

PIEZOELECTRIC MATERIAL AS A NEW SOURCE FOR MINOR NEEDS

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ABSTRACT

One of the promising electricity generation methods is by using the piezoelectric material. Strain on piezoelectric material causes charge separation which produces electricity. Instead of taking traffic as a problem we can take it as an opportunity to produce energy. In addition to energy used to move vehicle forward, part of energy is wasted on deformation in the asphalt, which is due to weight of vehicle, it can be transformed into electricity via piezoelectric effect by a road with embedded piezoelectric generators. The energy is converted into electricity and transferred to battery on the side of the road. Potential benefits of this solution are; the vehicle does not waste any additional fuel, it does not require development of vast areas, there are no moving parts, they need to be repaired or replaced long after 30 years, it records weight, frequency and speed of the vehicles.

Keywords—Piezoelectric Material, Piezoelectricity, Power Harvesting, Asphalt.

I: INTRODUCTION

The recent fluctuations in the price of petroleum and coal have affected world economy which has enforced increase in the price of other items including food, shelter and clothing. This shows that we are too dependent on petroleum and coal as sources of electrical power. Besides, petroleum and coal as a source of electrical energy they have also contributed to severe air pollution problem. Therefore, some alternative method to produce electricity has to be put in place. Other solutions which can be explored are nuclear energy, ocean thermal energy, and hydroelectric power generators. However, these options require huge financial capacity to run and to maintain. Besides, not many countries are allowed to use nuclear power generator due to world political scenario. Thus, ambient energy harvesting such as solar cells and wind turbines have been the popular choices and these renewable energy sources are gaining more attention. However, they are expensive and not affordable to many countries to acquire them. As a consequence, other possible energy sources must again be explored to fight with these problems.[3]

The process of acquiring the energy surrounding a system and converting it into usable electrical energy is termed as ambient energy harvesting.[4] In ambient energy harvesting one of the promising options for power generation is by using piezoelectric material. Vibrations from machines, mechanical stress, strain from high-pressure motors, manufacturing machines, and waste rotations can be captured and used as ambient mechanical energy sources for electricity generation.[1]

Piezoelectric material can be used as a mechanism to transfer ambient vibrations into electrical energy. This energy can be stored and used to power up electrical and electronics devices. Usually this is used in energy harvesting for low power and small

autonomous devices, such as wireless sensor networks, and portable electronic equipments. With the recent advancement in micro scale devices, piezoelectric power generation can provide a conventional alternative to traditional power sources used to operate certain types of power devices. The application of piezoelectric material as a power generator can be extended to operate daily low power electrical appliances such as tuner, light bulb, mobile phone, street light and so on.[3]

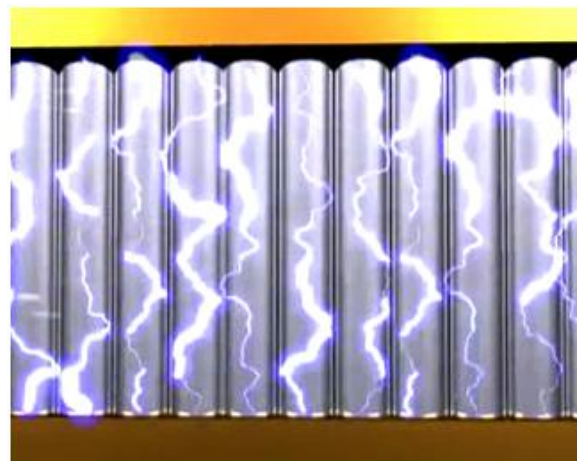


Fig. 1. Voltage generation in piezoelectric material (deformation is perpendicular to the plane of paper) [5]

It is recognized that with proper configuration, a single piezo-film can generate enough electrical density that can be stored in a rechargeable battery for later usage.

II: WORKING OF PIEZOELECTRIC MATERIAL

The piezoelectric phenomenon was first described by the Curie brothers, who observed that certain

materials generate electric current when they are deformed. 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.[2] Thus, they can be used as either actuators or sensors.

The direct piezoelectric effect alters mechanical energy into electrical energy by straining a piezoelectric material. Strain or deformation of a piezoelectric material causes charge separation across the device, producing an electric field and consequently a voltage drop proportional to the stress applied. The voltage produced varies with time and strain, effectively producing an irregular AC signal on the average. Piezoelectric energy conversion produces relatively higher voltage and power density levels than the electromagnetic system.[1]

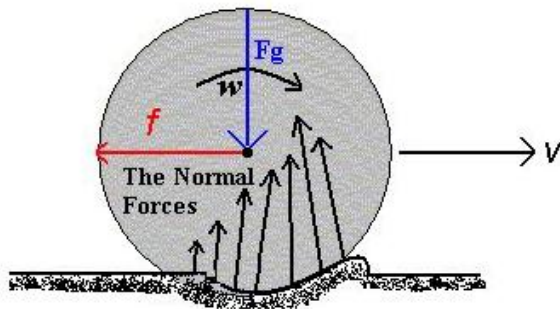


Fig.2 Forces exerted by a vehicle moving ahead on a road[5]

III: THEORETICAL BACKGROUND

Vehicles traveling on the road expend energy on movement in forward direction, on deformation of the asphalt layer and to operate systems such as air conditioning. The rest of the energy is lost to engine inefficiencies.

$$\text{Car fuel combustion} = \text{Energy for travel} + \text{Energy wasted on asphalt deformation} + \text{Other wasted energy} \quad [5]$$

Asphalt is a visco-elastic material; therefore, the vehicles travelling on the asphalted road expend part of their energy on deforming the asphalt layer. Only part of the energy, normally wasted on road deformation, is harvested by piezoelectric generators. Therefore, the vehicle does not waste any additional fuel when it travels over piezoelectric generators.[5]

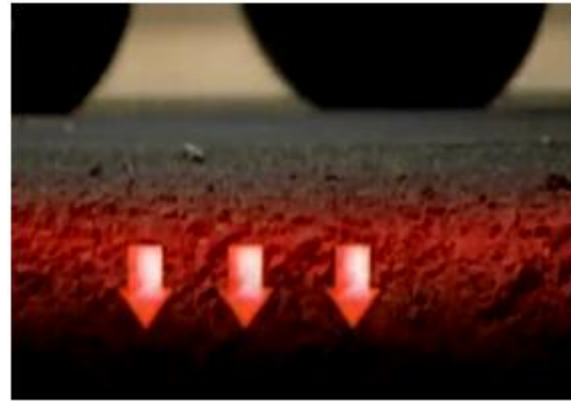


Fig.3 Energy wasted on asphalt deformation is transferred into heat[5]

When a vehicle passes over a road, the road deflects vertically. The deflection is proportional to the weight of the vehicle and the asphalt stiffness. This deflection is released as thermal energy.

For a road with embedded piezoelectric generators, part of the energy that the vehicle expends on road's deformation is transformed into electric energy via direct piezoelectric effect instead of being wasted as thermal energy.[5]

IV: INSTALLATION

It is known that the vertical load of the vehicle's wheels yields compression stress, diminishing with depth. Piezoelectric generators are embedded at a depth of about 5 cm; the area where the compression stresses is maximal. Installation method of piezoelectric generators is very easy. Piezoelectric generators are installed contiguously in two rows according to the wheel imprints.[5]

V: NO DEFORMATION TO ASPHALT LAYER

The energy needed to deform the road is a function of various parameters such as: the surface quality of the road, asphalt type, environment temperature and others. Moreover, the stiffness of the piezoelectric generators is function of the piezoelectric material; thus, the weighted Young modulus of the generator is higher than that of the asphalt. When piezoelectric generators are embedded under the asphalt, the total vertical deflection of the road is decreased due to the higher Young's modulus of the generator. Piezoelectric generators have no moving parts and are harder than asphalt. Thus piezoelectric generators do not increase the asphalt deformation.[5]

VI: EFFECT ON ROAD'S QUALITY

The generators are placed under the upper asphalt layer. The generators possess the same elasticity as the asphalt, and therefore, provide the same resistance to the wheels as asphalt. Thus piezoelectric generators do not affect the quality of the road in any way.[5]

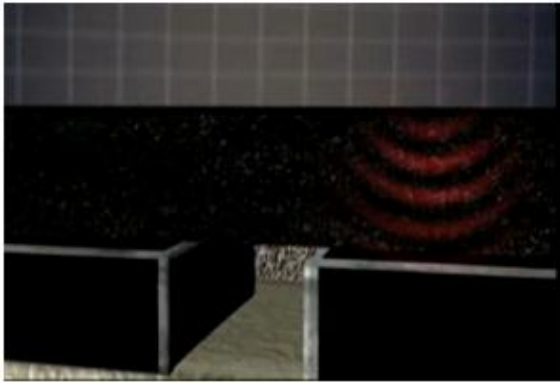


Fig.4 Energy from asphalt deformation is transferred into piezoelectric material[5]

VII: MAINTAINANCE

Piezoelectric generators have very low maintenance as there are no moving parts with the generators placed under asphalt. They need to be repaired or replaced once every 30 years.[5]

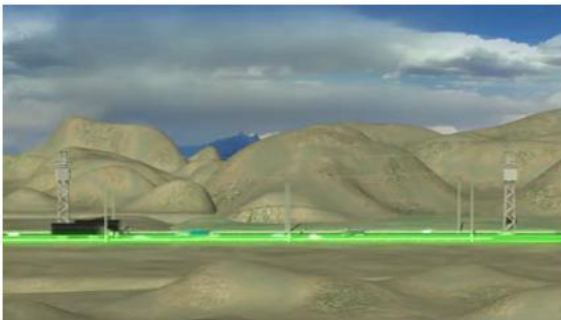


Fig. 5. Road With Piezoelectric Generators[5]

VIII: ADVANTAGES OF PIEZOELECTRIC GENERATORS AGAINST OTHER ENERGY SOURCES

- It maximizes retrieval of wasted mechanical energy converting it into electrical energy.
- It then stores the energy with minimal energy waste.
- The energy is also produced close to its end users.
- It does not require the use and development of vast new areas as do solar and wind farms.
- Additional benefits are that the system records weight, frequency and speed of the vehicles, giving extra information to "create smart roads".
- The solution is applicable to any place with heavy vehicle travel and not confined to specific climate and geographic areas as are solar and wind energy.[5]

IX. EXAMPLE

The first implementation was over a relatively small ten meter stretch of road on Israel's main north-south

highway, and is now being placed in one-kilometer sections for further study. When the technology was put to the test in 2009, the Israeli government was able to generate 2,000 watt-hours of electricity simply by implementing the system on a 10-meter stretch of highway.[1] The research is being carried out by an Israeli start-up called Innowattech, in conjunction with the Israel National Roads Company and Israel's technological institute in Haifa.

X. CONCLUSION

This paper presents an idea of having self-powered electronics with the advances in power harvesting. The methods of increasing the amount of energy generated by the power harvesting device or developing new and innovative methods of accumulating the energy are the key technologies that will allow power harvesting. One recent advance that shows great promise for power harvesting is the use of rechargeable batteries as a means of accumulating the energy generated during power harvesting. The rechargeable battery can be charged and then used to run any number of electronic devices for an extended period of time while being continuously charged by ambient motion with piezoelectric material. Furthermore, the efficiency of the power harvesting circuitry must be maximized to allow the full amount of energy generated to be transferred to the storage medium. By tuning the power harvesting medium with the structure, the excitation can be made to maximize the strain of the piezoelectric material using the concept of resonance. Finally, practical applications for power harvesting systems such as wireless sensors and self-powered damage detection units must be clearly identified to encourage growth in this area of research.[2] Further applications are also being evaluated, including pedestrian walkways, airport runways and railroads.

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