International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2019): 7.583

Harvesting Energy from Traffic Breakers using Piezoelectric Discs

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Abstract: ***With the rise in the demand for energy consumption, researchers are working on new means and ways to harness energy from various renewable sources. This research paper focuses on harnessing a new means of electrical energy by using piezoelectric technology. Piezoelectric discs were inter- connected and were embedded within a certain depth of the speed breaker which was capable of harvesting electrical energy from the transverse mechanical deformation of the piezo-discs by the sudden impact force caused by the automobiles passing through it is proposed . The piezoelectric discs were connected in series and parallel and embedded within a wooden plank which is enclosed with a rubber tyre and this arrangement was well placed within the speed breaker. On series of testing with the vehicular movement varying the impact loading over it was found that with small setup a maximum of volt could be generated with a single vehicle movement .The energy harnessed was stored in the battery for later use like college campus lighting during night time. The motive of this project work is to obtain an alternate source of energy which is environment friendly and pollution free and hence, to utilize and optimize this energy being harnessed.***

Keywords: Piezoelectric discs, Piezo-speed breaker, Energy harvesting, voltage

1. Introduction

With the instantaneous growth of population in our country, the demand for the electrical power, new technologies for generating power from renewable energy sources have become an eminent area of research these days. The piezoelectric effect has been contrivance in many research works due to its high power generation and low cost of applications. Currently, the demand for electrical power is of prime importance to meet the current prerequisite of undisrupted supply of electrical power. Hence, researchers are working on different ways and means to harvest the renewable and green energy sources. For powering up the devices, it is required to make the wired connection with batteries. However, the batteries have to be frequently maintained which makes it difficult every now and then and hence at locations such as busy roads, road junctions and remote places it becomes complex. To solve this circumstance, energy harvesting technique using piezoelectric technology can be used as an alternate means. This technique is mainly based on converting mechanical deformation into electrical power by means of low-frequency vibration using piezoelectric effect [1]. Further, a piezoelectric generator was developed that harness mechanical vibrational energy through a bicycle. The electrical energy thus generated can be used to power devices aboard the bike, or other portable devices that the cyclist uses. Electrical energy can also be generated from vibrations on the surface of the road due to traffic using piezoelectric material [2].

A piezoelectric transducer (PZT) developed was used to transfer ambient amount of energy into electrical power. However, the most annoying issue identified was to collect certain amount energy as efficiently as possible. The main constraint of using piezoelectric material was that they do not contribute to a steady state voltage and furthermore the current produced was quite low. Therefore this sort of materials was considered to be a source of micro energy which must be utilized by low power expending gadgets for an ultra-low power solution [3].

Electricity has become a lifeline of modern advancements and thus its demand is growing steadily and enormously. It seems that there is no end to the different ways man can generate eco friendly pollution free electricity. Energy demand and heavy traffic correlation motivates one to device something innovative in the road that would harvest the energy from vehicles impacting over and through it. For this very purpose, a piezoelectric material embedded beneath a road, the so called the piezo-smart road was adopted in many of the developed countries like Singapore and Canada. These roads can provide the magic of converting pressure exerted by the moving vehicles into electric current. When a vehicle produces impact load over it takes the vertical force and deforms the piezoelectric material, thereby producing change in voltage to generate electricity.[4]. Piezoelectric effect in piezoelectric crystal and power generation by thin film MEMS, PZT, PMPG and using them in piezoelectric roads, as congestion on roads is becoming inescapable with the fancy masses shifting towards more of personal transportation systems for their growing mobility and life standards [5]

Further, a system was developed that generates electricity from integrating piezoelectric cells with streets bumps having the advantage of the huge traffic density in developing countries to generate renewable and Eco-friendly electrical energy[6]. Using this vibration of the vehicle, the proposed embedded piezo-circuit implemented on the surfaces of the highway or roads, energy will be produced which can be stored in the battery or the invertor which on later stage be used for the roadside street lights and traffic signal lights. To authenticate this design, quite few simulations were carried out and the results were compared with the experimental data of the prototype, which came out to be quite approximate.[1]

As the population in Andaman & Nicobar Islands has tremendously increased due to tourism in the last decade it has led to the increase in consumption of electrical power . The primary source of electrical power for these islands is from diesel run power station and solar harvesting in certain defined areas. Hence, harvesting Energy by means of alternate renewable source is the prime concern of these islands. This project work proposes the use of low cost piezoelectric discs embedded within the speed breakers to harvest power which could be stored and could be used for street lights during the night time.

2. Piezoelectric Effect

The piezoelectric effect was first formulated and its behavior was studied and experimented back in the 19th century but its intended use with more importance was recognized in the last two decades especially in the developed countries of the world. There were many piezoelectric materials that the researchers had identified that were naturally available like cane sugar, Rochelle salt, quartz, topaz and tourmaline. Whereas, few others were artificially developed by man like Barium Titanate and lead zirconatetitanate. In recent years, due to growing concern on environmental toxicity in using lead containing devices the need to develop lead free piezoelectric materials were developed and proposed.

The piezoelectric effect is the potentiality of certain materials that could generate electric charges in response to an applied mechanical load. The piezoelectric word was derived from the Greek word "Piezein" which denotes to press or squeeze and "Piezo" meaning to push. One of the Unique feature of this piezoelectric effect is that its reversible that is the materials which exhibit the piezoelectric effect also are desirable to exhibit the converse piezoelectric effect , meaning the materials can produce mechanical stresses in the direction of an applied electric field .

The piezoelectric effect is the linear electro-mechanical correlation between the mechanical and the electrical state of the crystalline materials with no inversion of the symmetry. The piezoelectric effect is a reversible process in those materials which are capable of exhibiting the direct piezoelectric effect . A small mechanical deformation due to vertical load over the piezoelectric materials could create a change in voltage which in turn leads to harnessing of electrical power.

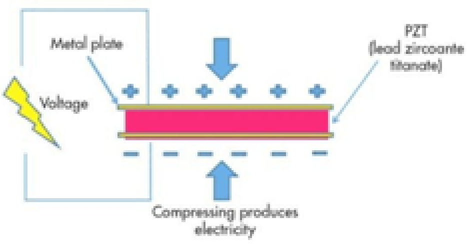

Figure 1: Piezoelectric Effect

Small Scale Model Testing

A Small scale model (stamp foot model) was made using the piezoelectric discs to check the voltage generated so as to design a large scale prototype. The small scale model was impacted with the impact of foot of people of varying weights.

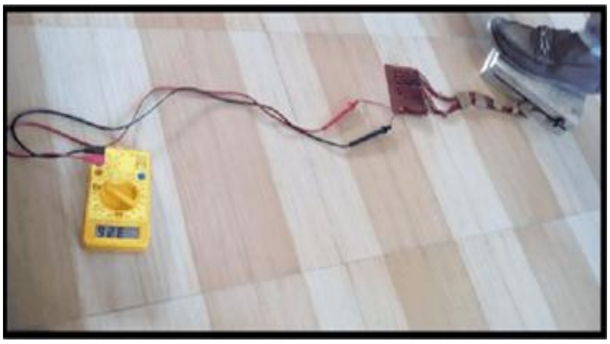

Figure 2: Stamp foot Model of Piezoelectric discs

The stamp foot model was tested by applying impact loads of varying weights and the corresponding voltage generated was recorded using a multimeter device which gives the electric current generated in terms of DC volts.

Table 1: Varying weights and voltage generated

S.NO	Weight (in Kg)	Voltage (in Volt)
1.	40	2.44
2.	43	2.45
3.	45	3.49
4.	56	3.51
5.	57	3.9
6.	60	3.6
7.	62	3.98
8.	63	4.33

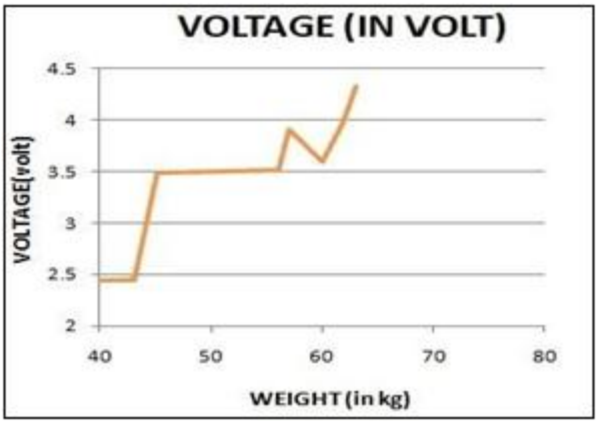

Figure 3: Output Voltage v/s Weights

In the above graph, it was observed that with the increase in weight ,the impact load on the discs also increases which would result in increase in the voltage generated. It is also observed in the constant value of voltage generated when the weights vary from 45-55 kg.

The calculations for the number of discs required were decided based on the assumption that a single piezoelectric disc is capable to produce 2.5 volt if the impact load is directly over it. It was also found that the discs resulted in higher voltage in parallel arrangement in comparison to series arrangement. Hence, in the design of our prototype model parallel connections were adopted.

3. Specification of Prototype Model

A pair of wooden planks made of plywood was used to make the prototype model. The piezoelectric discs were connected in parallel using insulating wire which was connected to the invertor via battery. These piezoelectric discs were embedded within the wooden planks. The sides of the wooden planks were covered using waste rubber tyres.

A. Piezoelectric Discs

The specification of the discs used for this project are as follows: Diameter of disc = 27 mm
Thickness of disc = 1 micron

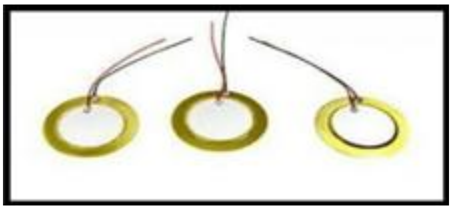

Figure 4: Piezoelectric Discs

B .Wooden Planks

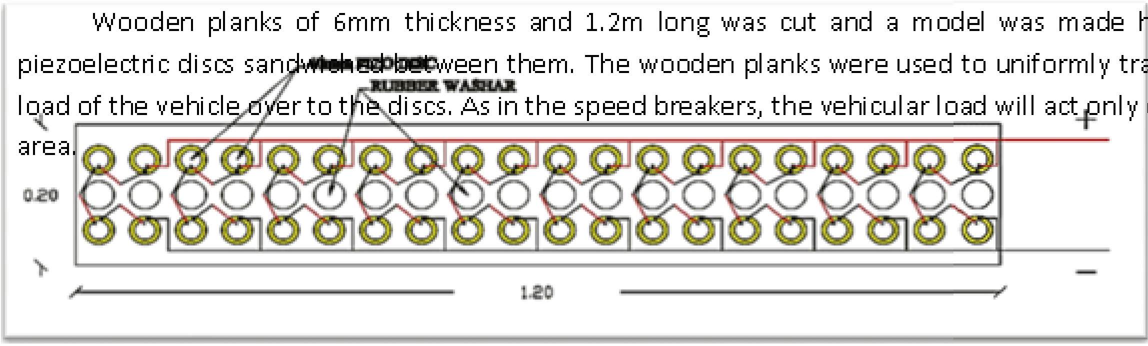

Figure 5: Plan view of the piezoelectric discs within the wooden plank

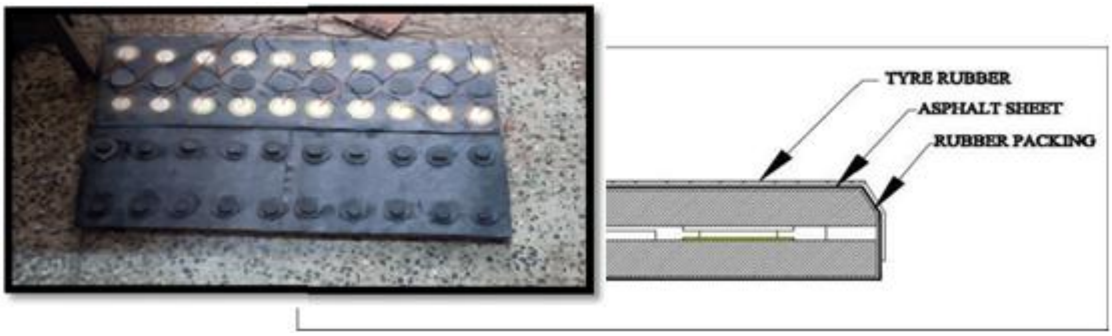

Figure 6: Sectional view of Piezoelectric discs embedded

Figure 7: Rubber tyres covering the sides of the prototype

Figure 8: Prototype Model tested

The waste rubber tyres were used to prevent the dislocation of the planks, absorb shocks due toimpact of vehicles and also to prevent the ingress of water during rainy season. As Andaman islands have monsoon for most time of the year . The prototype model was also tested during the peak monsoon season.

Size of the model 1.2 x 0.2 x 0.02 mm Design wheel load 'p' is taken as 5100 kg
Centre to center distance between the discs- 40 mm

In the prototype model to create the pressure of the the upper plank over the piezoelectric discs a small projection was made from the waste rubber tyre and glued in the plank. In the above figure, the piezoelectric discs are firmly embedded within the asphalt sheet covered over the planks.

The rubber tubes enclose the planks to prevent the ingress of water. The wires were connected in parallel arrangement so as to obtain high voltage.

4. Field Testing of the Prototype Model

The entrance gate of the college was selected as the suitable location to test the prototype as the maximum number of vehicles would pass in and out through it. The laying of the model was done by excavating the ground surface up to a depth of 5 cm at a location ahead of the gate. The soil was leveled to place the model .The model was placed and a small bump was made over it using the excavated soil and with additional fine aggregates so that the prototype model is well positioned and not much displaced. A thick layer of bitumen mix is placed over it to give it a smooth finish The positive phase of the circuit model is connected to the multimeter to check for the voltage generated. The working of the model was checked by passing a two wheeler vehicle over the model.

Figure 9: Small scale testing of two wheeler and Four wheeler vehicles to check the working of the prototype model

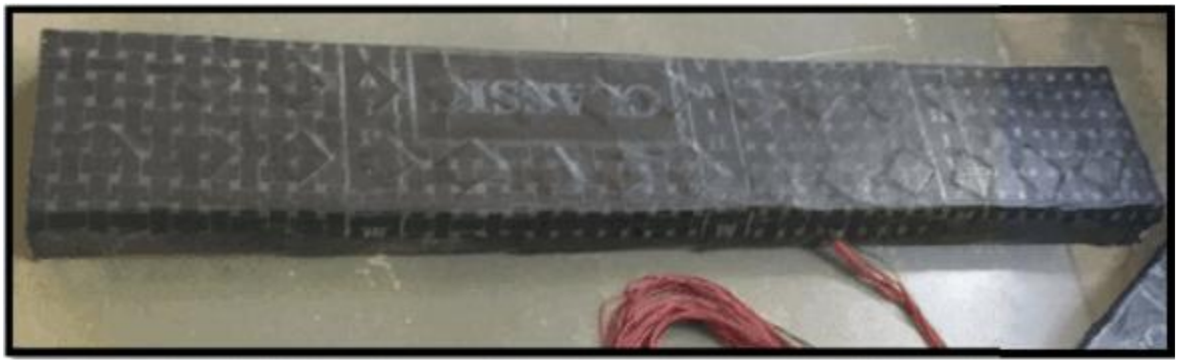

Figure 10: Prototype model to be embedded within a speed breaker

Figure 11: Laying of Prototype model at the entrance gate of College

5. Conclusion

This paper introduces a low cost piezoelectric disc energy harvester technique to harness electrical power. With several tests performed by allowing the vehicles passing through the model during the peak hours , It was found that the voltage generated from two wheeler is quite low as 4-5 volts. Whereas, the maximum voltage which was generated from a 4 wheeler vehicle is about 10-12.5 volt.

This energy harvested was stored in the battery connected to an invertor which was later proposed to be used for night lighting within the college campus .This way the load on the conventional energy being utilized will be reduced to a greater extent. Further, in future with more discs connected much better models could be proposed for the traffic intersections as the maximum vehicular load could result in more energy being harvested.

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