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Micro Power Generation using Piezo & Cam-Gear Mechanism

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***Abstract*—Harvesting Energy stands alone as one of the most promising techniques for approaching the global energy problems without depleting natural resources. Energy can be obtained while walking on certain arrangements like footpaths, stairs, platforms and these systems can be install in the dense populated areas. Piezo materials and Cam-Gear arrangement is used to harvest energy from footsteps of human beings. Piezoelectric crystal senses the vibrations and electrical signals are produced due to deformation of the crystal. In Cam-Gear arrangement footsteps which is linear motion is converted into rotary motion. This rotary motion is fed to stepper motor which converts mechanical energy into electrical energy, which is stored in a battery. The stored energy can be used for lighting.**

***Index Terms*— Piezoelectricity, Piezoelectric materials, Cam gear mechanism, Energy harvesting, Footfall harvesting**

I. INTRODUCTION

The ultimate aim is to develop much cleaner cost effective way of power generation method, which in turns helps to bring down the global warming as well as reduce the power shortages. Energy is a key element for our society and also a key input for economic development. Sustainable and renewable energies have been widely accepted as a key concept for our common future. There are several ways in which electricity is generated in the modern world.

- Burning fossil fuels, such as coal, petroleum or natural gas.
- Hydroelectric generation systems that harness the power with moving water.
- Nuclear reactors that create electricity by splitting the atom.

Each of these has a considerable number of drawbacks that affect the environment, the quality of life for human beings, and even the sustainability of the technology itself. Proposal for the utilization of waste energy of foot power with human locomotion is very much relevant and important for highly populated countries like India and China where mobility of its masses will turn into boon in generating electricity from its footsteps.

II ENERGY HARVESTING

Energy Harvesting (EH) is the process of electronically capturing and accumulating energy from a variety of energy sources deemed wasted or otherwise said to be unusable for any practical purpose. Energy harvesting or energy scavenging as the process is sometimes referred to, capturing residual energy as a by-product of a natural environmental phenomenon or industrial process and is therefore considered free-energy.

Examples of common target energy harvesting sources include mechanical energy resulting from vibration, stress and strain, thermal energy from furnaces, combustion engines and other heating sources, even solar energy from all forms of light sources, ranging from lighting, light emissions and the sun, electromagnetic energy that are captured via inductors, coils and transformers; wind and fluid energy resulting from air and liquid flow, chemical energy from naturally recurring or biological processes and huge amounts of RF energy in the environment because of ubiquitous radio transmitters and television broadcasting.

A variety of well know devices, materials and sensors are typically used to convert wasted energy sources and sunlight into electrical voltages and currents, which can then be harvested, stored. Examples of Energy generators include materials such as, piezoelectric (PZT) crystals, solar photovoltaic cells, and electromagnetic inductor coils to name a few. These materials generate a wide range of output voltage and currents – none however can be utilized directly as power sources for driving low-energy electronics without energy harvesting electronics designed to manage the available power and communicate handshake instructions to compatible wireless sensor systems.

Proposed system

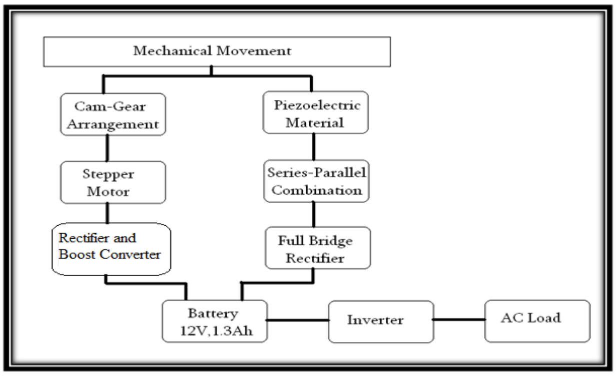

Figure 1 block diagram of proposed system

Proposal for the utilization of waste energy of foot power with human locomotion is very relevant and important for highly populated countries like China, India where the roads, railway station, bus stands and temples are all over crowded and millions of people move around the clock. This whole

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human/bio energy being wasted if can be made possible for utilization it will be great innovation and crowd energy farms will be very useful energy sources in crowded countries. Walking across a “crowd farm”, floor, then will be a fun for idle people who can improve their health by exercising in such forms with earning. The electrical energy generated at such farms will be useful for nearby application.

The block diagram of proposed system is as shown in the above figure 1. The main source of project is mechanical movement which is obtained when human beings walk or run on the floor. This waste energy is utilized for power generation using cam-gear mechanism and piezoelectric method. The cam mechanism is coupled to the stepper motor shaft through planetary gear arrangement. Output of the stepper motor is connected to rectifier which converts AC to DC.

When someone walks on the floor, mechanical vibration is converted into electrical signal using piezoelectric material. To get higher output the piezoelectric materials is connected in series parallel combination. A bridge rectifier is used to convert AC to DC and also to get full wave output. The output from both the mechanism is stored in battery. By using inverter AC loads can be drive

III CAM-GEAR MECHANISM

A cam mechanism is a type of mechanical operating system. Cam is a rotating or sliding piece in a mechanical linkage used especially in transforming rotary motion into linear motion or vice-versa. . Cam devices are versatile, and almost any arbitrarily-specified motion can be obtained. In some instances, they offer the simplest and most compact way to transform motions.

Gears are wheels with teeth. Gears mesh together and make things turn. Gear is a rotating part having cut teeth which mesh with another toothed part in order to transmit torque in most, cases with teeth on the one gear being of identical shape, and often also with that shape on the other gear. The gears in a transmission are analogous to the wheels in a crossed belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage. When two gears mesh, and one gear is bigger than the other, a mechanical advantage is produced, with the rotational speeds and the torques of the two gears differing in an inverse relationship.

Gears are generally used for following reasons:

- To increase or decrease the speed of rotation.
- To reverse the direction of rotation.
- To move rotational motion to a different axis.
- To keep the rotation of two axis synchronized.
- Suitable for high speed, high torque & high power transmission.

Types of Gears

- Spur gears
- rack and pinion
- Bevel gears
- Worm and worm wheel
- Planetary gears

Planetary gear

The epicyclical gear train family in general has a central “sun” gear which meshes with and is surrounded by planet gears as shown in fig 3.1. To compare with traditional gearbox, planetary gear has several advantages. One advantage is its unique combination of both compactness and outstanding power transmission efficiencies. A typical efficiency loss in a planetary gearbox arrangement is only 3% per stage. This type of efficiency ensures that a high proportion of the energy being input is transmitted through the gearbox, rather than being wasted on mechanical losses inside the gearbox. Another advantage of the planetary gearbox arrangement is load distribution. Because the load being transmitted is shared between multiple planets, torque capability is greatly increased. Greater load ability, as well as higher torque density is obtained with more planets in the system. The planetary gearbox arrangement also creates greater stability due to the even distribution of mass and increased rotational stiffness.

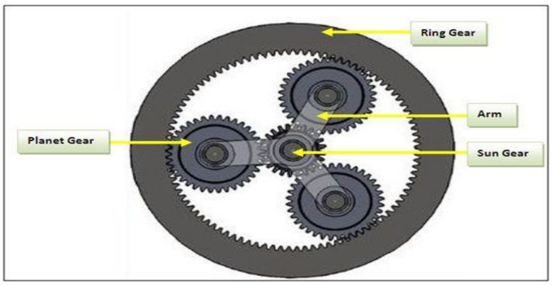

Fig 3.1 planetary gear

The steps to assemble gears could be summarized as follows:

- First Fix the ring gear, set the ring gear and sun gear to be concentric.
- Then adjust the sun gear, make the gear midline collinear to the ring gear.
- Finally import plant gears set them to be concentric to the plant shaft and the gear midline collinear to the ring gear.

Planetary gear calculation:

$$Nr = (2 \times Np) + Ns$$

Where,

N_r = Number of teeth in ring gear,

N_p = Number of teeth in planet gear $= 25$

N_s = Number of teeth in sun gear $= 24$

Hence number of gears in ring gear is

$$Nr = (2 \times 25) + 24$$

$$Nr = 74 \text{ teeths}$$

IV PIEZOELECTRIC MATERIALS

The piezoelectric effect is the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no symmetry. Different types of piezoelectric materials are available such like single crystals (e.g. quartz SiO2 and Rochelle salt), ceramics (e.g. lead zirconate titanate or PZT and BaTiO3 or BTO), thin films (e.g. ZnO and PZT), thick films (e.g. PZT), and polymers (e.g. polyvinylidenefluoride or PVDF).

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The most commonly known piezoelectric material is quartz. But piezoelectric materials are numerous, the most used are:

- Quartz (SiO_2): Quartz shows a strong piezoelectricity due to its crystalline structure, meaning that when a pressure is applied on a quartz crystal an electrical polarization can be observed along the pressure direction.
- Berlinite (AlPO4)
- Gallium orthophosphate (GaPO4): Gallium orthophosphate has almost the same crystalline structure as quartz. However its piezoelectric effect is almost twice as important as the one for the quartz, making it a valuable asset for mechanical application.
- Tourmaline: Crystal commonly black but can range from violet to green and pink.
- Barium Titanate ($BaTiO_3$): This element is an electrical ceramics; it is usually replaced by lead zirconate titanate (PZT) for piezoelectricity. It is used for microphones and transducers.
- Lead Zirconate Titanate (PZT): It is considered as one of the most economical piezoelectric element; hence it is used in lot of applications.
- Zinc oxide (ZnO)
- Aluminum Nitrate (AlN)
- Polyvinylidenefluoride (PVDF)

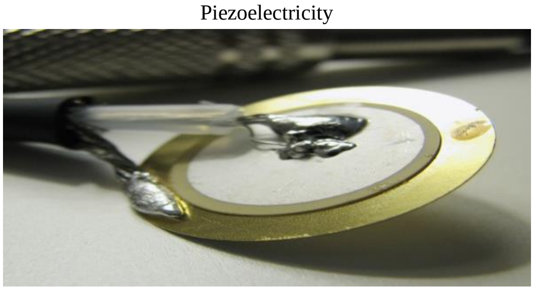
TABLE 4.1: LIST OF PROPERTIES OF SOME POPULAR PIEZOELECTRIC MATERIALS

Material and form	d_{31} (pm/V)	$\varepsilon_{33}/\varepsilon_0{}^a$	k_{31}	T_c (°C)^b
Quartz (single crystal)	2.3	4.4	-	-
BTO (polycrystalline)	-79	1900	0.21	120
PZT (polycrystalline)	-190~-320	1800~3800	0.32~0.44	230~350
PVDF (film)	23	12~13	0.12	80~100
PZT (sol-gel thin film)	190-250	800-1100	-	-
PZT (sputtered thin film)	100	-	-	-
ZnO (sputtered thin film)	10.5-11.5	10.8-11	-	-
AlN (thin film)	-	8.6	-	-

$\varepsilon 0$ = 8.854 × 10-12 F/m, permittivity of empty space (vacuum)
b = Curie or maximum temperature

From Table 3.1 we can see that PZT has a higher electromechanical coupling coefficient and higher Curie temperature, which is the highest temperature in which a piezoelectric material has the piezoelectric property. Additionally, PZT is easily poled and has a wide range of dielectric constant. The superior properties of PZT decide its popularity in piezoelectric material family.

Piezoelectricity



Piezoelectric Material

Piezoelectricity is the ability of some materials to generate an electric field or electric potential in response to applied mechanical strain. The effect is closely related to a change of polarization density within the material's volume. If the material is not short-circuited, the applied stress/strain induces a voltage across the material. However, if the circuit is closed the energy will be quickly released. So in order to run an electric load (such as a light bulb) on a piezoelectric device, the applied mechanical stress must oscillate back and forth. For example, having such a device in shoes could charge cell phone while walking but not while standing.

The piezoelectric effect exists in two domains; the first is the direct piezoelectric effect that describes the material's ability to transform mechanical strain into electrical charge, the second form is the converse effect, which is the ability to convert an applied electrical potential into mechanical strain energy.

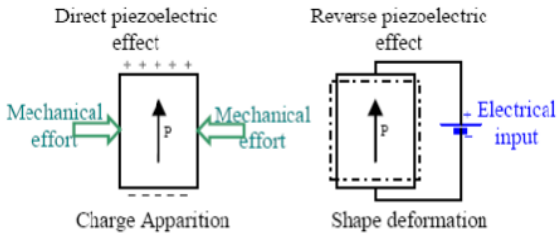


Fig 4.1. Electromechanical conversion via piezoelectricity phenomenon

The direct piezoelectric effect is responsible for the materials ability to function as a sensor and the converse piezoelectric effect is accountable for its ability to function as an actuator which is shown in fig 4.1. A material is deemed piezoelectric when it has this ability to transform electrical energy into mechanical strain energy and likewise transform mechanical strain energy into electrical charge. The piezoelectric materials that exist naturally as quartz were not interesting properties for the production of electricity, however artificial piezoelectric materials such as PZT (Lead Zirconate Titanate) has present advantageous characteristics.

Piezoelectric energy harvesting

Piezoelectric materials generate an electric voltage when exposed to alterations at their dimensions caused by mechanical stresses (vibrations) as shown in fig 5.3. Particularly, piezoelectricity provides a convenient transducer effect between electrical and mechanical oscillations. Reversibly, an applied electric field at piezoelectric materials will produce mechanical stress. The type and magnitude of the applied stimulus determines the producing power but in general piezomaterials produce a broad range of voltages. While they can respond to any type of physical stimulus (tensile force, torsion, pressure) piezoelectrics do not have a minimum requirement for producing a response. Piezoelectric transducers embedded into the pavements have the potential to harvest the waste mechanical energy as well as to store it in battery. The harvested energy can be used for small scale road applications like road furniture, lighting, roadside advertising or railway and airport signage where the installation and maintenance cost are low.

V CALCULATIONS

Power calculation in cam-gear mechanism

Part I

Record the height of one step in centimeters in Table 5.1.

Count the number of steps in the stair case.

Calculate the total height of the staircase in centimetres.

Calculate the total height of the staircase in meters.

Table 5.1: Height Measurements

1. Height of one step (cm)	3
2. Number of steps climbed	1
3. Total height of staircase (cm) = height of one step X number of steps climbed	3
4. Total height of staircase (m) = total height of staircase (cm) divided by 100	0.03

PART II

Calculate the weight of the stair climber.

Weight of climber: 1 N

Calculate the work done by the stair climber in climbing the stairs.

Work done (joules) = height of staircase (m) X weight of stair climber (N)

Table 5.2: Work Done

Climbing Stairs	Work Done(Joules)
1	0.03
10	0.3
100	3

PART III

Calculate the power output of climbing the stairs in watts.

$$\text{Power} = \frac{\text{Work done in climbing stairs (Joules)}}{\text{Time required to climb stairs (seconds)}}$$

$$\text{Power output of person climbing stairs} = \frac{0.03}{2}$$

$$= 0.015\text{Watts.}$$

Power calculation in piezoelectric material

Pressure is directly proportional to amount of power generated

$$P \propto W_t$$

Here by taking the constant of proportionality as Ƙ, then the equation becomes

$$P = Ƙ\, W_t$$

Where,

Ƙ - Constant of proportionality

W_t - Weight

P - Power

For $W_t = 50$ Kg,

The value of voltage

V = 0.6 V and

Current I = 0.01A

$P = V \times I = 0.6 \times 0.01 = 0.006$ W,

means that for 50Kg power obtained is

P =0.006 W

From this the value of Ƙ can be calculated as

$$Ƙ = \frac{P}{W_t} = \frac{0.006}{50} = 0.00012$$

Table 5.3: Observations at Different Conditions

Sl. No.	P in milli Watt	Wt in Kg
1	1.2	10
2	2.4	20
3	6	50
4	9	75

Advantages

- No need of fuel, therefore self-generating (Free energy).
- Harvest small, but still significant amounts of energy.
- Highly efficient in more crowded places.
- Promising technology for solving power crisis to an affordable extent.
- Simple in construction.
- Pollution free.
- Wide areas of application.

Disadvantages

- Suitable only in crowded areas.
- Mechanical moving parts are high.
- Maintenance of battery is necessary.

Applications

- In busy places like cinema theatres, shopping complexes, schools, colleges, airports and malls.
- It can be used in emergency power failure situations.
- Dancing floors, street lighting and home applications.

CONCLUSION AND FUTURE WORK

The objective of this project is to harvest the energy in the most feasible way by means of green source. This is an innovative idea of harvesting energy to meet the future energy need. This method generates the electric power without polluting environment. The energy from footsteps of human beings which is waste energy is utilized in this system. The degree of walking also has an effect on the power output. Energy harvested from this technique uses just the human power as source of harvesting. This energy source is renewable. Also this system looks very eco-friendly from the environmental point of view.

The proposed work portrays the concept energy harvesting at stairs and floors. The results obtained are very encouraging. Future work of the proposed idea encompasses further amplification of the piezoelectric crystal output to a greater extent. Future lies in the inclusion of advanced material used to design the piezoelectric crystal which further amplifies the crystal output in terms of voltage as well as current. A study could be carried out on including gear box to cam-gear mechanism and using stepper motor of higher ratings can

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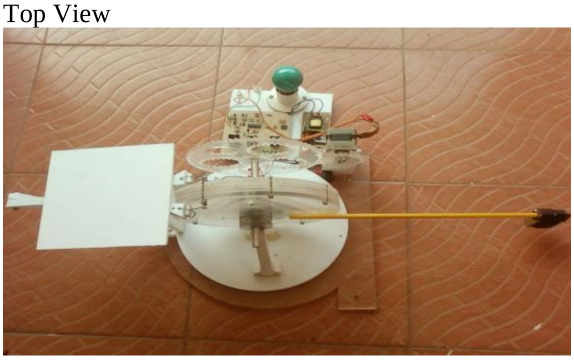
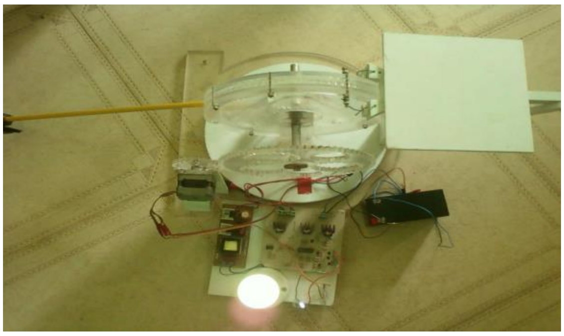
improve the power output to a greater extent. Combining of piezoelectric energy harvesting method to cam-gear mechanism will lead to get better results.

APPENDIX A CAM-GEAR MECHANISM

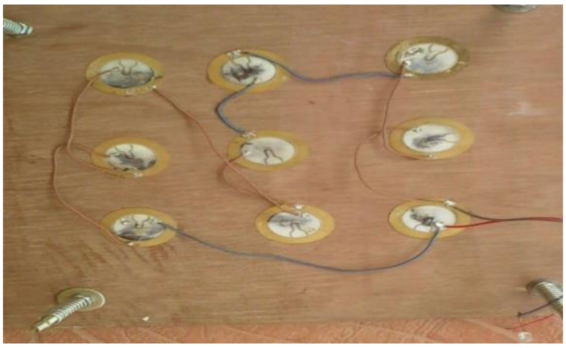
Top View



With Load



Appendix B Arrangement of piezo material



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