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GENERATION AND STORAGE OF ELECTRICITY BY AMBIENT VIBRATIONS AND PRESSURE BY USING PIEZOELECTRIC DEVICES

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ABSTRACT:

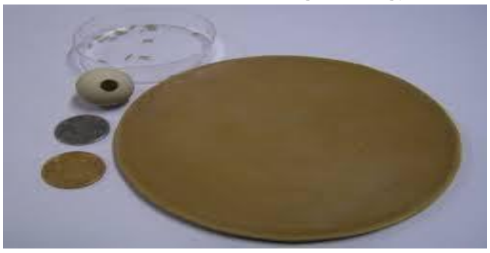
This paper discusses about the alternative source of energy by using piezoelectric materials which can be used as mean of transferring ambient vibrations into electrical energy that can be stored and used to power other devices. This work has been investigated the necessary condition to enhance the extracted AC electrical power from the exciting vibration energy using piezoelectric material. There is a lot of energy resources have been exhausted and wasted. In this paper two methods of energy harvesting have been discussed. Firstly, a proposal for the utilization of waste energy of foot power with human locomotion and waste vibration from many machines is very much relevant and important for harvesting the energy. Piezo materials are used for converting motor vibration into electrical energy and magnetic sensor is used for up/down movement. Through this work, it has been proposed two new ways of harnessing the piezoelectric energy. Implementation aspects focus on the work carried out in this field of Piezoelectric Energy Harvesting. The idea of vibration from the motor and pressure caused is by using biological system such as foot step, printing machine etc. So these two ideas can greatly help in harnessing the piezoelectric energy. The proposed work can be implemented for large machines in industries and maximum output voltage can be obtained for smaller loads.

KEYWORDS: Piezoelectric materials, crystals, magnetic sensor and magnetic switch

INTRODUCTION:

Piezoelectricity was discovered by Jacques Curie and Pierre Curie in 1880. They observed that certain crystals respond to pressure by separating electrical charges on opposing faces and named the phenomenon as piezoelectricity. The name Piezo originates from the Greek word piezo in which means to squeeze or press. Electricity has become important resources for human being hence, it is needed that wasted energy must have to utilize, walking is the most common activity done by human being and vibration from many machines, while walking energy is wasted in the form of vibration to the surface and this wasted energy can be converted into electricity. This principle is referred as piezoelectric effect. One source of typically wasted energy is an ambient vibration that presents around most of machines and biological systems. This source of energy is ideal for the use of piezoelectric materials, which have the ability to convert mechanical strain energy into electrical energy and vice versa. In general, there are three mechanisms to harvest the energy from the vibration: electrostatic, electromagnetic and piezoelectric techniques. Piezoelectric materials are perfect candidates for harvesting power from ambient vibration sources, because they can efficiently convert mechanical strain to an electric charge without any additional power and have a simple structure [1].

Three types of piezoelectric devices will be investigated and experimentally tested to determine each of their abilities to transform ambient vibration into electrical energy and their capability to recharge a discharged battery. The three types of piezoelectric devices tested are; the commonly used monolithic piezo ceramic material lead-zirconate-titanate (PZT), the bimorph Quick Pack (QP) actuator and Macro Fiber Composite (MFC). The outcome of this paper work is such that, to provide power to such a small electronic devices by using the vibration energy available in their environment. If this can be achieved, the requirement of an external power source as well as the maintenance requirement for periodic battery replacement can be minimized and make use of wastage energy [4].



a. PZT Plate

b. MFC Plate

c. QP Plate

Fig. No.1. Different types of piezoelectric devices [9]

FUNDAMENTALS OF POWER HARVESTING:

The piezoelectric effect exists in two domains [3**];** 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. The direct piezoelectric effect is responsible for the material's ability to function as a sensor and the converse piezoelectric effect is accountable for its ability to function as an actuator. A material is deemed piezoelectric when it has this ability to transform electrical energy into mechanical strain energy, and likewise to transform mechanical strain energy into electrical charge. Piezoelectric materials belong to a larger class of materials called ferroelectrics [1].

One of the defining traits of a ferroelectric material is that the molecular structure is oriented such that the material exhibits a local charge separation, know as an electric dipole. Throughout the material composition the electric dipoles are orientated randomly, but when the material is heated above a certain point, the Curie temperature, and a very strong electric field is applied, the electric dipoles reorient themselves relative to the electric field; this process is termed poling. Once the material is cooled, the dipoles maintain their orientation and the material is then said to be poled. After the poling process is completed the material will exhibit the piezoelectric.

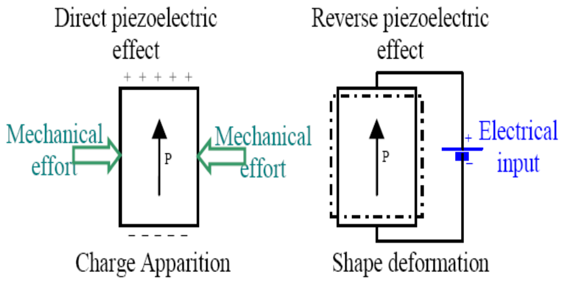


Fig. No.2. Effect of piezoelectric devices [4]

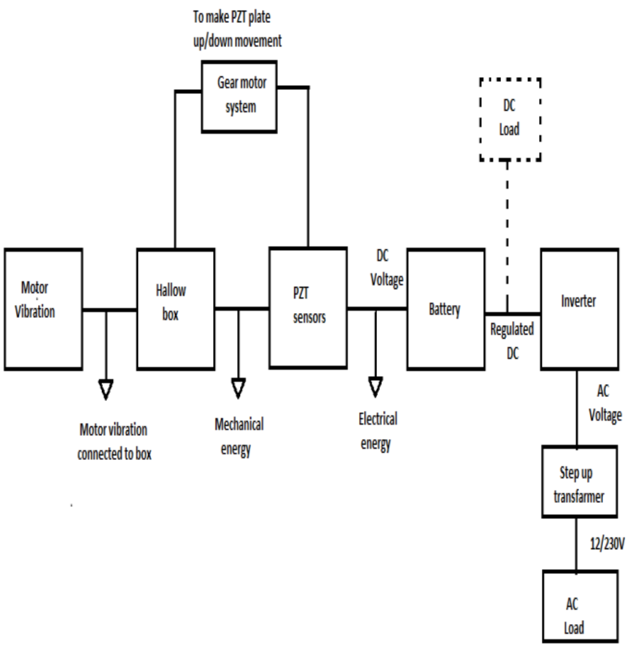


Fig. No.3: Block diagram

In this paper piezo sensor is used for power generation, whenever pressure is build, piezo will generate charges, piezo output is given to battery. Whenever vibration from the machines will be made off piezo sensor, when machine's pressure is generated sensor will develop charges across sensor, and using this charges battery is charged, there many ways we can generate power using piezo sensor and we can observe readings using multimeter for different forces applied to sensor. Stored power is given to inverter to convert dc to ac. In this above block diagram magnetic sensor is used from up/ down movement. Whenever motor moves in forward and backward direction, magnetic sensor will move up/down direction, and pressure is created in piezo sensor. Relay circuit is used to provide delay to circuit [1].

WORKING PRINCIPLE:

The piezoelectric effect is a special material property that exists in many single crystalline materials. Examples of such crystalline structures are Quartz, Rochelle salt, Topaz, Tourmaline, Cane sugar, Berlinite (AlPO4), Bone, Tendon, Silk, Enamel, Dentin, Barium Titanate (BaTiO3), Lead Titanate (PbTiO3), Potassium Niobate (KNbO3), Lithium Niobate (LiNbO3) etc. There are two types of piezoelectric effect, direct piezoelectric effect and inverse piezoelectric effect. The direct piezoelectric effect is derived from materials generating electric potential when mechanical stress is applied and the inverse piezoelectric effect implies materials deformation when an electric field is applied. The energy harvesting via Piezoelectricity uses direct piezoelectric effect. The phenomenon will be clear from the diagram shown in above figure. The structure of a piezoelectric component is being used for energy harvesting.

The output voltage obtained from a single piezoelectric crystal is in millivolts range, which is different for different crystals and the wattage is in microwatt range. So in order to achieve higher voltages, the piezoelectric crystals can be arranged in cascading manner, that is, in series. The energy thus obtained is stored in lithium batteries or capacitors. This is the working principle behind piezoelectric energy harvesting system. Now the extreme engineering lies in optimization of piezoelectric energy, which is done in various ways. A lot of studies are being carried out in order to know which crystal will be the best to obtain maximum output voltage, what should be the structure of piezoelectric component, which type of circuit should be used at the output terminals of piezoelectric crystal in order to have maximum wattage. In the next section, discuss about a number of sources of vibration which are already being used for piezoelectric energy harvesting and a new idea of energy harvesting has been proposed through this work [2].

SOURCES OF VIBRATION FOR PIEZO MATERIALS:

Power Generating Sidewalk

The piezoelectric crystal arrays are laid underneath pavements, sidewalks and other high traffic areas like highways, speed breakers for maximum voltage generation. The voltage thus generated from the array can be used to charge the chargeable Lithium batteries, capacitors etc. These batteries can be used as per the requirement [6].

Power Generating Boots or Shoes

In United States Defense Advance Research Paper Agency (DARPA) initiated an innovative paper on Energy harvesting which attempts to power battlefield equipment by piezoelectric generators embedded in soldiers' boots. However, these energy harvesting sources put an impact on the body. DARPA's effort to harness 1-2 watts from continuous shoe impact while walking were abandoned due to the discomfort from the additional energy expended by a person wearing the shoes.

Gyms and Workplaces

Researchers are also working on the idea of utilizing the vibrations caused from the machines in the gym. At workplaces, while sitting on the chair, energy can be stored in the batteries by laying piezoelectric crystals in the chair. Also, the studies are being carried out to utilize the vibrations in a vehicle, like at clutches, gears, seats, shock-ups, foot rests.

Mobile Keypad and Keyboards

The piezoelectric crystals can be laid down under the keys of a mobile unit and keyboards. With the press of every key, the vibrations created can be used for piezoelectric crystal and 1hence can be used for charging purpose.

Floor mats, Tiles and Carpets

A series of crystals can be laid below the floor mats, tiles and carpets which are frequently used at public places.

People Powered Dance Clubs

In Europe, certain nightclubs have already begun to power their night clubs, strobes and stereos by use of piezoelectric crystals. The crystals are laid underneath the dance floor. When a bulk of people use this dance floor, enormous amount of voltage is generated which can be used to power the equipments of the night club.

IMPLEMENTATION:

Experimentation has been done on a Piezo-crystal and it is tested with a Light Emitting Diode (LED). The two terminals of the LED are connected with the two terminals of the crystal. Choice of Blue LED is being made for experimentation. Single stroke on the crystal blows blue LED with full intensity. Measured values of output voltage and current from the crystal come out to be 3.5 Volt and 100 milliamps. The only shortcoming of this using a single crystal and a LED was that both the voltage and current obtained exists instantaneously. To increase the range of voltage and current output, an assembly of 6 crystals in series and 6 such series has been put in parallel. When number of voltage sources are put in series, then the net voltage increases, while when a number of voltage sources are put in parallel, then the strength of signal, that is, current increases. This is the concept used behind the assembly. The output of parallel connection is fed to the current amplifier for signal strengthening and the output of series connection is fed to the amplifier for biasing purpose and also to the voltage amplifier. The assembly has been put under a doormat and the output obtained from amplifier has been very encouraging, which was around 6 V voltage and 1 ampere current. This magnitude of voltage and current can be certainly used to charge a battery. Fig. 8 shows the assembly used in our system [2].

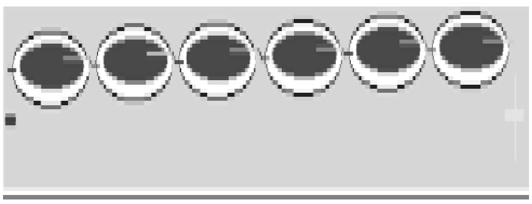


Fig. No.4. Series and parallel connection of crystals [2]

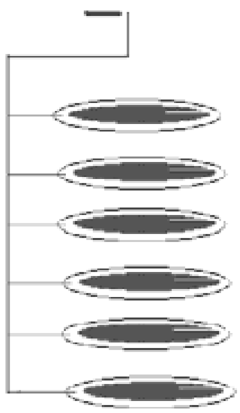


Fig. No.5. Series and parallel combination of crystals [2]

Next to determine the kind of connection that gives appreciable voltage and current necessary, three PZT are connected in series. A force sensor and voltmeter is connected to this series combination. As varying forces are applied on this connection, corresponding voltages are noted. Also the voltage generated across the series connection and the current is measured. Similarly the connections are done for parallel and series-parallel connections are done and the graphs are as in figures 4 and 5.

It can be seen from the graph that the voltage from a series connection is good but the current obtained is poor, where as the current from a parallel connection is good but the voltage is poor. But this problem is rectified in a series- parallel connection where a good voltage as well as current can be obtained.

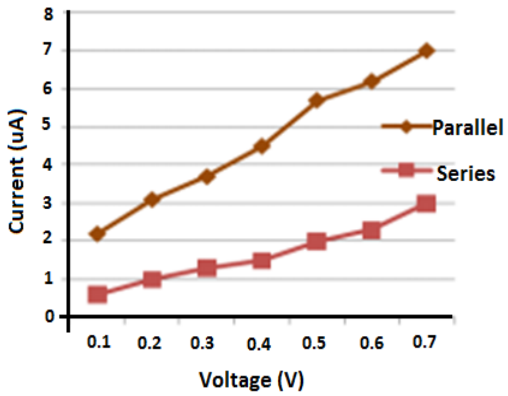


Fig. No.6. V - I graph of Series and Parallel connection [3]

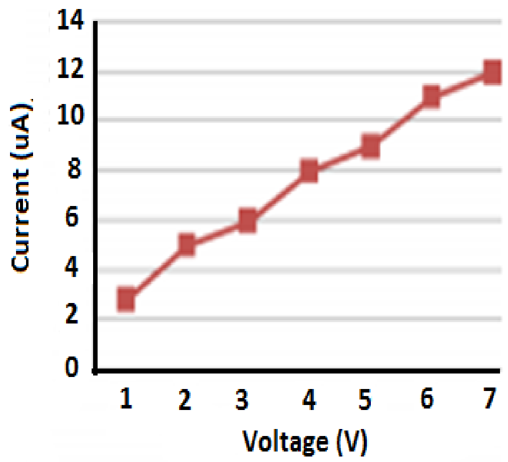


Fig. No.7. V - I graph of Series and Parallel combination [3]

It can be seen from the graph that the voltage from a series connection is good but the current obtained is poor, where as the current from a parallel connection is good but the voltage is poor. But this problem is rectified in a series- parallel connection where a good voltage as well as current can be obtained.

MAGNETIC SWITCH:

Here we are using magnetic switch, if magnet detected means it will give message. Here reed switch is used to perform this operation. The reed switch is an electrical switch operated by an applied magnetic field. It consists of a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. The contacts may be normally open, closing when a magnetic field is present, or normally closed and opening when a magnetic field is applied. The switch may be actuated by a coil, making a reed relay, or by bringing a magnet near to the switch. Once the magnet is pulled away from the switch, the reed switch will go back to its original position.

Here three reed switch is used for as three amount recharge card, based on the amount recharge card by consumer supply is provided, once its get over indication is given , suppose consumer select 10Rs/ magnetic card that much amount of power is supplied, by doing this paper amount is collected by K.E.B initially only, based on consumer usage. Thus, people can consume only as much power as they really need.

Fig. No.8. Magnetic sensor [5]

The reed switch is an electrical switch operated by an applied magnetic field. It was invented at Bell Telephone Laboratories in 1936 by W. B. Ellwood. It consists of a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. The contacts may be normally open, closing when a magnetic field is present, or normally closed and opening when a magnetic field is applied. The switch may be actuated by a coil, making a reed relay, or by bringing a magnet near to the switch. Once the magnet is pulled away from the switch, the reed switch will go back to its original position.

An example of a reed switch's application is to detect the opening of a door, when used as a proximity switch for a burglar alarm [5].

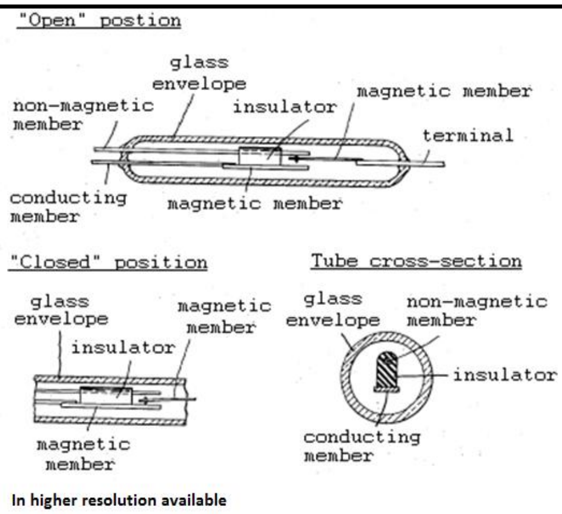


Fig. No.9. Internal structure of the magnetic sensor [5]

Description:

The reed switch contains a pair (or more) of magnetizable, flexible, metal reeds whose end portions are separated by a small gap when the switch is open. The reeds are hermetically sealed in opposite ends of a tubular glass envelope.

A magnetic field (from an electromagnet or a permanen magnet) will cause the reeds to come together, thus completing an electrical circuit. The stiffness of the reeds causes them to separate, and open the circuit, when the magnetic field ceases. Another configuration contains a non-ferrous normally-closed contact that opens when the ferrous normally-open contact closes. Good electrical contact is assured by plating a thin layer of non-ferrous precious metal over the flat contact portions of the reeds; low-resistivity silver is more suitable than corrosion-resistant gold in the sealed envelope. There are also versions of reed switches with mercury "wetted" contacts. Such switches must be mounted in a particular orientation otherwise drops of mercury may bridge the contacts even when not activated.

Since the contacts of the reed switch are sealed away from the atmosphere, they are protected against atmospheric corrosion. The hermetic sealing of a reed switch make them suitable for use in explosive atmospheres where tiny sparks from conventional switches would constitute a hazard.

One important quality of the switch is its sensitivity, the amount of magnetic field necessary to actuate it. Sensitivity is measured in units of Ampere-turns, corresponding to the current in a coil multiplied by the number of turns. Typical pull-in sensitivities for commercial devices are in the 10 to 60 AT range. The lower the AT, the more sensitive the reed switches. Also, smaller reed switches, which have smaller parts, are more sensitive to magnetic fields, so the smaller the reed switch's glass envelope is, the more sensitive it is.

In production, a metal reed is inserted in each end of a glass tube and the end of the tube heated so that it seals around a shank portion on the reed. Infrared-absorbing glass is used, so an infrared heat source can concentrate the heat in the small sealing zone of the glass tube. The thermal coefficient of expansion of the glass material and metal parts must be similar to prevent breaking the glass-to-metal seal. The glass used must have a high electrical resistance and must not contain volatile components such as lead oxide and fluorides. The leads of the switch must be handled carefully to prevent breaking the glass envelope [8].

CONCLUSION:

The method used to perform power harvesting is by using PZT materials that can convert the ambient vibration energy surrounding them into electrical energy. This electrical energy can be used to power other devices or stored for later use. This technology has gained an increasing attention due to the recent advances in wireless and MEMS technology, allowing sensors to be placed in remote locations and operate at very low power. A study could be carried out from the variety of piezoelectric crystals and after comparing the results, the choice of the optimum material for the best performing crystal could be devised. In this paper work two methods of energy harvesting have been discussed. Firstly, a proposal for the utilization of waste energy of foot power with human locomotion and waste vibration from many machines is very much relevant and important for harvesting the energy. Secondly, when the flooring is engineered with piezoelectric technology, the electrical energy produced by the pressure in machine is captured by floor sensors and converted to an electrical charge by piezo transducers, then stored and used as a power source. Through this work, the idea of vibration from the motor and pressure caused is by using biological system such as foot step, printing machine etc. So these two ideas can greatly help in harnessing the piezoelectric energy.

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