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Design and Development of Human Operated Flywheel to Generate Electricity

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Abstract

Power Generation Using human effort is a force for the future. With increasing demand for fuel and a new source of energy, development of human powered generators become a necessity. The most famous human powered generator is dynamo. On similar lines various human powered generators like backpack generators, biomechanical energy harvester and shoe generator are being developed. These harvesters are under development and are considered one of the best inventions of recent times. One such way is to develop alternate source of energy which will help us to save energy. Geothermal energy, biogas, solar energy, wind energy are various forms of energy which are used alternatively today. One such source of energy is Human Power. Human power is an endless source of energy which has been wasted. The energy is stored in a mechanical form and retransmitted to the wheel in order to help the acceleration. Electric vehicles and hybrid have a similar system called Regenerative Brake which restores the energy in the batteries. The device recovers the kinetic energy that is present in the waste heat created by the car's braking process. It stores that energy and converts it into power that can be called upon to boost acceleration. There are principally two types of system - battery (electrical) and flywheel (mechanical). Electrical systems use a motor-generator incorporated in the car's transmission which converts mechanical energy into electrical energy and vice versa.

Keywords: Human Power machine, Bicycle, Technology, Dinapod, Flywheel.

1. INTRODUCTION

In a world with growing demand for energy, it has become a necessity for alternate source of energy. As a result various inventions have been made to overcome the issue. Increasing efficiency of electrical and mechanical products has been one of the ways to reduce energy consumption. These techniques are useful for reducing energy consumption. One such way is to develop alternate source of energy which will help us to save energy.. One such source of energy is Human Power. Human power is an endless source of energy which has been wasted. Humans eat food and spend it on his work without proper conversion of energy. This paper brings to light various benefits of human power also the harvesters used to utilize this power.

Humans are a rich source of energy. An average-sized person stores as much energy in fat as a 1000-kg battery (1, 2). People use muscle to convert this stored chemical energy into positive mechanical work with peak efficiencies of about 25% (3). This work can be performed at a high rate, with 100 W easily sustainable (1). Many devices take advantage of human power capacity to produce electricity, including hand-crank generators as well as wind-up flashlights, radios, and mobile phone chargers (4). A limitation of these conventional methods is that users must focus their attention on power generation at the expense of other activities, typically resulting in short bouts of generation. For electrical power generation over longer durations, it would be desirable to harvest energy from everyday activities such as walking.

2. DESIGN

A. General Design Consideration

Generally, the design of this system depends primarily on the ratings of the DC permanent magnets which produce the DC and the required output power. The output power to be produced affects the dimensioning as well as the input parameters like torque, speed, etc. In light of the above constraints, the following design considerations and assumptions have been made for this project design.

i. Sizing and economic considerations:

This system is design to compact in consideration of the power requirement as well as reduction in the cost of fabrication. For affordability, the device is relatively small.

ii. Safety Considerations:

This system is design in such a way that women and children can use it for sustained period of time. It preserves the safety of our immediate environment from noise and air pollution because it's noiseless and smokeless. Stability of the unit was also considered to ensure that the equipment remains upright at all time, i.e. it should not drift or bend to one direction and it should remain stationary.

iii. Ergonomics:

The ergonomics aspect has to do with optimizing the physical contact between human and the equipment. Four important areas of bike ergonomics are usually considered:

- The strain of the arm and shoulder
- The muscle support and the position of the lower back
- The work of proper pedaling
- The crank length

iv. Technological consideration:

The design of this system is well considered in such a manner that it can be produced within the technology of our immediate environment.

B. Frame Design

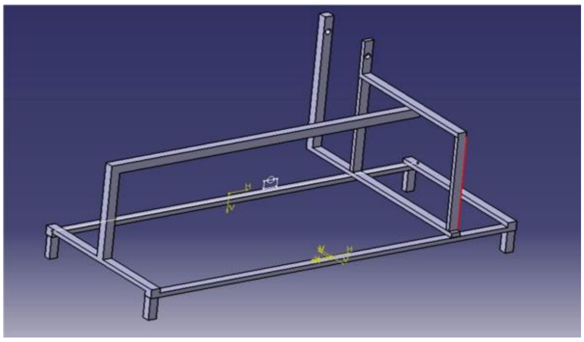

Fig. 1: Catia Design of Frame

One of the key elements of the design process of objects under cyclical changing loading is the knowledge of service load history. It is especially important in the case of the bike exerciser in which components are under threat of fatigue damage formation because of the diversified influence of many factors of deterministic and random nature. Bike frames encounter a complex set of stresses which in most cases cannot be calculated by hand. Therefore, in designing a frame, engineers usually makes use of an older design which has proven reliable as a starting point. The frame of the POPG was designed to replicate a typical Schwinn DX bike exerciser with little modifications on the materials used in order to minimize cost and also considering availability of materials. The materials used for exercise bike frames have a wide range of mechanical properties. For most bike builders, steel is the material of choice; steel bikes impart a certain level of confidence in the ability of the bike. It provides the ideal combination of performance and purchase cost. They can be inexpensively repaired and have the ability to reveal frame stress injuries before they become failures. When a steel frame breaks, it tends to break slowly rather than suddenly and they have the ability to store and release energy at different degrees of the pedal strokes. The table below shows a breakdown of all the component part of the pedal system and the materials used.

Frame Dimensions

To ensure the safety of the user and promote efficient cycling, the dimensions of the bike and cyclist must be taken into account, along with the amount of lateral and vertical clearance needed, in the planning and design of bicycle facilities. The dimensions of a typical bicycle are a handlebar height of 43 –55 cm, handlebar width of 71 cm, and bicycle length of 168 - 170 cm.

They often provide little traction. The general dimensions adopted for the design was (1200 x 200 x 860) mm (MN/DOT, 2007)

System Force Torque and Power Input

This system is designed assuming the average mass of 65kg and pedaling time as 60mins. From reviewed literatures, the pedal input force; torque and power can be computed as below:

Input force

$F = mv/t$

Input Torque

$T = F \times R$

Input Power

$P=2\pi NT/60$

Power Output of the pedal systems Work on a bike exerciser is determined according to the basic work equation.

Work = Force Distance

The force is a friction resistance (T1) provided by the belt around the large flywheel. This belt can be tightened to varying degree to apply different amount of resistance. One revolution of the flywheel is equal to a distance computed as follows the circumference of the flywheel

$A=distance=2\pi r$ Therefore, the work can now be computed as

$Work=f*d=T1*2\pi r$

To determine the power, we now substitute the number of revolution done in a given period.

Power= work/time= T1*2πr*N

Pedal Mechanical Efficiency

Using the volume of oxygen consumed during exercising, the persons overall or gross mechanical efficiency can be computed as follows:

Power= T1*2πr*N

This power output is equivalent to 2.1 Kcal/min

Pedal Power input = Pin pedal = VO2 /min * 5Kcal/VO2 (3.10)

Expended Power in the Pedal system = Pout - Pin

Efficiency = Pout / Pin * 100

4) Gear Ratio

Khurmi and Gupta (2012) stated the gear ratio is also known as its speed ratio, is the ratio of the angular velocity of the input gear to the angular velocity of the output gear. The gear ratio can be calculated directly from the number of teeth on the gears in the system. This system is made up of 2 stage belt systems. The teeth on gears are designed so that the gars can roll on the chain link smoothly without slipping. The number of teeth on gear is proportional to the radius of its pitch circle, which means that the ratios of the gears' angular velocities, radii and number of teeth are equal. Mathematically,

$$\frac{\omega_A}{\omega_B} = \frac{R_B}{R_A} = \frac{N_B}{N_A} = \frac{D_B}{D_A}$$

Where wA,B = angular speed of sprocket A and B respectively

RA.B = Radius of sprocket A and B respectively

NA.B = Number of teeth on sprocket A and B respectively

DA.B = Diameter of sprocket A and B respectively

First stage gear system: The first stage gear system is comprised of the input pedal system and the output sprocket which is shown in the figure below:

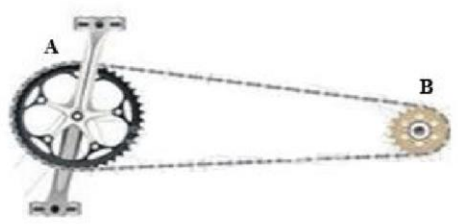

Fig 2: Chain Drive for Pedal and Gear

The gear system is made up of a driver toothed gear (A) which has 70 teeth and the driven gear (B) with 36 teeth. The 2 gears are linked with a chain.

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$$\frac{\omega_A}{\omega_B} = \frac{N_B}{N_A}$$

$$\omega_B = \frac{N_A}{N_B}\omega_A$$

The pitch P of a gear which is the distance between equivalent points on neighboring teeth along the pitch circle can be expressed as:

The pitch of the driver gear A can be computed from the number of teeth NA and the radius RA of its pitch circle as:

$$P_A = \frac{2\pi R_A}{N_A}$$

While the pitch of the driven gear B can be computed as:

$$P_B = \frac{2\pi R_B}{N_B}$$

The speed ratio can be obtained as:

$$S_R = \frac{N_B}{N_A}$$

Second state gear system (sizing of the pulley diameter)

The second stage belt system is composed of pulleys of different diameters which can be seen in the figure below:

To get the speed (rpm) of the flywheel, since the smaller sprocket in the first stage and the flywheel form a compound gear arrangement, they rotate at same speed, that is wB = wC

Given the Alternator's specifications, the motor's pulley diameter can be calculated by rearranging equation (3.14)

$$\frac{\omega_C}{\omega_D} = \frac{D_D}{D_C}$$

From equation, the pulley's diameter can be calculated as:

$$D_D = \frac{\omega_C \, X \, D_C}{\omega_D}$$

Where,

$\omega_{c,d}$ = Angular speed of flywheel and Alternator pulley respectively

$D_{C,D}$ = Diameter of flywheel and Alternator pulley respectively

Hence the overall gear ratio of the system can be expressed as: For the first stage gear system:

$$G_{R1} = \frac{N_B}{N_A}$$

For the second stage gear system;

$$G_{R2} = \frac{D_C}{D_D}$$

Then the overall gear ration (GR)

GR = GR1 X GR2

C. Flywheel Design

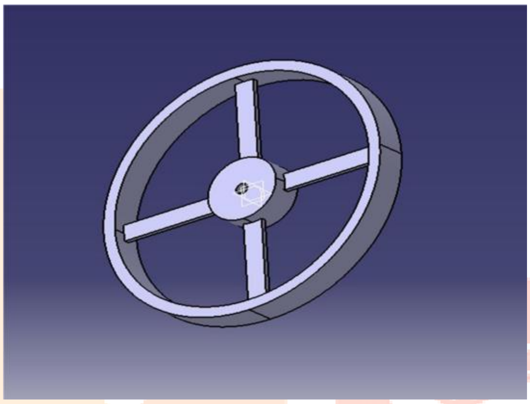

Fig. 3: Flywheel catia Design

Flywheels are designed to store and release kinetic energy. A Flywheel is disc-shaped, and true to its weight on all sides and locations of the disk. The flywheel is designed to provide a more steady flow of momentum. The size and weight of the flywheel will determine the amount of energy that can be produced from peddling the bike. The mechanical advantages of using a flywheel is that its energy output is consistent and, depending on the size of the flywheel, it is able to store and release great amounts of energy even after the peddling has ceased. The kinetic energy stored in the flywheel is given as:

K. E = $^1/_2$* I * w

Where,

I= Polar moment of Inertia

w=Angular velocity of flywheel

Two types of flywheel are available: Heavy and light flywheel:

- A heavy flywheel will take much more effort to get started but will be able to provide the steadiest flow of energy once the heavy weighted disk is in motion. The disadvantage in using a heavy flywheel to power a mechanical device is the individual peddling the bicycle would also have a hard time getting the wheel’s momentum engaged and would require more energy input than is required.

- A light flywheel will be easy to engage through peddling power. The amount of momentum is not as great as a heavier flywheel but will be sufficient enough to rotate the pulley of the DC permanent magnet without causing much stress on the individual. A flywheel weighing about 25 - 35 pounds is light enough for an individual to mechanically power.

  In the light of the above, the light flywheel scored higher than the heavy flywheel. Because the aesthetics of the drive is not crucial to the appearance of the design project in general, the use of the light flywheel for the final design is chosen over the use of the heavy flywheel.

Fig. 4: Overall system view

3. WORKING PRINCIPLE

Pedaling a modern stationary bicycle to produce electricity might be a great work-out, but in many cases, it is not sustainable. While humans are rather inefficient engines converting food into work, this is not the problem we want to address here; people have to move in order to stay healthy, so we might as well use that energy to operate machinery. The trouble is that the present approach to pedal power results in highly inefficient machines. When operating a bicycle generator you are basically pedaling to produce the energy required to manufacture the battery. There are two ways to power a device by pedaling. You can power it directly through a mechanical connection - as was the case with all pedal powered machines for sale at the turn of the 20th century. Or, you can pedal to generate electricity, which is then used to power the device. In the 1970s, most research was aimed at direct mechanical power transmission. Today, the interest in pedal powered machines is almost exclusively aimed at generating electricity, for instance for charging cell phones and laptops - products that did not even exist in the 1970s.With one exception (the 'Fender Blender', a pedaled powered machine to make smoothies), the only pedal powered machinery that is now commercially available in the western world (offered by Wind stream, Convergence Tech and Magnificent Revolution) are stands to fit your bike to, connected to an electric motor/generator and a battery - a combination that can quickly convert your regular road bicycle into an electricity generator. These are also the pedal powered machines which are used for educational and arts projects, like powering a music concert, a cinema projection or a supercomputer, or teaching kids the difference in energy use between, for instance, an incandescent light bulb and an energy saving lamp.

- Equipment Used

  The following equipment's were used:

  Tachometer – to measure the speed (rpm) of the Alternator

  Multi-meter – to measure the voltage and current produced from the Alternator.

4. OUTPUT & CALCULATION

Maximum rpm of Flywheel	=	600 rpm
Rotation of Pedal per min.	=	72 rotation
Ratio of pedal to Gear Wheel	=	1:2
Alternator Rotational Speed	=	1400 rpm
Voltage Output	=	14.2 Volt
Current Output	=	9.8 Amp.

Power = Voltage * Current [Watts]

Energy = Current * Time [Watt-hr.]

Energy Produced by cycling:

Peak Voltage is 14.2 V maximum by cyclist.

Power = Voltage * Current

= 14.2 * 9.8

= 139.16 watt

139.16 watt Energy is generated from this Model

Time elapsed for charging a 12 V battery:

7 hours by cyclist

Energy consumption:

It consume 0.1 V in 10 minutes for a 10 Watt LED bulb so LED bulb Continue lighting 15 hour.

5. CONCLUSION

Human powered generators are the future of human kind. If mobile phone, laptops get charged while doing our daily chores it will reduce consumption of power to substantial value. This technology requires development but is a proper solution to our energy woes. Biomechanical energy harvester has been rated among the 50 best inventions of 2008. Development of power generating gym equipment will result into a wonderful development in human powered generators.

In concluding the words of our project, since the power generation using gym get its energy requirements from the Non-renewable source of energy. There is no need of power from the mains and there is less pollution in this source of energy. It is very useful to gym and house hold and gyms.

Generated Electricity form our system is Renewable Energy Source.

It's total Pollution free means Save Environment as well as Earth.

Exercise is important for human health so our device exercised also done.

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 economic condition and employability of such countries in backward or remote areas.

This system is only used for small type of devices not Suitable for heavy devices

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 areas.

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