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ENERGY HARVESTING USING BACKPACK

(Submitted in partial fulfilment of the Requirements of B.Tech Degree Course in

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ISSN No: - 2456 - 2165

ABSTRACT

This study develops a novel energy harvesting backpack that can generate electrical energy from the differential forces between the wearer and the pack. The goal of this system is to make the energy harvesting device transparent to the wearer such that his or her endurance and dexterity is not compromised. We have developed the suspended-load backpack, which converts mechanical energy from the vertical movement of carried loads to electricity during normal walking [generating up to 7.4 watt].A Suspended load back pack designed to permit the load to move relative to the back pack frame during walking and running. The large movement between the load and the frame of the back pack reduced the fluctuations of absolute vertical motion of the load. This motion of the load is transferred to a motor (generator) through a rack and pinion gear and converts the mechanical movement to electrical energy. This electricity generation can help give field scientists, explorers, and disaster-relief workers freedom from the heavy weight of replacement batteries and thereby extend their ability to operate in remote areas.

ISSN No: - 2456 - 2165

CHAPTER 1

INTRODUCTION

Harvesting energy from everyday mechanical interactions offers a potentially significant benefit. Such mechanical interactions can vary in magnitude from the motion of a wristwatch, to a large scale ocean wave energy harvesting. The harvesting of energy from natural and existing mechanical interactions has the potential to reduce our drain on non-renewable energy sources. Many such mechanical interactions exhibit motion that is sinusoidal in nature, which allows for the harvesting of energy due to the displacement and force of the mechanical action. Recent work has led to the development of energy harvesting mechanisms in many forms for many applications.

The "energy harvesting backpack" is a general term for a backpack capable of harvesting mechanical energy from the user's walking motion. The method of energy generation and storage is highly variable depending on the specific application. The vertical motion of the backpack has the greatest potential for energy harvesting, while walking the potential of the energy harvesting backpack is that the user is already carrying a large mass, which can be utilized to help generate energy from the periodic motion of the load. The challenge is to develop a mechanical system that would allow for the most efficient harvesting of the energy that would normally be used to oscillate the backpack**.**

CHAPTER 2

LITERATURE SURVEY

The increasing use of portable electronic devices has created a corresponding need to power these devices. In recent years an interest has developed in generating electricity from human movement, especially movement associated with the user's everyday actions.

Mateu et al proposed to harvest energy by using piezoelectric film-bending beams inside a shoe, and use part of the mechanical energy employed during normal walking activity to generate electricity.

Duffy et al. instead applied an electromagnetic generator integrated into the shoes to generate energy. However, during all the researches focusing on shoe applications, the maximum power reported is only 0.8W. Another energy harvesting approach is to use a knee-mounted energy harvester to generate electricity during the passive work of walking, as proposed by Donelan et al. in and 7W power was reported to be harvested. Apart from generating power from human motion, Mateu et al also proposed to harvest energy from heat radiated by the human body using thermo generators. In this case power levels generated are in the MW range. Another approach to human-based energy harvesting is based upon the movement of a backpack or rucksack. This approach is promising in that the movement of a backpack can introduce both large force and large displacement, and so much more potential power is available compared to other methods.

Granstrom et al proposed a backpack-based energy harvesting approach by using a piezoelectric polymer Polyvinylidene fluoride (PVDF) strap, which utilizes the differential forces between wearer and backpack to generate electric energy .The advantage of this design is that it has a minimum parasitic effect on the human body, and almost adds no additional mass to the backpack. However, in this work only 45.6mW power was harvested for 100lb backpack load.

Rome et al instead proposed an approach that has been shown to be quite effective, a backpack design where the pack itself constitutes the mass of a spring-mass system. When the walking gait of the wearer excites this system at or near the resonant frequency of this system, the displacement of the backpack mass can become quite large. By converting the linear motion of the backpack into rotational motion via a rack-and-pinion gear, a magnetic-field-based generator can be cuts and hence generate electrical power. The system can also provide ergonomic benefits to the wearer .

A key aspect of this system is the power electronic circuitry that converts the output of the generator into a usable form. Elmes et al, who proposed a similar backpack-based energy harvesting system but with a linear generator, used a PFC boost converter which emulated a resistive load to improve generator efficiency. Testing of their generator and circuit, however, was limited to a laboratory test bed rather than an actual backpack. This paper will present a design of a power electronic interface circuit for the backpack energy harvesting system reported by Rome et al. The circuitry applies a power electronic Single-Ended Primary Inductor Converter (SEPIC). The SEPIC converter has the advantage of being a buck/boost converter, and so its output voltage can be either less than or greater than the input voltage. This is a convenient feature due to the varying nature of the input voltage with backpack velocity, and the output voltage due to the amount of energy stored. Furthermore, the SEPIC converter topology has an inductor at its input, allowing the regulation of the input current. By regulating the input current to be proportional to the input voltage, the input terminals of the converter emulate a resistive load.

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ISSN No: - 2456 - 2165

CHAPTER 3

COMPONENTS AND DESCRIPTION

The components that are used in the project ENERGY HARVESTING USING BACKPACK are as follows,

- Supporting Frame,
- Guide Rod,
- Guide Bush,
- Rack and pinion gear arrangement,
- Load plate,
- Spring,
- Generator,
- Battery charging unit.

3.1 SUPPORTING FRAME

The frame is the supporting part of the all components of the energy harvesting backpack mechanism. The vertical guide rods, springs, load plate, backpack (load) are attached to the frame .It is usually a rectangular section made up of solid or hollow pipe. The arm strap is also connected to the frame.

Fig.3.1 Square hollow M.S pipe

3.2 GUIDE ROD

It is a vertical element which supports the load plate. The guide rod is attached to the frame. Guide bush is slides through the guide rod. The load plate is attached to the guide bush and it cause the load plate slide though the rod in up and down motion.

Fig 3.2 Guide rod & bush

3.3 GUIDE BUSH

Guide bush is slides through the guide rod. The load plate is attached to the guide bush and It can cause the load plate slides through the rod during walking with load. So the up and down movement is obtained. Ref fig 3.2.

ISSN No: - 2456 - 2165

3.4 RACK AND PINION MECHANISM

Fig 3.3 Rack & Pinion

A rack and pinion is type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion. A circular gear is called the Pinion engages teeth on a linear gear bar called the Rack, rotational motion applied to the pinion causes the rack to move relative to the pinion ,thereby translating the rotational motion of the pinion into linear motion. The rack is a portion of a gear having an infinite pitch diameter and the line of action is tangent to the pinion. The rack and pinion is mostly used for the timing and the reverse mode of the operation of the system. In this project the rack and the pinion is used for transferring the liner motion of the load plate into rotary motion.

Pinion:

This is a gear wheel which is provided to get mesh with rack to convert the linear motion into rotary motion. They are made up of Mild Steel. The pinion is connected to the dynamo. Due to the rotary motion of the pinion can rotate the dynamo and produce electric power.

Rack:

Rack teeth are cut horizontally about the required length. This is made up of Mild Steel. The rack is connected to the frame which is mesh with the pinion gear.

3.5 LOAD PLATE

Load plate is attached to guide bush and it is slide thorough the guide rod. The load or bag is fixed on the load plate. During walking with load the load on the load plate move relative to the body movement and the load plate moves up and down motion. It is a flat rectangular plate.

Fig 3.4 Flat plate

3.6 GENERATOR

Dynamos and generators convert the mechanical rotation into electric power. Its commonly works using the phenomena of electromagnetism. The generator or dynamo is made up of stationary magnets (stator) which create a powerful magnetic field, and a rotating magnet (rotor) which distorts the magnetic lines of flux of stator. Then according to the Faraday's law of electromagnetic induction, whenever the rotor cuts through the lines of magnetic flux it makes electricity.

Here the pinion gear is coupled with the dynamo. During walking with backpack, the relative movement between the shoulder and the frame cause the rack and pinion to move up and down .The up and down movement of the rack with respect to the pinion gear turns the generator shaft and thereby produce the electric current

Fig. 3.5 Dynamo coupled with pinion gear

3.7 SPRING

Fig 3.6 spring

A spring is an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Springs are usually made out of spring steel. Helical springs are made up of a wire coiled in the form of a helix and are primarily intended for compressive or tensile loads. The cross section of the wire from which the spring is made may be circular, square or rectangular. Helical compression springs have applications to resist applied compression forces or in the push mode, store energy to provide the push. The helical spring are said to be closely coiled when the spring wire is coiled so close that the plane containing each turn is nearly at right angles to the axis of helix and the helix angle is small .It is usually less than10 degree.tto or the major stresses produced in helical springs are shear stresses due to twisting. The load applied is parallel to or along the axis of the spring. In open coiled helical spring , the spring wire is coiled in such a way that there is a gap between the two consecutive turns, as a result of which helix angle is large. In the energy harvesting mechanism the load plate is attached to the frame by means of the helical compression spring over the guide rod. So the oscillatory movement is provided by the spring.

3.8 BATTERY CHARGING UNIT

The output of the dynamo (Dc generator) is connected to a electronic charging unit. It consists of the following components,

1. Rectifier
2. Filter

3. Battery charger
4. Battery pack

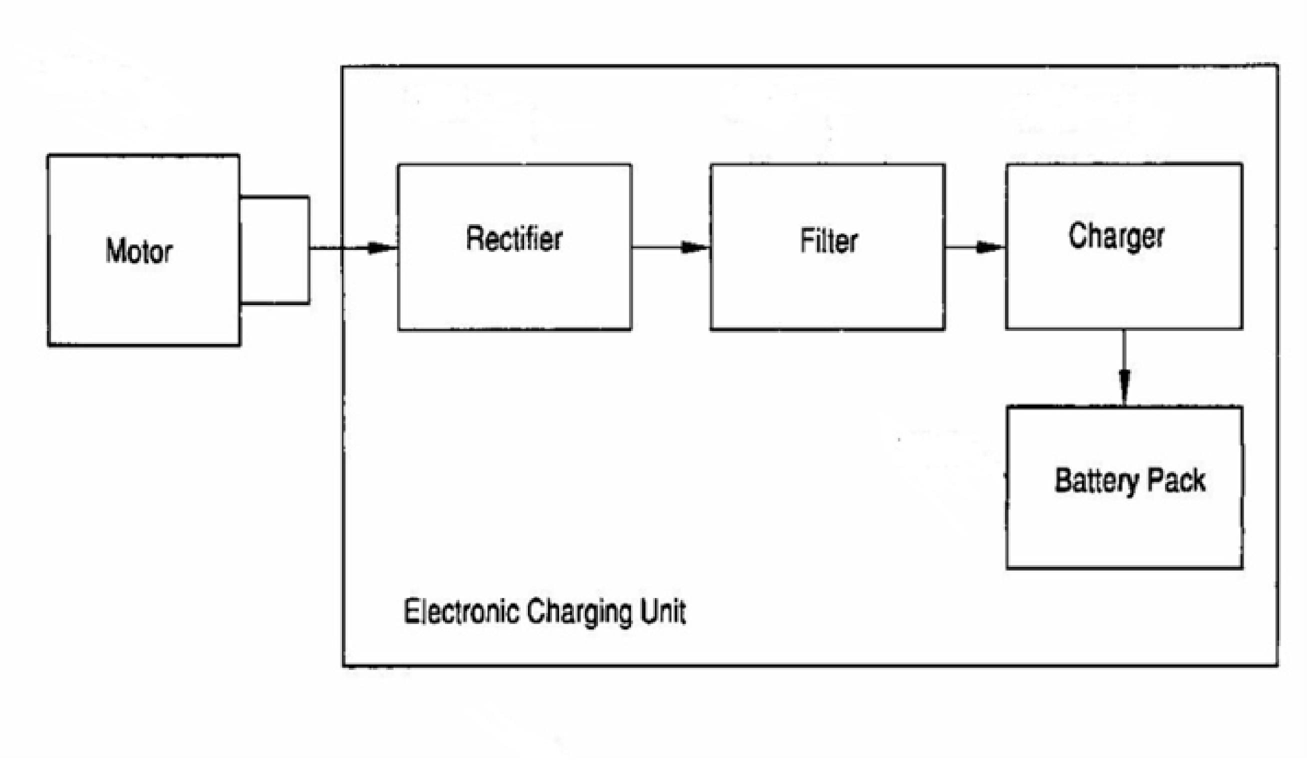

Fig 3.8 Battery charging unit

The output current produced by the dynamo is in the form of alternating nature. So this alternating current is rectified by using a rectifier. Then it is filtered by a capacitive filter before being provided to a battery charger for recharging the batteries as well as the electronic equipment such as mobile phone etc.

3.9 LITHIUM POLYMER BATTERY

Fig 3.9 Li-Polymer Battery

A lithium polymer battery, or more correctly lithium-ion polymer battery (LiPo), is rechargeable battery of lithium ion technology in a pouch format. Unlike cylindrical and prismatic cells, LiPos come in a soft package or pouch, which makes them lighter but also less rigid.

This is currently the most popular use, in which "polymer" refers more to a "polymer casing"(the soft, external container) rather than a "polymer electrolyte". While the design is usually flat, and lightweight, it is not truly a polymer cell, since the electrolyte is still in liquid form, although it may be “plasticized" or "gelled" through a polymer additive. These cells are sometimes designated as "Li Po"; however, from a technological point of view, they are the same as the ones marketed simply as "Li-ion", since the underlying electrochemistry’s the same. LiPos work on the principle of intercalation and de-intercalation of lithium ions from a positive electrode material and a negative electrode material, with the liquid electrolyte providing a conductive medium. To prevent the electrodes from touching each other directly, a micro porous separator is in between which allows only the ions and not the electrode particles to migrate from one side to the other.
Just as with other kinds of lithium-ion cells, the voltage of a LiPo cell depends on its chemistry and varies from about 2.7-3.0 V (discharged) to about 4.20-4.35 V (fully charged), for cells based on lithium-metal-oxides (such as $LiCoO_2$), and around 1.8-2.0 V (discharged) to 3.6-3.8 V (charged) for those based on lithium-iron-phosphate ($LiFePO_4$).

ISSN No: - 2456 - 2165

CHAPTER 4

COMPONENT SPECIFICATION

COMPONENTS	SPECIFICATION	MATERIAL
Hollow Square pipe (Vertical)	20×20×400 mm	Mild Steel
Hollow Square pipe (Horizontal)	20×20×300 mm.	Mild Steel
Guide rod	Ø15 mm	Mild Steel
Guide Bush	OD 25mm ID 16 mm	Mild Steel
Spring(Compression)	Ø20 mm,200 mm length	Spring steel
Rack	12×12×400 mm 2.5 mm module	Mild Steel
Pinion	Ø45 mm 18 teeth	Mild Steel
Load plate	250×250×2.5 mm	Mild Steel
Dynamo	12 V,20 W DC	Standard
Shoulder strap		Bag Material

ISSN No: - 2456 - 2165

CHAPTER 5

DESIGN CALCULATIONS

5.1. RACK

Number of teeth =70

Length of rack =400 mm

Width of rack =12 mm

Thickness of rack =12 mm

Pressure angle of rack =20 degree full depth system

Module of rack(m) =2.5 mm

Pitch of the rack = $\pi \times m$

$=3.14\times2.5$

$=7.85$ mm

Addendum (a) = 1m

$=1\times2.5$

=2.5 mm

Dedendum (d) = 1.25m

=1.25×2.5

=3.125 mm

Tooth depth (h) =2.25m

=2.25×2.5

=5.625 mm

Working depth (hw) =2m

=2×2.5

=5 mm

Tip and root clearance(c) =0.25m

=0.25×2.5

=.625 mm

5.2.PINION

Diameter of the pinion(D)=45 mm

Number of teeth(T)=18

Thickness of the pinion=10 mm

Module =D/T

= 45/18

=2.5 mm

Pressure angle = 20 degree full depth system

Addendum (a) =1m

=1×2.5

=2.5 mm

Dedendum (d) =1.25m

=1.25×2.5

ISSN No: - 2456 - 2165

=3.125 mm

Circular pitch (Pc) =π×D/T

=3.14×45/18

=7.85 mm

Diametrical pitch (Pd) =T/D

=18/45

=0.4 mm

5.3 SPRING CALCULATIONS

Spring diameter (Do) = 20 mm

Wire diameter (d) = 2 mm

Length of spring (L) = 200 mm

Mean diameter of spring (D) = Do-d

=20-2

ISSN No: - 2456 - 2165

=18 mm

Number of coils = 26

Shear modulus of material (G) = $\frac{E}{2(1+U)}$

Where, G=modulus of rigidity in N/mm^2

E=Young's modulus of elasticity

=210×10^3 N/mm^2

U=Poisson's ratio

=0.3

Modulus of rigidity (G) = $\frac{210\times10^3}{2(1+0.3)}$

=8.076×10^4 N/mm^2

Spring stiffness(K) = $\frac{Gd^4}{8nD^3}$

Where, G= modulus of rigidity in N/mm^2

= 8.076×10^4 N/mm^2

d = wire diameter of the spring

= 2 mm

n =Number of coils

=26

D=mean diameter of the spring

=18 mm

Spring stiffness (K) = $\frac{(8.076\times10^4)\times2^4}{8\times26\times18^3}$

$= \frac{1292160}{1213056}$

=1.065 Nmm

Spring geometry

Pitch (p) =L/N

=200/16

=7.692 mm

ISSN No: - 2456 - 2165

Angle of spring coils (α) = $\tan^{-1}\frac{p}{\pi D}$

$$=\tan^{-1}\frac{7.692}{3.14\times18} = 7.749 \text{ degree}$$

5.4 CURRENT CALCULATION

5.1.4.1 Work generated with a 20 kg load

Force = Mass×Acceleration due to gravity

=20×9.81 =196.2 N

Work = Force × Displacement

= 196.2 × 0.05

= 9.81 Joules

Power generated = 9.81 J × 2 steps/sec

= 19.62 W

= appr. 20 W

5.1.4.2 From the Generator (20 KW,12 V, DC)

Power,P = 20 W

ISSN No: - 2456 - 2165

Voltage, V= 12 V

Current produced, I = P/V

= 20/12

= 1.67 A

5.1.4.3 From the experimental analysis

Voltage produced, V = 3.25 V

Current produced, I = 0.3 A

Power produced, P = V × I

= 3.25 × 0.3

= 0.975 W

ISSN No: - 2456 - 2165

CHAPTER 6

WORKING PRINCIPLE

The basic principle of the power production using the vibrative pressure of the back pack on the shoulders. This setup consists of the frame on which the vertical column is placed on it and the springs are placed on them for the retracting action of the load. It has a load plate on which the load such as the bag or the load weight.

When the weight is kept on the load plate and when the man is in the motion due to the spring action the load plate reciprocates or oscillates along the path. It is connected to the rack arrangement and the pinion gear is attached to the dc generator which when oscillates the DC generator shaft is made to rotate and small amount of the power is generated inside the generator and the produced power can be transferred through the wire connection to the battery and save it for the future usages.

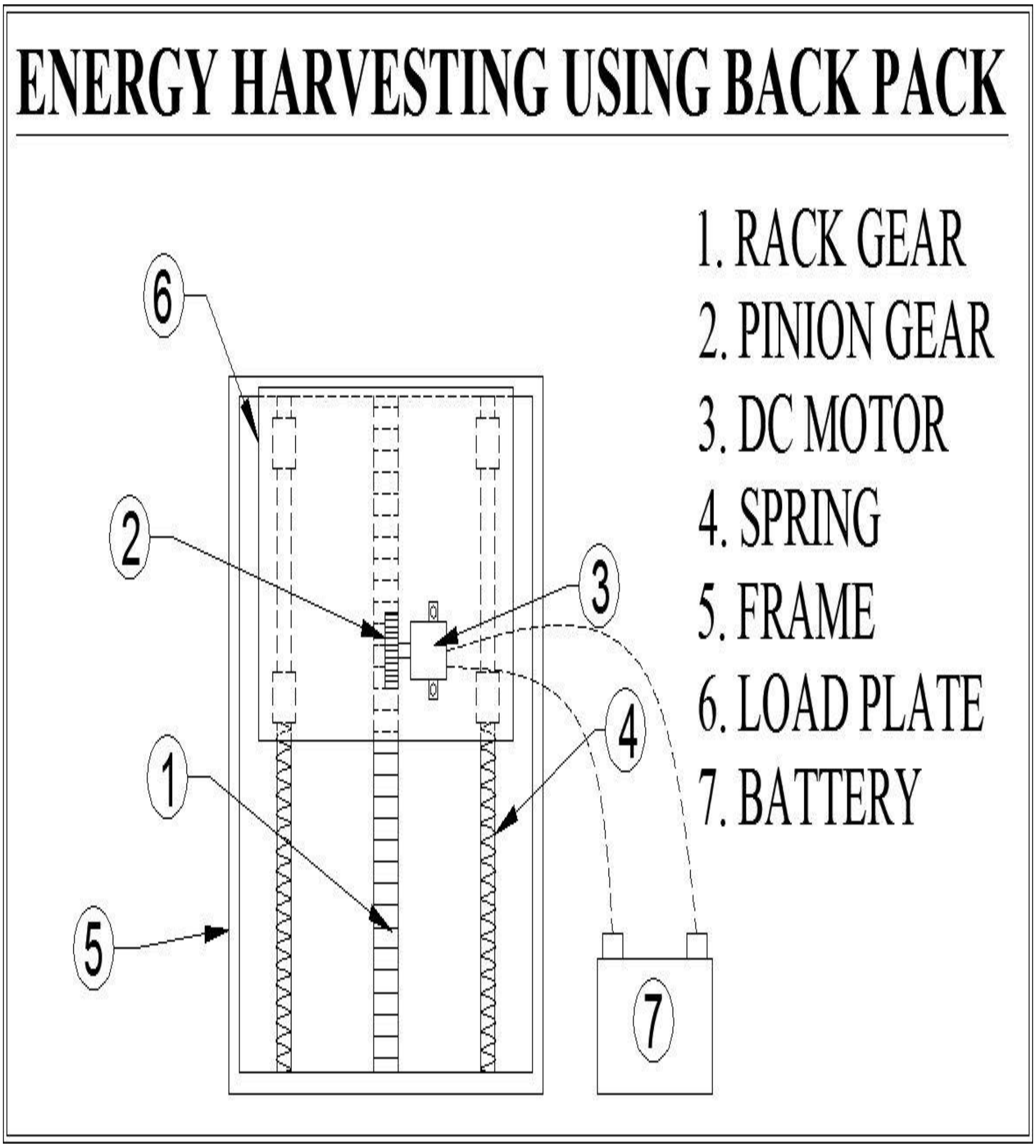

Fig 6.1 2D DRAWING

CHAPTER 7

APPLICATION

- It can be used for commercial power generation system.
- Useful in power generation during Military purpose.
- Power generation while Trucking.
- Mobile charging.
- Laptop charging.
- Charging of torch.

ISSN No: - 2456 - 2165

CHAPTER 8

FUTURE SCOPE

Biomechanical energy harvesting from human motion presents a promising clean alternative to electrical power supplied by batteries for portable electronic devices and for computerized and motorized prosthetics. We present the theory of energy harvesting from the human body and describe the amount of energy that can be harvested from body heat and from motions of various parts of the body during walking, such as heel strike; ankle, knee, hip, shoulder, and elbow joint motion; and center of mass vertical motion.

ISSN No: - 2456 - 2165

CHAPTER 9

9.1 WEIGHT COMPARISON

9.1.1 WEIGHT CALCULATIONS OF THE MODEL PRODUCE

9.1.1.1 Weight of supporting frame

Hollow square pipe (vertical) = 20×20×1mm 400 mm long (2 Nos.)

Hollow square pipe (horizontal) = 20×20×1mm 300mm long (2 Nos.)

Volume of the frame = 2(b×t×l) + 2(b×t×l)

= 2(20×1×400 + 2(20×1×300)

= 16000+12000

= 28000mm^3

Density of mild steel = 0.00785 g/mm^3

Weight of frame = volume of frame ×

Density of mild steel

=28000×0.00785

=219.8 g

9.1.1.2 Weight of guide rod (2nos)

Diameter of rod =15 mm

Length of rod =360 mm

Volume of rod =2(πr^2l)

=2(3.14×7.5^2×360)

=127170 mm^3

Density of Mild Steel =0.00785 g/mm^3

Weight of vertical rod = Volume of the guide rod ×

Density of mild steel

=127170×0.00785

=998.28 g

9.1.1.3 Guide bush (4 Nos.)

ISSN No: - 2456 - 2165

Outer diameter of guide bush = 25mm

Inner diameter of guide bush =16mm

Height of guide bush =30mm

Volume of guide bush = 4 (πh(R^2 - r^2))

=4 (π×30× (12.5^2 - 8^2))

= 3759.8 mm^3

Density of mild steel =0.00785 g/mm^3

Weight of the guide bush = 34759×0.00785

=272.86g

9.1.1.4 Rack and pinion

Diameter of pinion = 45mm

Dimension of rack =12×12×360

Volume of pinion and rack = (π×r^2×h) + (b×t×h)

= (π×22.5^2×10) + (12×12×360)

=15896.24+51840

= 67736.35 mm^3

Density of mild steel =0.00785 g/mm^3

Weight =volume of rack and pinion ×

Density of mild steel

=67736.25×0.00785

=531.729g

9.1.1.5 Load plate

Volume of load plate = (b × t × l)

=250×250×2.5

=156250mm^3

Density of Mild Steel =0.00785g/mm^3

Weight of load plate =Volume of load plate ×

Density of mild steel

=156250×0.00785

=1226.656g

9.1.1.6 Back plate

Volume of back plate = (b × t × l)

= 300×250×2.5

= 187500 mm^3

Density of aluminium = 0.0027g/mm^3

Weight of back plate = Volume of back plate ×

Density of Aluminium

= 187500×0.0027

= 506.22g

9.1.1.7 Spring (2 Nos.)

Weight of spring =50g

Total weight of the mechanism

Total weight of the mechanism =Weight of supporting frame + Weight of guide rod

+Weight of guide bush + Weight of rack and pinion

+ Weight of load plate + Weight of back plate

+Weight of spring

= 439.6 + 998.28 + 272.86 + 531.72 + 1226.56+506.22+50

= 4025.336g

=4.025kg

9.1.2 WEIGHT CALCULATION OF THE FUTURE PRODUCT

9.1.2.1 Weight of supporting frame

Hollow square pipe (vertical) = 20×20×1mm 400 mm long (2 Nos.)

Hollow square pipe (horizontal) = 20×20×1mm 300mm long (2 Nos.)

Volume of the frame = 2(b×t×l) + 2(b×t×l)

= 2(20×20×400) + 2(20×20×300)

= 320000+240000

= 560000mm^3

Density of PVC plastic = 0.00141 g/mm^3

Weight of frame = volume of frame ×

Density of mild steel

=560000×0.00141

=789.6 g

9.1.2.2 Weight of guide rod (2nos)

Diameter of rod =15 mm

Length of rod =360 mm

Volume of rod =2(πr^2l)

ISSN No: - 2456 - 2165

$=2(3.14×7.5^2×360)$

$=127170\ mm^3$

Density of PVC plastic $=0.00141 g/mm^3$

Weight of vertical rod = Volume of the guide rod × Density of mild steel

$=127170×0.00141$

$=179.31\ g$

9.1.2.3 Guide bush (4 Nos.)

Outer diameter of guide bush = 25mm

Inner diameter of guide bush =16mm

Height of guide bush =30mm

Volume of guide bush = $4 (\pi h(R^2 - r^2))$

$=4 (\pi×30× (12.5^2 - 8^2))$

$= 3759.8\ mm^3$

Density of Nylon $=0.0011\ g/mm^3$

Weight of the guide bush = 34759×0.0011

= 4.13g

ISSN No: - 2456 - 2165

9.1.2.4 Rack and pinion (Nylon)

Diameter of pinion = 45mm

Dimension of rack =12×12×360

Volume of pinion and rack = (π×r^2×h) + (b×t×h)

= (π×22.5^2×10) + (12×12×360)

=15896.24+51840

= 67736.35 mm^3

Density of nylon =0.0011 g/mm^3

Weight =volume of rack and pinion ×

Density of mild steel

=67736.25×0.0011

=74.5 g

9.1.2.5 Load plate

Volume of load plate = (b × t × l)

=250×250×2.5

=156250mm^3

Density of carbon fiber =0.00175g/mm^3

Weight of load plate =Volume of load plate ×

Density of mild steel

=156250×0.00175

=273.43 g

9.1.2.6 Spring (2 Nos.)

Weight of spring =50g

Total weight of the mechanism

9.1.2.7 Total weight of the mechanism

Total weight of the mechanism =Weight of supporting frame + Weight of guide rod +Weight of guide bush + Weight of rack and pinion + Weight of load plate +Weight of spring

= 789.6 + 179.31 + 4.13 + 74.5+273.43+50

= 1370.97g

=1.37kg

9.3 RESULT

We made the model of energy harvesting using backpack by using the easily available materials such as the mild steel, aluminium and bag material. So the weight of the mechanism is slightly increased.

In practical case, the product can be made by using the suitable materials such as the plastic, Fibre, Nylon etc. By comparing the weight of the model and the future product, it can be seen that the weight is reduced greatly. About 3 kg is reduced by using the suitable material.

ISSN No: - 2456 - 2165

CHAPTER 10

10. ADVANTAGES AND DISADVANTAGES

10.1. ADVANTAGES

- Power can be easily generated,
- No external force is required,
- Manual force is not required,
- Generated power can be used for mobile charging applications.

10.1. DISADVANTAGES

Only small amount of power can be generated

ISSN No: - 2456 - 2165

CHAPTER 11

CONCLUSION

A strong multidiscipline team with a good engineering base is necessary for the Development and refinement of advanced computer programming, editing techniques, diagnostic Software, algorithms for the dynamic exchange of informational different levels of hierarchy.

This project work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while doing this project work.

We are proud that we have completed the work with the limited time successfully. The **"FABRICATION OF ENERGY HARVESTING USING BACK PACK"** is working with satisfactory conditions. We are able to understand the difficulties in maintaining the tolerances and also quality.

We have done to our ability and skill making maximum use of available facilities. In conclusion remarks of our project work. Thus we have developed a **"ENERGY HARVESTING USING BACK PACK"**. By using more techniques, they can be modified and developed according to the applications.

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