Harnessing Piezoelectricity from Various Mechanical Stresses at Different Surroundings

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Abstract— In our age, depleting natural resources have created a thirst to look for alternate sources of energy. Piezoelectricity is one such pragmatic solution to our energy crisis. In our paper, we will be discussing the applications of piezoelectricity in various surroundings. The exhibition of mechanical stress on a piezoelectric crystal produces some voltage which is capable of driving low power electric equipment. A responsive sub-flooring system made up of blocks that depress under the force of foot traffic if installed at public places, can power display boards and lights at public places such as railway and bus stations, cinema halls and so on. Piezoelectricity can also be incorporated to drive devices in offices, homes and gyms. This human powered electricity generation when coupled with efficient storage systems will give rise to a reliable source of energy which can be utilized whenever required. By harnessing energy from piezoelectric crystals, humans will be made aware of their contributions to the environment by helping produce a steady supply of energy from piezoelectric elements.

Keywords— Piezoelectricity, mechanical stress, vibration, crystal, pressure, renewable energy, electricity.

1. INTRODUCTION

The world's supply of fossil fuels is large, but finite. With each passing day, exhaustible energy sources are depleting resulting in the urge to look for alternative sources such as wind energy, hydro-power, solar energy, piezoelectricity, etc. Piezoelectricity is one such form of energy which is easy to harvest and can be installed easily at public places to harness electricity. Piezoelectricity is the development of electric charge produced by the application of mechanical stress on a piezoelectric crystal. It is the linear electromechanical interaction between the electrical and mechanical state in crystalline materials that do not exhibit symmetry. Electricity harvested from piezoelectric crystals may not be enough to power high voltage appliances, but such form of electricity can act as supplementary power sources such as batteries, lamps, display systems, radio, etc. In this paper, we will be describing the application of piezoelectricity at public places to power appliances at these places.

2. WORKING PRINCIPLE

Many materials exhibit piezoelectricity. Some are naturally occurring whereas some are chemically synthesized. Quartz, Berlinite ($AlPO_4$), Sucrose, Rochelle Salt, Topaz, mineral macedonite ($PbTiO_3$), bone, silk, wood, enamel, DNA are some naturally occurring piezoelectric materials. Barium titanate ($BaTiO_3$), lithium niobate ($LiNbO_3$), potassium niobate ($KNbO_3$) are some synthetic ceramics exhibiting piezoelectricity. Piezoelectric crystals do not exhibit symmetry. Such crystals are electrically neutral. When a mechanical force is applied on a piezoelectric crystal, the structure is deformed, pushing some atoms closer or farther, thereby upsetting the balance of positive and negative charge. Hence net electrical charges appear on opposite, outer faces of the crystal. In the following section, we have described the different sources from where piezoelectricity is harnessed. Further on, we have proposed a new idea which can be used in this field.

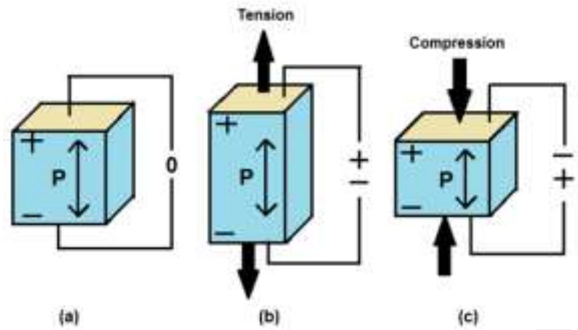

Fig.1.Piezoelectricity generated when the piezoelectric crystal is deformed

3. APPLICATIONS OF PIEZOELECTRICITY (PRE-EXISTING WORK)

3.1. RAILWAY STATIONS

The floorings at railway stations in Tokyo and Shibuya in Japan have piezoelectric ceramics embedded within. The electricity developed is used to power the energy-hungry parts of the station such as the electrical lighting system and the ticket gates.

3.2. HIGHWAYS

Vehicular traffic produces vibrations which can easily generate ample amount of electricity via piezoelectric materials laid underneath the road. This electricity produced can power the automatic gates and display systems at the toll booths.

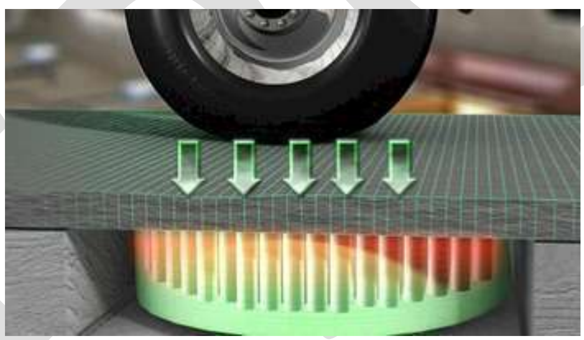

Fig.2.Pressure exerted by vehicular traffic activating piezoelectric crystals

3.3. FLOORINGS

Door mats, tiles and floors of sidewalks can have piezoelectric crystals underneath. The pressure exerted my people walking on them can be stored in capacitors acting as supplementary storage during power shortage. The energy generated via pedestrian traffic weight on sidewalks is used to power the lights along the roads.

3.4. GYMS

The treadmills at gyms can have piezoelectric crystals under the belt. When a person works on the treadmill, his weight along with vibrations can produce sufficient mechanical stress on the piezoelectric crystals so as to produce enough energy to power iPads or any other form of display systems in front of the treadmill.

3.5. DANCE CLUBS

In London, a dance club has incorporated piezoelectric crystals in its floorings. The impact of the foot movements by those using the dance floor is powerful enough to generate sufficient electricity so as to power the lights at the club.

4. PROPOSED WORK

4.1. PIEZOELECTRICITY POWERED STUDY LAMPS

A person sitting on the chair of study tables will produce sufficient mechanical stress so as to produce electricity that will power the lamp on the table. Once the person gets up, the stress acts no more, thereby turning off the lamp when not in use.

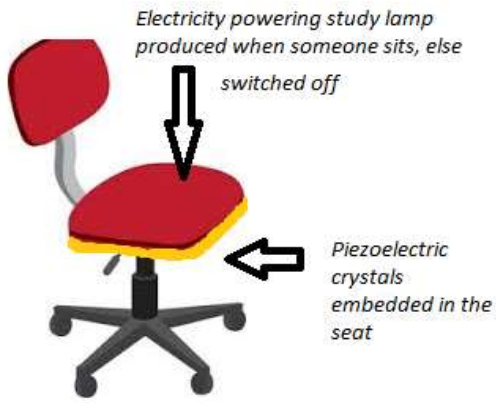

Fig.4.Piezoelectricity powered study lamp

4.2. VEHICLE METERS POWERED BY PIEZOELECTRICITY

Auto-rickshaw and taxi meters can also be powered using piezoelectricity. Piezoelectric ceramics when embedded underneath the driver's seat can act as a responsive system. When the driver is seated, his weight will turn on the meter. The electricity produced can be stored in capacitors which can be used when the driver is not in his seat and the meter is still running.

4.3. PIEZOELECTRIC LIFTS

The weight exerted by lift users can produce enough stress to compress the embedded piezoelectric material and power digital displays. Assuming that, on an average, 2 people are always in the lift the time delay is also drastically reduced. Furthermore, during peak office hours, more people will use lifts leading to more power output, which can then be stored for later usage.

The following table describes the weight requirements and its corresponding wattage for the production of piezoelectricity from the application of human weight. The power outputs described in the table can be used to drive the vehicle meters, lamps and display systems. From this table, it can be estimated that if an average person weighing around 55 kgs, sits on the piezoelectric chair, he will produce 0.065 watts/sec and time taken to light up a 9 Watt CFL will approximately be 2 minutes 30 seconds. Also, the minimum requirement for small voltage digital displays is 1-2 watts. Hence time required to power the digital display system will be from 15.38 second to 30.7 seconds.

Calculation:

0.065 watts/sec for 55 kgs.
To light up a 9-13 watt CFL, time required will be 9/0.065= 2.307 minutes;
13/0.065= 3.33 minutes

Weight (in kgs)	Power (in watts)
40	0.05
45	0.055
50	0.06
55	0.065
60	0.07
70	0.08
75	0.09

Table.1.Power output for corresponding weight

To light up a low power digital display, time required will be 2W/0.065=30.7 secs and 1W/0.065=15.38 secs.
Assuming that there are two people in a lift, approximate weight inside the lift is now 100 kgs. Power produced will be 0.12 watts. Therefore time delay is:
Max=16.66secs (2/0.12)   Min=8.33 secs (1/0.12)
To avoid this time delay in the lighting up of bulb, it can be noted that a person can use the chair when not using the bulb or the vehicle. The electricity generated from the piezoelectric chair during this period can be stored in lithium metal hydride batteries. This stored electricity can be in turn used during the initial time, before the system lights up on its own via real time piezoelectricity production.

5. OUTPUT OBTAINED FROM PIEZOELECTRIC MATERIALS

It has been observed from pre-existing experiments that power output from a single piezo-film was in the range of 0.2μW. The direct application of a piezo-film as a power source is not practical. The outputs from a single piezo-film can produce a root-mean-squared voltage of 1.18V which is high enough to be stored in a nickel metal hydride battery. After the rechargeable battery charged up completely, it was discharged through a load of 10 kΩ for 1 hour. During this discharging period, the current measured maintained at 760 mA and the potential difference across the resistor was 1.2V which is nearly equal to a power of 0.9 watts. The output obtained from a piezoelectric crystal is an alternating signal. In order to make this signal usable for low power devices it has to be first converted into digital signal. This is done by using AC to DC converter. It consists of a simple diode rectifier. This is followed by a capacitor, which gets charged by the rectifier to a predefined voltage. At this point, the switch closes and the capacitor discharges through the device.

6. INCREASING THE PRODUCTIVITY

Power obtained from a single piezoelectric material is very low. To increase the productivity of the piezoelectric materials, they can be placed in series or parallel. However, series connection of piezoelectric materials is preferred over the parallel, as the series connection increases the voltage output of the system.

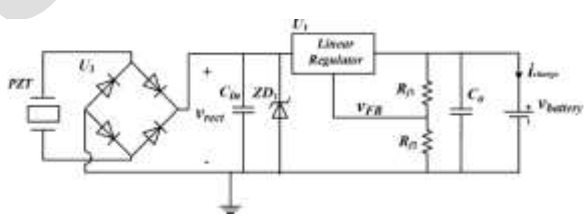

Fig.5. AC to DC converter used to harvest energy from a piezoelectric material

7. LIMITATIONS

Although piezoelectricity has its own advantages, there are some limitations that can be incurred during installation. The piezoelectric sheets have stress-strain limits. A sheet can be stretched to a strain of approximately 500 microstrain (micrometers per meter) in regular use. Higher surface strains can be achieved, but the statistics of survival get worse. Also, the initial costs of installation of the entire piezoelectric circuit are high owing to the high costs of AC to DC converters used. These converters are manufactured primarily by countries like USA and Germany and their costs range from 30-35$. In the foreseeable future it is expected that India will start producing its own AC to DC converters which will reduce the installation costs drastically.

8. FUTURE PROSPECTS

The field of piezoelectricity is still in its infancy. Studies are going on to use the properties of piezoelectric materials in various fields. Some of the proposed concepts that can be used are:

8.1. BRIGHT WALK

A design for a pair of shoes has been proposed that is equipped with piezoelectric devices. It utilizes kinetic energy generated while walking and converts it into usable electrical energy.

8.2. P-ECO ELECTRIC VEHICLE

P-Eco is a car design proposed by some designers. It describes a car which runs on piezoelectric batteries. The vibrations produced by the car will act as mechanical stress for the piezo-elements thereby feeding power to the car. Besides these proposed applications, several other models have been developed such as hearing aids for the deaf, self-powering tablets, self-heating piezoelectric shower that works without consuming electricity, etc. Piezoelectricity is a promising field as it provides sufficient energy for low power sources in an eco-friendly way.

8.3. USE AT CRYOGENIC TEMPERATURES

Researchers are studying the use of piezoelectric crystals at cryogenic temperatures (near zero Kelvin). Since piezoelectricity functions on the basis of electric dipoles, these dipoles remain unaffected by changes in temperature. Hence this quality of piezoelectric materials can be used in the extremely cold parts of the world.

9. CONCLUSION

This paper presents the usability of piezoelectricity in various surroundings such as public places. The advantages of piezoelectric materials are more than its limitations, hence it is expected that this field will witness in-depth research to exploit its advantages. Although most of the applications of piezoelectric effect have been proposed, two new applications have been mentioned that can be tested and put to use. By using piezoelectric materials at public places, people can be made aware of their contributions to the society and can hence, be encouraged to use this eco-friendly, cost effective and efficient method of electricity generation.

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