PIEZOELECTRICITY : A NEW WAY OF TAMING ENERGY

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Abstract

Recent globalization of Indian market loaded with a heavy dose of communism and have caused and credited speedy transport of heavy vibrations over and inside of highway surface. The energy radiated from these vibrations goes dissipated or wasted into surroundings and may be a cause of environmental pollution (apparent or hidden) wasted. In this paper we intended to tap and harness this energy of vibrations and wish to identify, scrutinize and devise ways so that a possible methodology could be developed. Vehicles on the highways that is spread across our whole country/land. This high speed of heavy vehicle necessarily exerts intense

1. Introduction

In recent times, there has been a soaring necessity of harvesting energy from various possible resources. It is the practice of acquiring energy from the environment which is being sent into trash and taming it for use wherever we needs.

Energy has always been regarded as a valuable diamond for the development of economy and is central to social growth of the country. There are two long-term energy challenges are being faced. One of them is undertaking climate change by mitigating Carbon Dioxide (CO_2) emissions and the other one is ensuring to secure clean and affordable energy.

Recently, the prices of petroleum based products are growing like ripple, which also affects our eating items. There is no way to negotiate with petroleum price hike. Besides, petroleum is like a good omen as well as a min giant for us.

Therefore, an alternative method to produce electricity has to be put in place.

Among other solutions which can be explored are nuclear and hydroelectric power generators. Besides, not every independent country is allowed to have the coolness of these power generators due to world political scenario. Thus, photovoltaic cells and wind turbines have been the popular choices and these renewable energy sources are gaining more attention. However, these options are much expensive and you should be a spendthrift to maintain them. As a consequence other possible energy sources need to be explored.

Energy can also be harvested from ambient environment such as mechanical, thermal, light, electromagnetic and also human body to replace traditional sources.

Generally, the energy harvesting procedure include capturing of energy (resources), storing of

energy using batteries or other kind of capacitors, and finally the energy will supply power to nearby grid or system as shown in **Figure**

There are various forms of recycling of energy which have existed so far like:-

- Electrochemical Conversion
- Photovoltaic Panels
- Turbines
- Solar Cells
- Piezoelectricity

Energy Harvesting for Road Application[4]

We introduces a new concept of energy recycling using the vibrations produced by the moving vehicles on the road and a transducer known as *piezoelectric transducer*. This method can be best utilized for efficient recycling of energy if we make use of this in a proper way. Vehicles such as cars, bus, trucks are the major user on the road. When every vehicle is in motion, it always will release energy in form of force or vibration direct to the road surface. An energy taming system will capture all these energies and convert it into electrical energy.

what is piezoelectricity ?

Discovered by J and P Curie in 1880, this is the method of converting mechanical energy into electrical energy. The piezoelectric effect exists in two domains, the direct piezoelectric effect that describes ability of material to convert mechanical strain into electrical energy, and its inverse effect, which is the ability of material to transform an applied electrical potential into mechanical strain.

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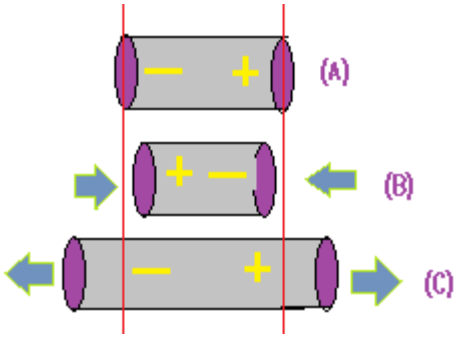


fig.1 (a) piezoelectric material with net dipole moment in horizontal direction

(b)&(c) direct piezoelectric effect, any compression or tension generates an emf in the closed circuit

How to use energy from roads[4]

The installation of piezoelectric sensors beneath the road surface which would produce electricity by using the vibrations caused by the movement of vehicles, is what our design proposes. This works in this way: the motion of a moving vehicle over pavement produces vibrations in the road surface which are being absorbed by a piezoelectric transducer. By installing relatively inexpensive and efficient piezoelectric transducer beneath the road surface, the vibrations transferred by vehicles can be converted into electricity.

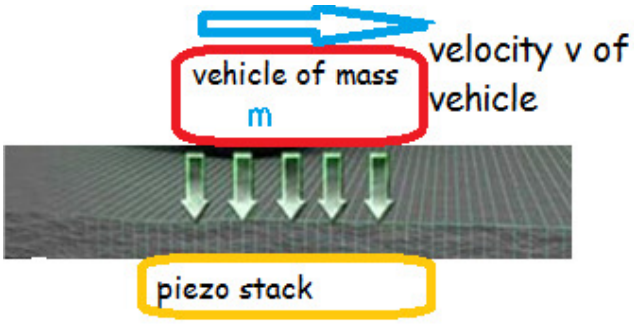


fig 2 : velocity of the vehicle is in horizontal direction and energy transferred to the piezo stack is in downward direction

2. Mathematical Treatment

The energy generated can be calculated by assuming this model in two parts: mechanical model and electrical model.[5]

Mechanical Model

It consists of one or more piezoelectric elements between two heavy masses. This is known as Piezo stack. Consider a vehicle, of mass **m,** passes over this piezo stack, there will be a slightly decrease in the potential energy of the vehicle due to the deformation in the road. This changed potential energy is transferred into the piezo stack.

Here **mg** will be known as deforming factor and will be responsible for amount of deformation in the piezo stack, **g** being because of earth's gravitational field.
Let **Δl** is the deformation produced in the piezo stack. Thus change in potential energy of the vehicle is given by **mgΔl.**
Δl depends on two factors
- elastic properties of the piezoelectric element
- mass, m, of the vehicle
Consider that the piezo stack having thickness **h** and area of cross section **A**, the Young's modulus for this stack is defined by :

$$Y = \frac{(mg)h}{\Delta l.A}$$

or $\Delta l = (mg).\frac{h}{YA}$

the energy transferred to the stack is, therefore

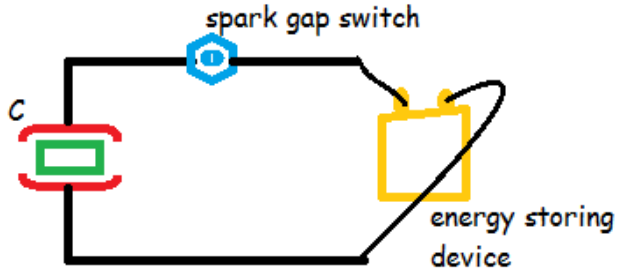
$E_t = m.g.\Delta l$

or, $E_t = (m.g)^2.\frac{h}{YA}$

Where E_t is the energy transferred to the piezo stack by the moving body.

Electrical Model

Let us consider the case(ideal condition) when the whole energy lost by the vehicle is transferred to the piezo stack, and it converts all the energy transferred to it into the electrical energy. The piezoelectric element is a metalized dielectric material which is analogous to a capacitor.



Capacity of the stack is given by

$$C = \frac{\varepsilon_r \varepsilon_0 A}{h}$$

ε_0 is absolute permittivity of free space, ε_r is relative permittivity of material which the piezo stack is made up of

If V is the voltage generated as a result, the energy stored in the capacitor is given by

$$E = \frac{1}{2}.CV^2$$

This stored energy in the capacitor is the energy transferred to the piezo stack because of the change in the potential energy of the moving mass. Therefore, the electrical energy produced and change in potential energy of the vehicle should be equal to each other, that we have formulated earlier.

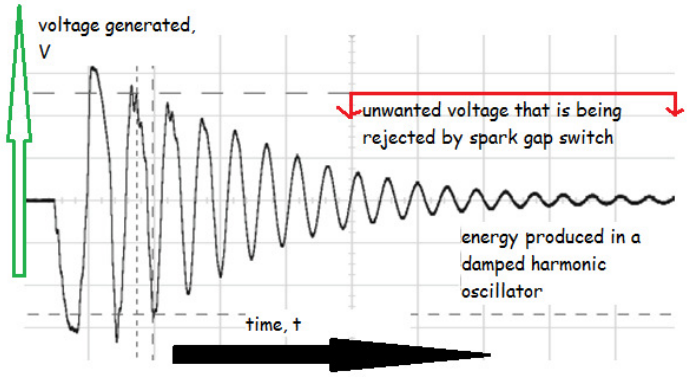
$E = E_t$

$$\frac{1}{2}.CV^2 = (m.g)^2.\frac{h}{YA}$$

$$V^2 = (m.g)^2.\frac{\varepsilon_0.\varepsilon_r}{Y}$$

or, $$V = m.g\sqrt{\left\{\frac{\varepsilon_r \varepsilon_0}{Y}\right\}}$$

All other quantities except mass will remain constant for a particular piezoelectric element. Thus the voltage generated depends directly on mass, greater is the mass of the moving body larger is the voltage generated. Since the velocity is in horizontal direction and the force responsible for generation of electricity is in vertically downward direction, the velocity of the moving body, therefore, will not leave any impact on the energy produced, except the contact time will be decreased on increase of velocity which will result in changed frequency of the current generated. The piezo stack will continue to oscillate even after the vehicle has passed over it, therefore damped harmonic motion will occur in the piezo stack. The energy of damped harmonic decreases as shown in fig . That's why we use a spark gap switch to reject the unwanted amount of voltage.



2. Results and Discussion

According to law of conservation of energy, energy can neither be created nor be destroyed, only transferred from one form to another. This is the same phenomena that is applied in this paper by capturing the energy wasted by the vehicle in the form of transferred vibrations and converting it into electrical energy, storing it and making useful for various purpose. Theoretical results shows that a large part of energy that is being wasted can be tamed and used for various purposes. A report[4] based on a project in Japan, shows that a considerable amount of electrical energy was generated after installation of piezoelectric transducers at the busiest railway station of Japan. Not the all the energy dissipated by the vehicle is made useful, most of the energy gets demolished during the process and output power is very low about 0.0018 kW/km for 45,000 N truck weight.[2]

Berkeley Result	**Modified Berkeley Calculation**	**Virginia Tech Demonstration**
600 trucks per hour	600 trucks per hour	As low as 167 vehicles per hour
45,000 N tuck weight	147,000 N truck weight, tractor trailer	Tractor trailer
8 axles per truck	tractor trailer, 5 axles	5 axles
0.0018kW/km, <1mW at the module	0.01 kW/km, 0.017 W/module	0.08-0.14 W per module

Table1: Comparison of Calculation Results across Multiple Third-Party Investigators into the Compression-Based Energy Harvesting Technology[2]

The report discussed above is not only the work that has been done. Many others has done a significant work in this field and others are trying to find new possibilities that can increase the efficiency and make it useful for every aspect of life.

Limitations and Scope

1. The vibrations have to transfer through the material of which the road surface is made up of. In this case there will always be **structural damping** which leaves impact on the amount of electrical energy generated.

2. Consider the case of appearance of charge. Let **n** number of electrons transfer because of applied force **f** (or **m.g**). For a particular value of force the charge generated will be the same. It will depend on the structure of the crystal of piezoelectric element or the dipole strength of the crystal. But every crystal has a critical value of mass over which it will possess only a slightly change in the value of electrical energy generated, even on the great change in force applied, or in other words change in mass of the body.

3. Not all the energy dissipated by the vehicle is made useful, most of the energy get demolished during the process and output power is low.

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