3$$

Where, p= chain pitch=15.875mm,
V = Vp2 =0.66m/sec, T =T2 =21

$$P = 15.875^2\left[\frac{0.66}{104} - \frac{0.66^{1.41}}{526}\left(26 - 25\cos\frac{180}{24}\right)\right]\times 10^3$$

P = 1275.6W
No. of strands = 1080/1275.6 =0.84
No. of strands =1
Tooth Load (Ft) = Pd/Vp = 1080/0.66 = 1636.36 N
Other dimensions:
Pitch diameter of larger sprocket = 232.17 mm, Center distance C = 120.82 mm, Recommended Cmin = 285.42mm, Length of chain in pitch Lp = 72.75, Outer Diameter of the smaller sprocket = = 130.10 mm, Outer Diameter of the larger sprocket = 251.73mm, Width of the sprocket 9 mm.

3.3 Gear Design (Stage 1)

Pd = 2000 W, Module = m, pitch diameter, Dp=20 × m,
Vp = 0.8373 × m,
Ft = Pd/Vp = 2000/0.8373m = 2388.63/m
Assuming 1045 steel with heat treatment, So= 210 MPa, [12, 13, 14].
Bending strength,
Fb = So.Cv.b.Y.m
=210 × 0.30 × 0.3415 × 10m × m = 21.145m2
Basic strength, So = 210 MPa
Velocity factor, Cv=0.3 (trial value)
Face width of gears, b= 10m (trial value.)
Modified Lewis form factor,
Y = 0.485 – 2.87/tp
= 0.485 - 2.87/20 = 0.3415
Fb = 215.145m2
Equating Fb = Ft, 215.145m2 = 2388.63/m,
m = 2.23, select module, m = 3.
Dp =m.tp = 3 × 20 = 60 mm.
After calculation, the actual values of Vp, Cv & Ft are as follows:
Vp= 2.5119 m/sec, Cv = 0.544, Ft = 796.21 N
Calculated dimensions for other gears

Pinion	Gear
m=3	m=3
T=20	t=80
Dp=60mm	Dp=240mm

3.4 Bearing

For shaft 1:
The horizontal and vertical components of the reactions at two bearings B1 & B2 are already calculated while designing the shaft.
The reactions at two bearings are given by:

$$R_{B1}=\sqrt{R_{DH}{}^2+R_{DV}{}^2}=\sqrt{561.17^2+186^2} = 591.19 \text{ N}$$

$$R_{B2}=\sqrt{R_{BH}{}^2+R_{BV}{}^2}=\sqrt{899.788^2+744.2^2} = 1167.66 \text{ N}$$

The expected bearing life (L10) :

$$L_{10}=\frac{60\times n\times L_{10h}}{10^6}$$ [12, 13, 14].

Where, n = speed of rotation of shaft= 200 rpm.
L10h = Expected bearing life = 20000 hours (for the machines used for eight hours of service per day)
L10 = (60×200×20000)/106
= 240 million revolutions.
The dynamic load carrying capacity (C1 & C2):
Load factor = 1.5 (for Chain Drive)
C1 = P1 [L10]1/3(Load Factor)
Considering no axial load, P1 =RB1=591.19 N
C1 = 591.19×2401/3×1.5 = 5510.89 N
C2 = P2 [L10]1/3(Load Factor)
Considering no axial load, P2 =RB2=1167.66 N
C2 = 1167.66 ×2401/3×1.5 = 10884.57 N
For the Shaft diameter 25 mm following Bearings are available:
i) No. 61805 (C =3120 N), ii) No. 16005 (C = 7610 N),
iii) No. 6005 (C =11200 N)
For required dynamic load carrying capacity, Bearing No. 6005 is suitable at B1 & B2.
Other dimensions of the bearing:
Inner diameter of the bearing = 25 mm,
Outer diameter of the bearing = 47 mm,
Axial width of the bearing = 12 mm.
Similarly by calculations,
Bearings available for shaft 2 and 3,
i) No. 61806 (C =3120 N), ----- For shaft 1
ii) No. 16006 (C = 11200 N), ----- For shaft 2
iii) No.16006 (C =13300 N). ----- For shaft 3
For required dynamic load carrying capacity, Bearing No. 16006 is suitable at B3 & B4.
Other dimensions of the bearing:
Inner diameter of the bearing = 30 mm,
Outer diameter of the bearing =55 mm,
Axial width of the bearing = 9 mm.

4. Conclusions

1) The energy sources of such types are considered as one form of non- conventional energy source.
2) Such an energy source if developed and utilized, it will be of great help to poor people / people in villages, as it does not need conventional energy.
3) In countries like India where ample human power is available, such human powered man machine systems will help in a great extend to improve the economical condition and employability of such countries.
4) Such systems are of utmost importance in Asian countries as almost all Asian countries are facing electricity scarcity which results in ten to twelve hours load shedding in rural/undeveloped areas.

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