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Design of Human Powered Air Compressor

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Abstract— we all better know the scenario of present India where there is scarcity of natural resources because of ever increasing population. The world continuously looking for difference means from where energy can be generated. One such effort is to utilize the useful human energy or human effort to run various appliances, although very small amount of energy can be produce from human power but this energy is capable of running some important instrument. It also well practiced earlier to run some application using human effort thus I have tried to use this human effort in a new direction .i.e. in running application but also compressing air in the compressors. This effort and direction is chosen to make no use of electricity in this mechanism and without any pollution out of it. Thus besides more useful for the user it is also an eco-friendly thing which will avoid any side effect to our environment. Since no chemical fuel used in this, so there is no chance of air or sound pollution out of it. This project also gives a continuous dive to the output application even when the operation or user is not riding the tricycle. Thus keeping the process continuous the productivity of application purpose also increases without fatigue to the driver.

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I. INTRODUCTION

Over the centuries, the treadle has been the most common method of using the legs to produce power. A human being can produce four times more power (1/4 horsepower (hp)) by pedalling than by hand-cranking. At the rate of 1/4hp, continuous pedalling can be done for only short periods, about 10 minutes. However, pedalling at half this power (1/8 hp) can be sustained for around 60 minutes. Pedal power enables a person to drive devices with far less effort and fatigue Treadles are still common in the low-power range, especially for sewing machines. Only up to 15 percent of what an individual using pedal operated cranks can generate under optimum conditions.

It was almost 50 years after Karl von Krais invented the steerable foot-propelled bicycle in 1817 that Pierre Michaud added pedals and cranks, and started the enormous wave of enthusiasm for bicycling that has lasted to the present.[1]

Pedal power is still being use for bicycling, at least in the high-power range (75 watts and above of mechanical power). In the lower-power range there are a number of uses of pedal power--for agriculture, construction, water pumping, and electrical generation--that seem to be potentially advantageous, at least when electrical or internal-combustion engine power is unavailable or very expensive.[2]

II. OBJECTIVE

Today fossil fuels are widely used as a source of energy in various different fields like power plants, internal & external combustion engines. But its stock is very limited and due to this tremendous use, fossil fuels are depleting at faster rate. So to overcome this energy crisis, we are working on HPAC, so that fossil fuels can be conserved.

1. The objective of the project is to achieve the following three conditions

a) To run the tricycle only and keeping the system stationary
b) To run both, tricycle as well as the system.
c) To run on the system alone keeping tricycle stationary

2. Successfully replace the electric motor by human
3. To make applicable where no electricity available
4. To make the whole system eco-friendly
5. To make the project pollution free

III. WORKING

Human power driven air compressor has number of moving and stationary parts .The system comprises of three stages of chain drive for transmission of torque, power and achieving a speed of 615 R.P.M at the final shaft at input shaft human is applying a force of 300 Newton on the paddle by means of gear arrangement which gives 0.19 Horse power, 2.25 Newton meter of torque and required speed. The power transmission from paddle shaft to compressor shaft is illustrated in three stages as follows. [3]

A. First Stage:-

The stage comprises of two gears ‘A’ & ‘B’ connected to each other by means of a chain. On gear ‘A’ paddle is attached for giving input force which will tend to rotate sprocket ‘B’. Gear ‘A’ is bigger than sprocket ‘B’.

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B. Second Stage:-

This stage have gear 'D' and a multiple sprocket gear 'E' connected by means if chain .The gear 'D' is mounted on the same shaft as of sprocket 'B'. 'D' & 'B' will have the same speed, torque & power as there mounted on the same shaft 'a'. Gear 'D' is bigger than multiple sprocket gear 'E'.

C. Third Stage:-

Shaft 'b' carrying multiple sprocket gear 'E' is also holding gear 'F' on it .in this stage gear 'F' and gear 'G' are connected by means of a chain. Gear 'F' is bigger than gear 'G' shaft 'd' which is the final shaft is carrying gear 'G'. Final shaft'd' is coupled to the compressor shaft by means of a clutch. Gear 'F' drives gear 'G' the final shaft 'D' is coupled to the compressor shaft by means of a clutch. Shaft 'c' is carrying flywheel which is connected to the shaft 'b' and 'c' are connected to each other by means of clutch.

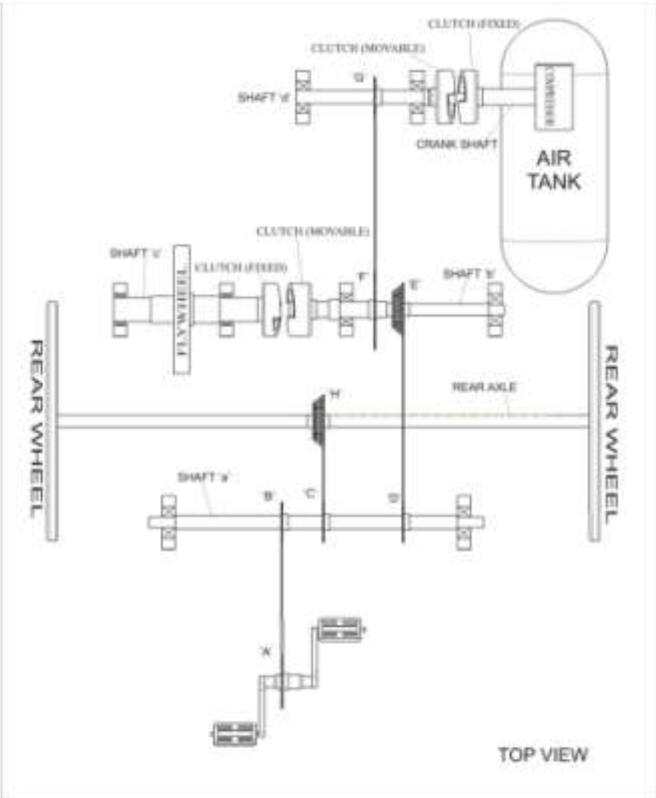

Figure 1. Schematic diagram of the system Components of human powered air compressor Spiral jaw clutch

Figure 2. Spiral jaw clutch.

Clutch is a device which is used to couple or join two shafts in a mechanical temporarily. These are made up of grey cast iron and casted for their effective rigidity spiral jaw clutches use sloping engagement surfaces to overcome the limited engagement speed of square jaw type. Through the smooth, sloped engagement surfaces allow for speed up to 150 rpm, they can operate in only one direction, and have a tendency to freewheel. A clutch is a mechanical device that provide for the transmission of power (and therefore usually motion) from one component (the driving member) to another (the driven member) when engaged, but can be disengaged. Clutches are used whenever the transmission of power or motion must be controlled either in amount or over time (e.g., electric screwdrivers limit how much torque is transmitted through use of a clutch; clutches control whether automobiles transmit engine power to the wheels). [4]

D. Flywheel

Figure 3. Flywheel

A flywheel is an inertial energy-storage device. It absorbs mechanical energy and serves as a reservoir, storing energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement if energy is more than the supply. The main function of the flywheel is to smoothen out variations in the speed of shaft caused by torque fluctuations. If the source of the driving torque or load torque is fluctuating in nature, then a flywheel is usually called for. Piston compressors, pinch press, rock crushers etc. are the other systems that have flywheel. [5]Compressor

Figure 4. Compressor.

An air compressor is a device that converts power into kinetic energy by compressing and pressurizing air, which on demand, on be released in quick bursts. A gas compressor is a mechanical device that increases the pressure of gas by reducing its volume. An air compressor is a specific type of gas compressor.

Compressors are similar to pump, both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of gas. Liquids are relatively incompressible, while some can be compressed, the main function of the pump s to pressurize and transport liquids.[6]

E. Bearings

Figure 5. Bearing

A bearing is a machine element that constrains relative motion and reduces friction between moving parts to only the desire motion. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis or it may prevent motion by controlling the vectors of normal forces that bear on the moving parts. Many bearings also facilitate the desired motion as much as possible, such as minimizing friction. Bearings are classified broadly according to the type of operation, the motion allowed, or to the directions of loads (forces) applied to the parts.[7]

F. Multi-sprocket

A sprocket or a sprocket wheel is a profiled wheel with teeth or cogs that mesh with a chain, track or other perforated or indented material. The name “Sprocket” applies generally to any wheel upon which are radial projections that engage a chain passing over it. It is distinguished from a gear in that sprockets are meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth. The word “Sprockets” may also be used to refer to the teeth on the wheel.[8]

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G. Ratchet mechanism

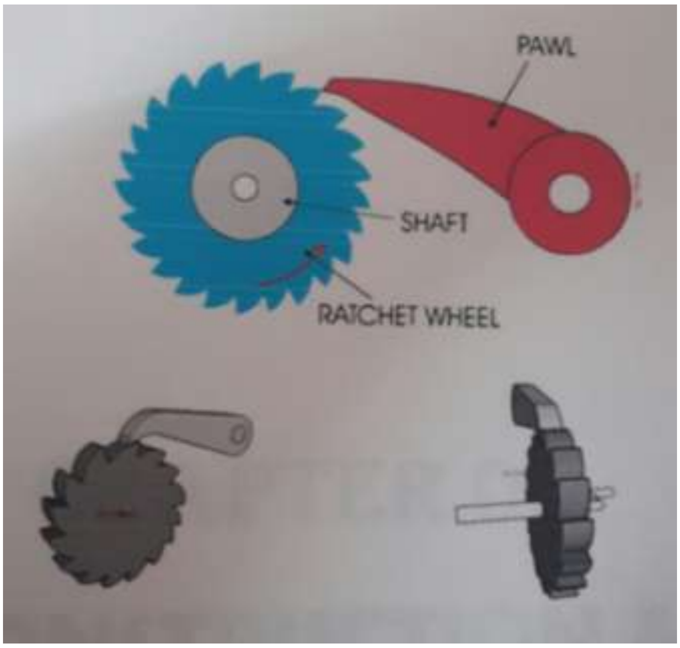

Figure 6. Ratchet mechanism

A ratchet mechanism is based on a wheel that has teeth cut out of it and a pawl that follows as the wheel turns. Studying the diagram you will see that as the ratchet wheel turns and the pawl falls into the 'dip' between the teeth. The ratchets wheel can only turn in one direction in this case anticlockwise.Power Transmission from pedal shaft to the rear axle shaft of tricycle is achieved in two stages.First Stage:- In this stage pedal shaft drive the shaft a by giving the rotation to sprocket 'B'. Since sprocket 'C' is also mounted on shaft 'a',it rotates with the same speed as that of sprocket 'B'.Second Stage:- In second stage sprocket 'C' will drive multiple sprocket 'H' mounted on rear axle shaft which will tend to drive rear wheel of the tricycle. By employing a neutral gear in multiple sprocket transmission of power can be disrupted and rear wheel will not rotate keeping tricycle stationary.Stages of Power Flow:-

H. Compressor operating mode:-

Power transmission: -

A ⇨ ⇨ **D** ⇨ ⇨ **G** ⇨ ⇨

I ⇳

I. Tricycle and Compressor simultaneously Operating:-

Power Transmission:-

Tricycle:- **A** ⇨ **H** ⇨

Compressor:-**A** ⇨ ⇨ **E** ⇨ ⇨ ⇨

J. Tricycle Operating Mode:-

Power Transmission:- **A** ⇨ ⇨

IV. DESIGN CALCULATIONS

A. Design of Flywheel

Nmax =592.92 rpm

Wmax=62.09

Nmin=506.94

Wmin= 53.08

Nmean=549.93

K_s= (Wmax –Wmin)/Wmean

K_s =0.1564

Rim cross Section

b=50 mm

K=Dm/2

Do=580 mm = 0.58m

b=2h

50=2h

H=25

Do= Dm+h

0.58=Dm+0.025

Dm=0.555

Now,

K=Dm/2=0.27

Assume that rim provides 95% of the required moment of inertia

$0.95I=mk^2$

I= (44*0.272)/0.95

$I=3.376$ kg.m^2

Maximum fluctuation of energy (ΔE)

(ΔE)= [(W/g)*K]K_s* Wm^2

=[(44*0.27)*0.156*57.582]

=1663.26 J or N-m

Coefficient of fluctuation of energy (C_e)

C_e = E/WD

WD= P*60/n

WD= 0.109104 P

Take,

C_e= 1.93 (For single cylinder and single acting)

1.93= 1663.26/0.109104 P

P= 7898.81 W

If surface speed Vs = 1600 m/min

Than P< 75 KW table (Table XI-6)

P=2πNT/60

T=137.15 N-m

Weight of flywheel = Area *length* density

=A*πDm*ρ

A= m/πDm*ρ

ρ =7.2 gm/cm^3 =7200 kg/cm^3 (Table II-2)

A= 0.003536 m^2

Stress in the Rim (Table XI-6)

Nmean= 549.93

Vs = πDoN/60

Vs =16.7 m/s

$\sigma_1 = \rho\ Vs_2$

=7200*16.72

=2*106 N/m^2

=2 Mpa

Since it is less than 8 Mpa

Hance design is safe

$\sigma_2 = \pi^2$ * Vs *ρ *Do / L_2 * h

L = no of arms =6

σ_2 = 12.77*106 N/m^2

=12.77 Mpa

It is the range (35-40) Mpa

Hence design is safe

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$\sigma_3 = 0.75 * \sigma_1 + 0.25 * \sigma_2$
$= 0.75*2 + 0.25*12.77$
$= 4.96$
$\sigma_3 = 35$ Mpa

Hence design is safe

B. *HUMAN EFFORT CALCULATIONS*

Input calculations on the basis of applied force of 50.96 Kg or 500 Newton.

T =F× D
=500×0.180
T=90 N-m

P=2πNT/60
P=282.743 watt Or P=0.37 Hp
Where,
T-Torque (N-m)
F-Applied Force (N)
D-Perpendicular Distance or Crank Length (m)
P-Power Input (watt)
N-Speed (Rpm)
(Assume N=30 Rpm)
Input Calculation on the basis of Normally Applied Force of 30.58 Kg or 300n
T=F×D
=300×.180
T = 54 N-m
P=2πNT/60

P=169.646 watt or 0.22 Hp

Output Calculation on the basis of Initial Applied Force of 50.96 Kg or 500 N

No. Of Stages	Gear No.	No. Of Teeth	V.R	Speed(N) (Rpm)	Torque(T) (N-m)	Power(P) (Hp)
First		Sb=48		30	90	0.37
		Ss =24	2	60	42.3	0.35
Second		Sb =48		60	42.3	0.35
	1st	Ss =28	1.71	102	23.99	0.34
	2nd	Ss =24	2	120	20.51	0.34
	3rd	Ss =20	2.40	144	17.09	0.34
	Neutral	Ss =17	2.82	168	---	---
	4th	Ss =14	3.42	205	11.99	0.34
Third		Sb =42		102	23.99	0.34
		Sb =42		120	20.51	0.34
		Sb =42		144	17.09	0.34
		Sb =42		205	11.99	0.34
Effect of 1st		Ss=14	3	306	7.51	0.32
		Ss=14	3	360	6.42	0.32
		Ss=14	3	432	5.35	0.32
		Ss=14	3	615	3.75	0.32

TABLE I. OUTPUT CALCULATION ON THE BASIS OF INITIAL APPLIED FORCE OF 50.96 KG OR 500 N

Where,

Sb- No. Of teeth on Bigger Sprocket
Ss- No. of teeth on Smaller Sprocket

- Neglect the effect of friction less on speed.
- Consider Reduction in Torque due to friction loss.
- Assume Friction loss as in 1st stage=6%

Output Calculation on the basis of Normal Applied Force of 30.58 Kg or 300 N

No. Of Stages	Gear No.	No. Of Teeth	V. R	Speed(N) (Rpm)	Torque(T) (N-m)	Power(P) (Hp)
First		Sb=48		30	54	0.22
		Ss =24	2	60	25.38	0.21
Second		Sb =48		60	25.38	0.21
	1st	Ss =28	1.71	102	14.39	0.20
	2nd	Ss =24	2	120	12.30	0.20
	3rd	Ss =20	2.40	144	10.25	0.20
	Neutral	Ss =17	2.82	168	---	---
	4th	Ss =14	3.42	205	7.19	0.20
Third		Sb =42		102	14.39	0.20
		Sb =42		120	12.30	0.20
		Sb =42		144	10.25	0.20
		Sb =42		205	7.19	0.20
Effect of 1st		Ss=14	3	306	4.50	0.19
		Ss=1	3	360	3.85	0.19

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		4				
		Ss=14	3	432	3.29	0.19
		Ss=14	3	615	2.25	0.19

TABLE II. OUTPUT CALCULATION ON THE BASIS OF NORMAL APPLIED FORCE OF 30.58 KG OR 300 N

C. Compressor Specifications:-

1. Single cylinder ,Single Acting ,Reciprocating Engine
2. Power(P) =0.19 Hp
3. Speed (N)= 615 rpm
4. Torque(T) = 2.25 n-m
5. Tank Volume (V) = 33.81 Psi or 2.33 Bar.
6. Bore × Stroke =57 mm × 40 mm
7. Piston Displacement (CFM) = 3.1
8. SCFM = Cylinder Area × Stroke Length × Speed

$$= \pi/4*d^2*l*N/2$$
$$= 0.0313\ m^3/min$$
$$SCFM = 1.1075\ ft^3\ /min$$

D. POWER CALCULATION

Power calculation for Adiabatic Compression of air can be expressed as,

$$HP = \left(\frac{144 \times N \times P1 \times V \times k}{33000(k-1)}\right)\left(\left(\frac{P2}{P1}\right)^{\left(\frac{k-1}{N.k}\right)} - 1\right)$$

$$0.19 = \left(\frac{144 \times N \times 14.1 \times 3.1 \times 1.41}{33000(1.41-1)}\right)\left(\left(\frac{P2}{14.1}\right)^{\left(\frac{1.41-1}{1 \times 1.41}\right)} - 1\right)$$

$$P_2 = 33.81\ Psi$$

Where ,
HP- Horse Power
N - no of Compressor Stages
K - 1.41 (Adiabatic)
P_1 - Absolute Initial Atmospheric Pressure (Psi)
P_2 - Absolute Final Pressure after compression(Psi)
V – Volume of Air at atmospheric pressure (CFM)
Adiabatic compression or expansion takes place without transmission of heat.

E. Air Tank Filling Time Calculation

Approximate time for air tank filling at 33.81 Psi is given by,

Time = V*[(P2+P1)/P1]/U
Time = 4.33 min
Or Time= 4 min & 19 sec
Where,
V-Air Tank Volume (cubic foot)
U-SCFM
P1- Initial Atmospheric Pressure (Psi)
P2- Final Pressure after Compression (Psi)

V. FACTS AND FIGURE OF ELECTRIC MOTOR DRIVER RECIPROCATING AIR COMPRESSOR

Parameter	Electric motor	Air Compressor
Power (P)	0.5 Hp	0.4 Hp
Torque (T)	2.47 N-m	4.74 N-m
Speed (N)	1440 Rpm	600 Rpm

TABLE III. FACTS AND FIGURE OF ELECTRIC MOTOR DRIVER RECIPROCATING AIR COMPRESSOR

Other Parameters,
Velocity Ratio = 2.4
Working Presser = 72.5 Psi or 5bar
Transmission = Belt Drive

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