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Green Energy Harvesting from Speed Breakers using Piezoelectric Materials

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Abstract:*Piezoelectric materials produce electric charge when a stress is applied on it. This phenomenon is known as piezoelectric effect. This effect takes place only in crystals that have no centre of symmetry. The charge produced by the application of stress can be rectified , boosted and accumulated using the electrical circuits.*

Various techniques have been proposed to harness energy using piezoelectric materials. In this paper we have shown that piezoelectric materials can be implanted on the surface of speed breakers on the road to produce green and efficient energy. The energy produced can be used to light street LEDs.

Vehicles when pass through the breakers will exert a force on the piezoelectric material which will result in the deformation of the material due to which AC voltage is produced. This AC voltage cannot be directly used,so we need it to convert to DC and then store it in Lithium cell/battery. The voltage produced sometimes may be not sufficient to fulfil our requirements , so we can use the booster circuit to amplify the voltage. This technique has a very high potential of becoming the energy harvesting technique of upcoming generation as it is very cost efficient , no pollution and most importantly it is renewable and sustainable source of energy.

Index Terms—Piezoelectric effect, booster circuit, rectifier, dipoles, green energy.

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I. INTRODUCTION

Green energy means the energy which has been harnessed without deteriorating the environment and not utilizing any other non-renewable source of energy. This form of energy comes under renewable and sustainable source of energy. Due to the advancement of the technology in the present decades green energy seems to be the future source of energy. It is highly cost effective in the long run. It doesn't have any severe health impacts.

In our paper we have proposed the idea to harvest green energy using piezoelectric materials.Piezoelectric materials convert mechanical energy into electrical energy. The energy produced can be stored and used for various purposes. The nature of these materials is closely associated to the presence of the dipoles within the structure. It can either be natural or man-made but most commonly used ones are man-made and are highly efficient.

In this paper we have designed a prototype to harvest energy from the speed breakers using piezoelectric materials. The energy harvested can be utilized to light street LEDs.

II. PIEZOELECTRIC EFFECT

The piezoelectric effect refers to a change in electric polarization that is produced in certain materials when they are subjected to mechanical stresses. This stress-dependent change in polarization provides a measurable potential difference across the material. Referred to as the direct piezoelectric effect, this phenomenon is observable in many naturally available crystalline materials, including quartz, Rochelle salt, and even human bone. Engineered material, such as lithium niobate and lead zirconate titanate (PZT), exhibit a more pronounced piezoelectric effect.

An important feature to note about this phenomenon is that the process is reversible. The inverse piezoelectric effect refers to a deformation of these materials that results from the application of an electric field. The deformation could lead to either tensile or compressive strains and stresses in the material depending upon the direction of the electric field, the preferred direction of polarization in the material, and how the material is connected to other adjacent structures.

A piezoelectric substance is one that produces an electric charge when a mechanical stress is applied (the substance is squeezed or stretched). Conversely, a mechanical deformation (the substance shrinks or expands) is produced when an electric field is applied. This effect is formed in crystals that have no center of symmetry. To explain this, we have to look at the individual molecules that make up the crystal. Each molecule has a polarization, one end is more negatively charged and the other end is positively charged, and is called a dipole. This is a result of the atoms that make up the molecule and the way the molecules are shaped. The polar axis is an imaginary line that runs through the center of both charges on the molecule. In a mono-crystal the polar axes of all of the dipoles lie in one direction. The crystal is said to be symmetrical because if you were to cut the crystal at any point, the resultant polar axes of the two pieces would lie in the same direction as the original. In a poly-crystal, there are different regions within the material that have a different polar axis. It is asymmetrical because there is no point at which the crystal could be cut that would leave the two remaining pieces with the same resultant polar axis. Figure 1 [3]illustrates this concept.

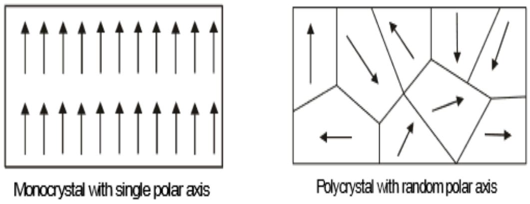

Figure 1: Mono vs. Poly Crystals

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III. PIEZOELECTRIC CONSTITUTIVE EQUATIONS

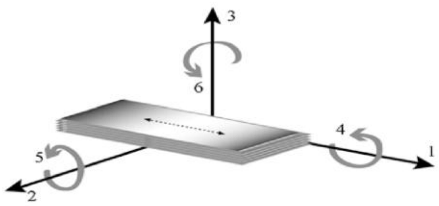

Figure2 : Tensor directions for defining the constitutive relations [4]

The electromechanical equations [4] for a linear piezoelectric material can be written as :

$$S_i = S_{ij}^E \sigma_j + d_{mi} E_m \qquad (1)$$

$$D_m = d_{mi} \sigma_i + \varepsilon_{ik}^{\sigma} E_k \qquad (2)$$

where the indexes i , j =1 ,2,...,6 and m , k =1 ,2,3 refer to different directions within the material coordinate system, as shown in Figure 2.

TABLE 1 : SYMBOLS AND THEIR USUAL MEANINGS

Symbol	Quantity	Unit
σ	Stress Vector	(N/m2)
S_i	Strain Vector	(m/m)
E	Vector of applied electric field	(V/m)
ϵ	Dielectric constant	(F/m)
d	Matrix of piezo electric constant	(m/V)
S_{ij}^E	Matrix of compliance coefficient	(m2/N)
D	Vector of electric displacement	(C/m2)
F	Applied force	(N)

A. Piezoelectric Constant

Piezoelectric constantd_{ij} is the ratio of short circuit charge per unit area flowing between connected electrodes perpendicular to the j direction to the stress applied in the i direction. Once a force F is applied to the transducer, in the 3 direction, it generates the stress

$$\sigma_3 = \frac{F}{lw}$$

which results in the electric charge $q = d_{33}F$

B. Dielectric Constant

The dielectric coefficiente_{ij} determines the charge per unit area in the i-axis due to an electric field applied in thej-axis. In most piezoelectric materials, a field applied along the j-axis causes electric displacement only in that direction. The superscript σ in e_{11}^{σ} refers to the permittivity for a field applied in the 1 direction, when the material is not restrained.

C. V*oltage Calculation*

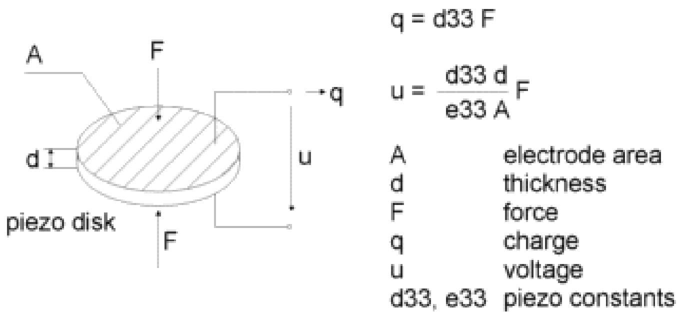

Figure3: Piezoelectric circular disc [7]

IV. CIRCUITRY

The proposed circuitry for energy harvesting comprises a piezoelectric which when subjected to force produces mechanical energy which can be converted to electrical energy. Voltage generated from piezoelectric material will have wave form as shownin figure 2.As the waveform has some ripples so, it should be rectified and filtered before storing it to the battery. A full wave bridge rectifier provides rectified voltage which is filtered by a simple capacitor to produce a dc voltage. This dc voltage will have some ripple or ac voltage variation. A regulator circuit removes these ripples and even also maintains the same dc voltage even if the input dc voltage varies, or the load connected to the output of regulator varies. The regulator IC used is IC 7806. This regulated voltage is fed into DC-DC Boost Convertor, which step up the voltage before applying it to battery charging circuit. The circuit uses MCP 73862 IC to charge lithium ion / lithium polymer batteries.The MCP73862 is a highly advanced Single or Dual Cell, Fully Integrated Li-Ion/Li-Polymer Charge Management Controllers. They are linear charge management controllers for use in space-limited, cost-sensitive applications. The device combine high-accuracy, constant voltage and current regulation, cell preconditioning, cell temperature monitoring, advanced safety timers, automatic charge termination, internal current sensing, reverse blocking protection, charge status and fault indication. Thus at the final stage, the lithium polymer battery is used to store the charge obtained from the piezoelectric material which can be used to light the street lamp or can be used for other purposes

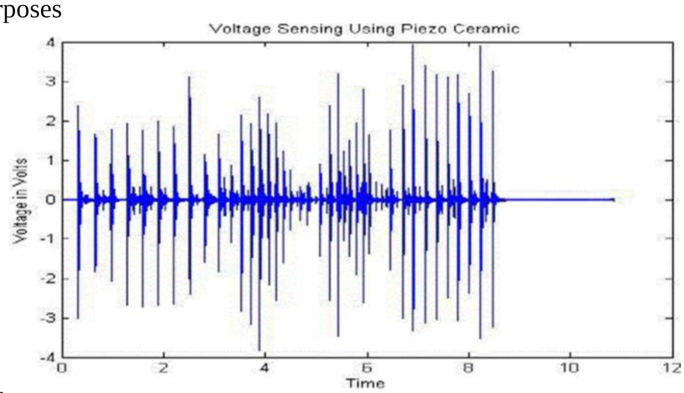

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Figure4: Voltage waveform output of piezoelectric material [11]

C. The Diode Bridge Rectifier

Full-wave bridge rectifier uses four individual rectifying diodes connected in a closed loop bridge configuration to produce the desired output. The main advantage of this bridge circuit is that it does not require a special centre tapped transformer, thereby reducing its size and cost[10].

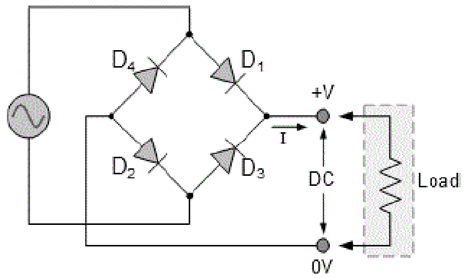

Figure3: Diode bridge rectifier [10]

D. Voltage Regulator

7806 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7806 provide +6V regulated power supply Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.

E. Boost Convertor

The boost is a popular non-isolated power stage topology, sometimes called a step-up power stage. The boost power stage is often chosen in designing because the required output is always higher than the input voltage. The input current for a boost power stage is continuous or non-pulsating because theoutput diode conducts only during a portion of the switching cycle. The output capacitor supplies the entire load current for the rest of the switching cycle. A simplified schematic of the boost power stage is as shown in figure below. Inductor L and capacitor C make up the effective output filter. The capacitor equivalent series resistance (ESR), RC, and the inductor dc resistance, RL, are included in the analysis. Resistor R represents the load seen by the power supply output. The boost converter is so designed to operate only in Continuous Conduction Mode (CCM). [12]

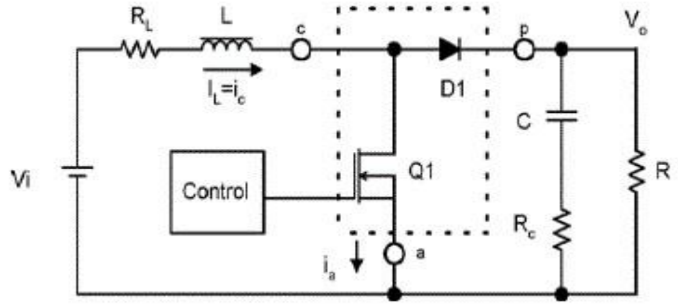

Figure3: DC-DC Boost convertor [12]

F. Lithium Polymer/ lithium ion Battery Charger Circuit

The MCP73862/4 is intended for dual series cell Lithium-Ion or Lithium-Polymer battery packs. The MCP73862/4 has two selectable voltage-regulation options available (8.2V and 8.4V), for use with coke or graphite anodes, and operate with an input voltage range of 8.7V to 12V. The MCP73861/2 and MCP73863/4 differ only in the function of the charge status output (STAT1) when a charge cycle has been completed. The MCP73861/2 flashes the output, while the MCP73863/4 turns the output off.

V. PROPOSED DESIGN FOR SPEED BREAKER

The design proposed for the speed breaker is similar to classical speed breakers but it has some of the part moveable so as to convey the force applied on the surface of the speed breaker to the piezoelectric material. The two portion of the speed breaker which experience the most of the force during the evolvement with the vehicle are radically moveable and these are attached to the piezoelectric material with a spring and a support structure which holds the piezoelectric material to the spring. The center part of the speed breaker has cylindrical cavity for the spring. When the force is applied, the spring gets compressed and there is stress in the piezoelectric material. The spring provides damping and it also act as a protective aspect for the piezoelectric material. large number of springs will be used to avoid the use of "high spring constant" springs and provide stability to the damping system.

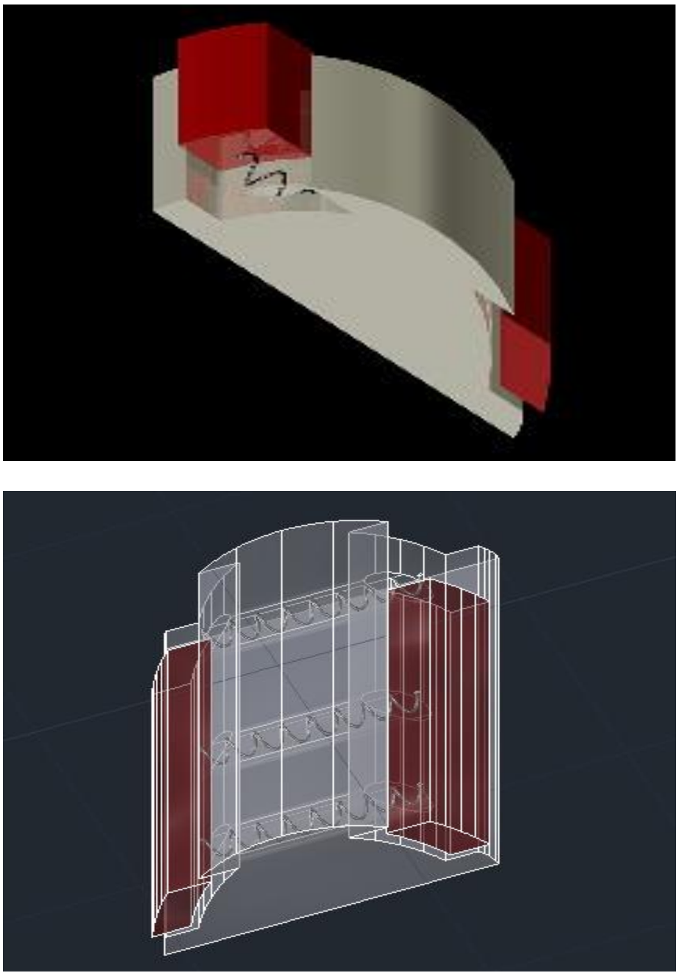

Figure3: Auto cad design for the speed breaker.

VI. APPLICATIONS AND RELATED RESEARCH WORKS

Piezoelectric materials as a market entity is worth approximately 14.8 billion$ and has a potential to grow to 25 billion$ by 2020, while solar energy market is worth approximately 40 billion $ given that much larger scale research has taken place in the solar energy field. Anywhere there is force we can think of piezoelectricity the only barrier is efficiency and safety.Many a researches are taking place as the world looks for more green energy sources. Some of the ideas that can be feasible for piezoelectricity are:

1) Use of piezoelectric materials beneath the synthetic basketball courts.
2) They can be used at pivotal on a suspension bridge(but the materials should have larger life time).
3) Piezoelectric materials in running shoes can be used to charge mobile phones and other low power portable devices.
4) Heat maps can be used to design piezoelectric material roads at popular tourist destinations and markets.
5) On the dance floors of various disco night bars.

Piezoelectricity as an efficient method for wide scale power generation may seem farfetched but smaller applications like above are more realistic. Some revolutionary researches are going on in this field . For instance - A pilot research project into vibration energy on the N34 provincial motorway near Hardenberg in the eastern Netherlands has shown that vibration energy as a local energy source is a sustainable alternative for the batteries of roadside sensors and other applications.

VII. CONCLUSION

In this paper we have used piezoelectric materials in collaboration with a spring based damping system to synthesize electricity for lighting street LEDs. Piezoelectric powers efficiency, speed and availability make it a strong competitor with solar power. Since piezoelectric materials are custom made, they can be used in different types of applications depending on rigidity, power generated, cost etc. These ideas may seem futile for now but 20-30 years from now when petroleum will skyrocket, we will need these types of ideas. One of the major causes of global warming is energy generation; 20 years from now neglecting environmental issues will no longer be a choice. We cannot hope for some miraculous source of energy to be discovered we must plan for the future. Adopting and motivating more of these technologies will pave the way for sustainable future.

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