Energy Harvesting through Footsteps

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Abstract: Power and energy are two very important needs of humans in day-to-day life. With the increase in population, electrical energy consumption is increasing and the resources from which electricity is generated are depleting at a much faster rate. So nowadays the idea of electricity generation from renewable resources is gaining interest among people. For this, a device is made to utilize the energy, which is wasted while walking. The device is made using wooden-frame and special pair of rack and pinion, and this will generate approximately 3.127MW annually (10 installed units) with a displacement range of 0.75-1.5 inch. And the cost of this machine and its installation can be incurred by the saving in the electricity. If this is compared to conventional systems, it is very useful, easily accessible and an ecofriendly system.

Keywords: Electricity generation; Renewable resources; Energy harvesting

I. INTRODUCTION

To overcome the issues of increased energy prices and carbon emissions, most of the government agencies and technical companies are focusing on use of non-conventional resources for power generation [2]. For this purpose, solar panels, wind turbines and hydro power plants are used to produce electrical energy [1]. But there is a need to come up with new ideas to harvest energy from our day-to-day activities. An average person walks about 5210 steps per day. When a person steps on road, his body weight is transferred on the road and this cause waste of energy in the form of heat, friction and sound. In order to use and covert this energy into useful form, we have made an electricity-harvesting device. When a pedestrian over it, the weight of the person causes the downward movement of the top plate. This linear movement of plate is converted into rotational motion with help of rack and pinion combination and then used to rotate the shaft of the dynamo [3]. The generated electricity will be stored in a 12V battery and can be used to lighting the building [4]. When the device is overcrowded, then more electricity will be produced. So this concept can be very beneficial, if it is embedded in crowded places where there is continuous movement such as railway platforms, city footpaths and shopping malls etc.

II. WORKING MECHANISM

The main aim of this study is to harvest electrical energy through footsteps. Herein the human load is applied to the prototype. The working mechanism behind this device is as follows:

The top plate of this device is mounted with a rack and four springs. The teeth of rack are engaged with the teeth of pinion and pinion shaft is connected to the dynamo shaft.

When a person steps on the top plate of the device, due to his body weight there will be a small downward displacement of the plate. When the person moves on and removes his step, due to the force of spring the plate is pushed back to its initial position. By using the special combination of rack & pinion, the linear reciprocating motion is converted into rotational motion. The rotational motion of the piston shaft rotates the dynamo shaft and generates the voltage. For further use the voltage is stored in a capacitor.

III. DESIGN OF COMPONENTS

A. *Rack & Pinion*

Rack and pinion is one type of linear actuator. It is a set of two gears, which is used to convert the linear motion into the rotational motion. The linear gear bar is known as rack engages its teeth with the circular gear known as pinion. The linear movement of the rack causes the rotational movement of the pinion.
In this device, rack is mounted on the top-plate and the pinion is connected to the rack. Such two pairs of rack and pinions are used. Dimensions of rack and pinion used are:

Table I: Dimensions of Rack & Pinion

S.No	Component	Specification	Measurement
1	Rack	Length	950mm
		Number of teeth	66
2	Pinion	Diameter (D)	6.66mm
		Number of teeth (z)	14
		Module (m=D/z)	0.475mm
		Addendum (a=m)	0.475mm
		Dedendum (d=1.25*m)	0.5937mm
		Clearance (0.25*m)	0.11875mm
		Working depth (2*m)	0.95mm
		Whole depth (2.25*m)	1.0687mm
		Tooth thickness (1.5708*m)	0.746mm

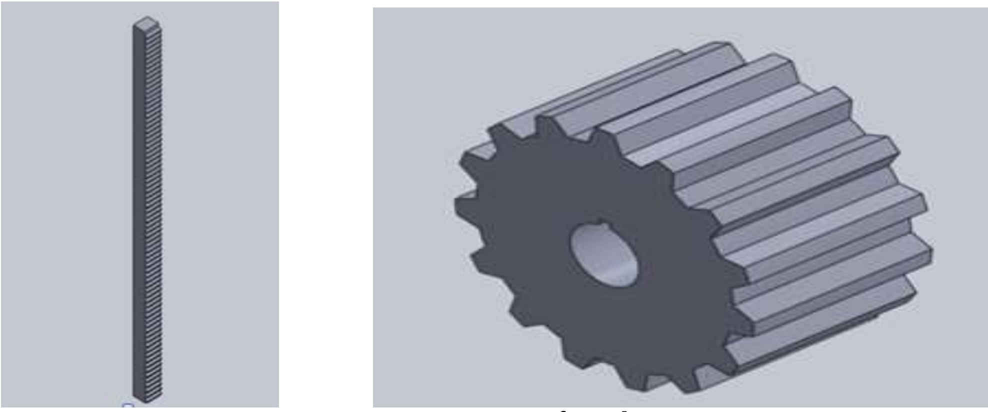


Figure 1: Isometric view of Rack & Pinion

B. ***Top plate***

It is a wooden plate of 254 x 355.6 mm² on which pedestrian will Step. This plate is mounted with a rack and four springs. The linear movements of this top plate will move the rack, which is brought back to its original position with the help of springs.

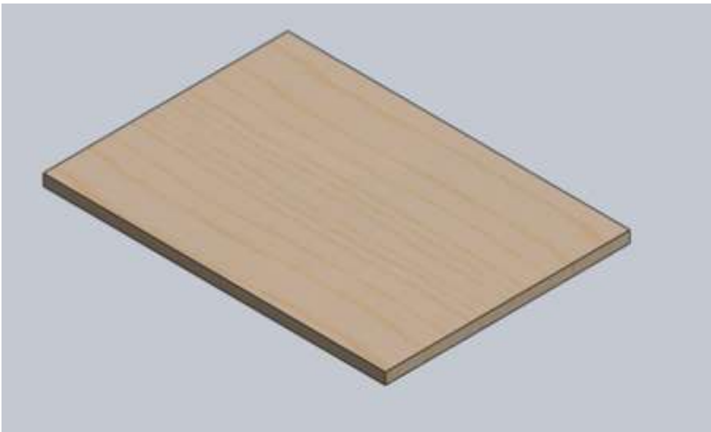


Figure 2: Isometric view of Top plate

C. ***Springs***

Spring is a device, which changes its shape on the application of external force and returns to it initial position once the external force is removed. When a spring deforms some amount of expended energy is stored in the spring and this energy is recovered when spring returns to its initial position. The amount of external force applied is directly proportional to deformation of spring [6]. In this device four springs are mounted on the four corners of the top plate, which helps the top plate to return to its initial position.

There are certain properties which are kept in mind while designing a spring. The design of spring is done considering the application of the force on the top plate of the machine. There are some properties like ultimate tensile strength, Yield strength, shear strength, Deflection of the spring, Stiffness of the spring, Amplitude load etc are calculated. These values are calculated using PSG design data book & tabulated in table II.

Table II: Dimensions of spring

S No.	Factor	Value
1	Ultimate tensile strength (using distortion energy theory)	692.4N/mm²
2	Yield tensile strength (from PSG)	1765.8N/mm²
3	Ultimate shear strength	346.2N/mm²
4	Shear stress in endurance limit	145N/mm²
5	Deflection of spring	36.83mm
6	Stiffness of the spring	1.062N/mm
7	Amplitude load	39.11N
8	Mean diameter of spring	27.5mm
9	Wire diameter of spring	2.5mm
10	Wahl factor	1.1309
11	Amplitude torsional shear stress	197N/mm²
12	Number of cycles (By plotting S-N curve (stress fatigue- life))	70794cycles ~ 71000cycles

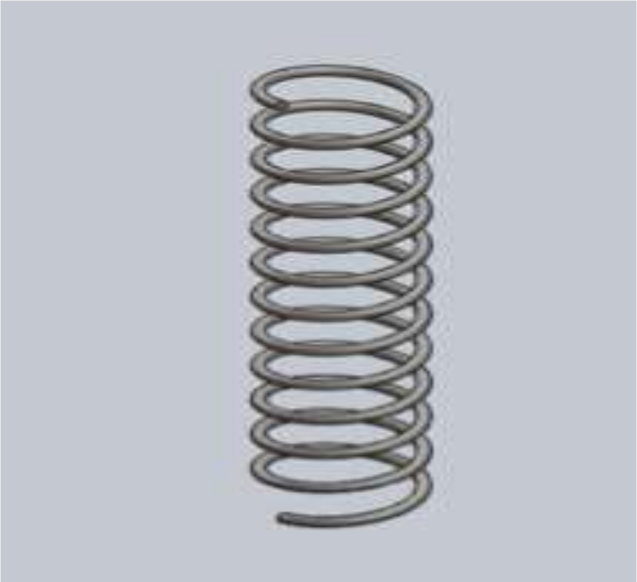


Figure 3:Design of spring

D. ***Dynamo***

It is an electricity generator, which produces alternating current and voltage. It is main component of the device because it converts the mechanical movement into electricity. It works on the principle of induction when a conducting material moves through the magnetic field some electricity is generated.

E. Nuts & Bolts

Carriage bolts are used. Factor of safety is calculated for extreme case that is 150 kg describing the structural capacity of a system beyond the expected loads or actual loads.

Table III: Dimensions of spring

S No.	Factor	Value
1	Core diameter of bolt	5mm
2	Yield tensile strength (from PSG data book)	245N/mm²
3	Thread angle	14.5° (ACME)
4	Mean diameter of bolt	4.6mm
5	Coefficient of friction between nut and bolt (clean and dry)	0.78
6	Direct compressive stress for 150 kg	18.73N/mm²
7	Torsional moment on the body of bolt	712Nmm
8	Torsional shear stress on the body of bolt	29.00N/mm²
9	Principle shear stress	30.47N/mm²
10	Yield shear strength (using distortion energy theory)	141.36N/mm²
11	Factor of safety	4.7

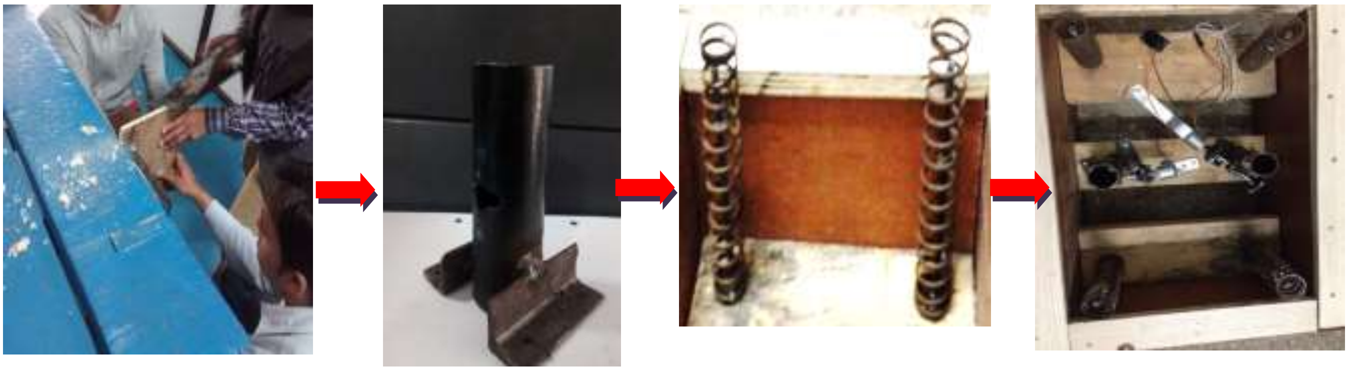
F. Storage Battery

A storage battery is made of one or more electrochemical cells. It can be charged, discharged, recharged again and again. There are different types of storage batteries, which are classified on the basis of combination of their electrode material and electrolytes.

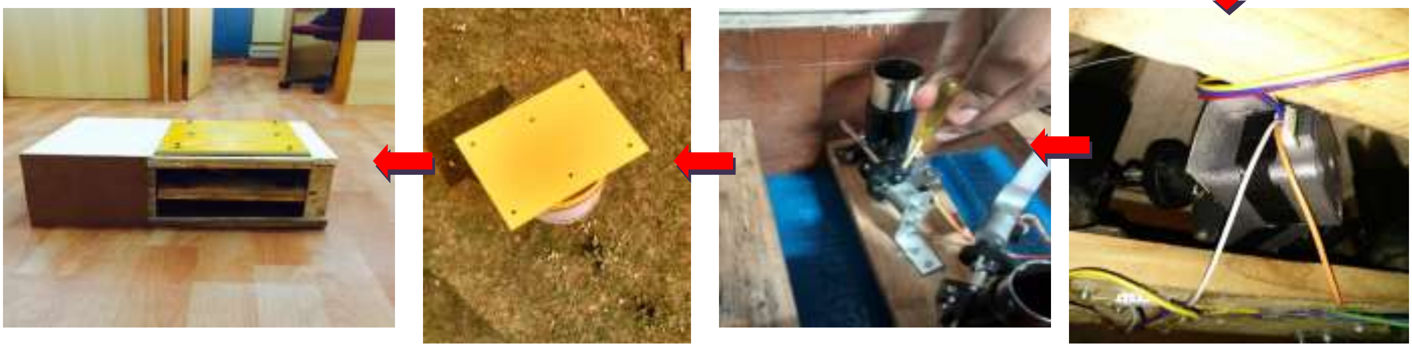
IV. ASSEMBLY OF THE COMPONENTS

All the designed components are mounted together to make a final prototype. The assembly is done in the following stages:

1. Woodworking operation of the outer cage and the wooden slab over which a person steps.
2. Mounting of rack holder/guide inside the bottom of the cage with help of screws.
3. Insertion of springs inside the cage for supporting the wooden slab when a person steps on it and bring it back to its original position
4. Mounting the rack inside the rack holder and meshing the pinion teeth with that of rack carefully.
5. Mounting the dynamo with the pinion. The dynamo shaft is connected with the shaft of the pinion with the help of a connector.
6. Circuit completion. All the wires are connected together to the output of the dynamo and the LED bulb.
7. Wooden slab over which pedestrian step is painted and mounted over the springs support with help of nuts and bolts.
8. Assembly of all components completed.



Woodworking operation | Mounting of rack holder | Insertion of springs inside the cage | Mounting the dynamo with the pinion.



Final Prototype | Wooden slab | Connection of wires together to the output of Dynamo & LED bulb. | Circuit completion

Figure 4: Assembly of the components to make an Energy harvesting through footstep prototype

V. WORKING OF THE DEVICE

The electricity harvesting through footstep device is shown in figure below. Figure 5 shows device in ideal condition and figure 6 shows the image of the prototype when full weight is transferred to top plate. An LED bulb connected to output of dynamo glows, indicating electric output in loading condition. The equipment is designed to produce full power pulse when apply maximum load of 90 Kg.

Figure 5:Final Prototype

Figure 6: LED Glows when a person step on the platform

A. *Energy Storage*

The generated power of device can be stored in energy storing electric battery. The output was fed to 4V and 0.5Ah battery. Initial phase, the battery was totally discharged. When, the device was works by applying load and energy gets stored in battery. A LED bulb was connected to battery through circuit.
The main goal was to demonstrate harnessing of energy from walking of humans. However, multiple units may be more productive in producing usable power.

VI. RESULTS & DISCUSSION

A. *Power Calculations*

The output power calculations are shown below:

The output of one device = 4.2V and 0.085Amp

From this we can calculate the Power produced = 4.2 x 0.085= 0.357 W
In one minute, this device will be used 4 times = 4 x 0.357= 1.428W

So the power generated in 1 hour will be = 1.428 x 60 = 85.68W

If this machine is used for 10 hours in a day
Then power = 85.68 x 10 = 856.8W
So the power generated by the device in a year (365 days) will be = 856.8 x 365 =312732W

Such 10 devices are installed at various locations, so total power generated by these devices will be = 10 x 312732 = 3127320W = 3.12732 MW

The output of the device increases with the increase in load applied. So, a graph between load and voltage is generated which illustrates the increase in voltage with increase in load applied,

Table IV: Load versus voltage calculations

Load	***Voltage***
65	4.2
70	4.86
80	5.6
85	6.3

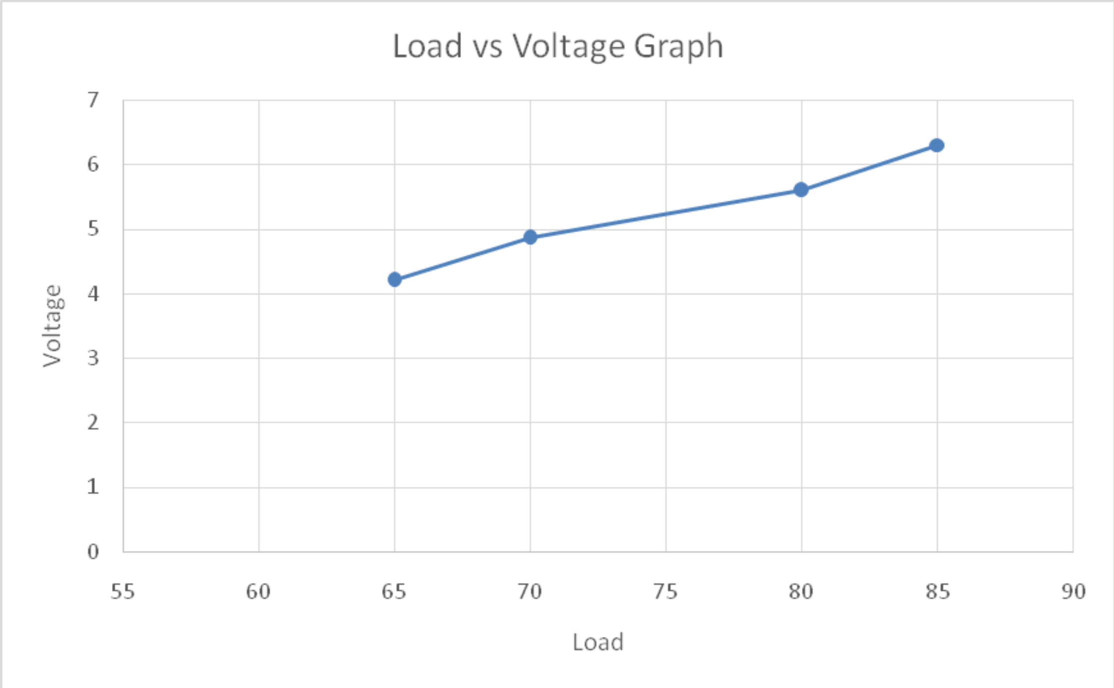


Figure 7: Load versus Voltage Curve

VII. CONCLUSION

This device is very useful as it harvest electricity from waste energy of our footsteps. The device is environment friendly and durable. If such devices are used in large numbers in city malls, railway platforms, footpaths, speed breakers and rural areas then a sufficient amount of energy will be harvested to run small and large electric appliances.

VIII. FUTURE ASPECTS

This device can be used in upcoming railways and metro stations with little modifications. The principle of this device can be used in speed breakers at roads where the movement of vehicles is continuous. It can be also used in gym equipment where the energy wastage is high.

IX. REFERENCES

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