Application of Piezoelectricity in DMRC

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Abstract— What have we done to our environment? Everyone should ask this question to themselves. Due to increasing demand of energy, the world is leading towards the depletion of carbon fuel. Today the need of the hour is the correct transformation of energy and reuse of energy. Fossil fuel based power generating technologies have much large amount of carbon emission leading to climate change. Today the need of century is to move towards carbon free energy and find every possible way to do so. One of the possible implementation is what we have done in our research. We at Maharaja Agrasen College, University Of Delhi, have tried to use Piezoelectricity, which is a charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress, pressure and vibrations. We came up with an idea to convert pressure and mechanical stress into electricity in Metro stations. The energy people apply in walking on metro station platforms is converted into electric charge which is converted into electric voltage required to charge the battery using the piezoelectric transducer generators.

Keywords: Piezoelectric Generator, ZirconateTitanate (PZT)

I. INTRODUCTION

Daily, about 2.70 million people travel in Delhi metro. These 2.70 million riders, you see as humans, we see them as power sources and are huge power assets. We aim to quantify the mechanical energy that is generated by humans daily but gets wasted. We will install piezoelectric transducer generators on the floor of metro stations which produce electric charge when we apply pressure on them. This electric charge can be used to generate an electric voltage which can be used to charge batteries. Now, let’s see how piezoelectric transducer generators actually work does.

Piezoelectricity (also called the piezoelectric effect) is the appearance of an electrical potential (a voltage, in other words) across the sides of a crystal when you subject it to mechanical stress (by squeezing it). In practice, the crystal becomes a kind of tiny battery with a positive charge on one face and a negative charge on the opposite face; current flows if we connect the two faces together to make a circuit.

A. Piezoelectric Generator

Piezoelectric effect is the generation of electric charge when mechanical strain is applied on piezoelectric materials. Piezoelectric effect is employed in manufacturing sensors. The piezoelectric materials are both natural and artificially made. Quartz is a natural piezoelectric material while Lead ZirconateTitanate (PZT) is an artificial piezoelectric material.

Throughout the artificial piezoelectric material composition the electric dipoles are orientated randomly, but when a very strong electric field is applied, the electric dipoles reorient themselves relative to the electric field; this process is termed poling. Once the electric field is extinguished, 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 effect. This would result in accumulation of charge at the electrodes connected to the piezoelectric crystal. Using a transducer, a potential difference will be created and will ultimately result in

\[ D = d.T + T.E \]

Generation of a current flow. We will then rectify the output of the Piezo Electric generator and then send it to a small battery, so that the generated power is harvested for later use.

The following equation describes piezoelectric effect. Where, D denotes electric displacement vector, T denotes stress vector, d denotes piezoelectric constant matrix, E denotes electric field vector. In piezoelectric effect, charge density is developed on its surface when external pressure is applied. Where, D is the charge density, Q is the electric charge that is accumulated on the surface, A is the area of the conductive electrode.

Fig. 1: Piezo-electric Transducer
II. DESIGN AND METHODOLOGY

The piezoelectric material converts the pressure applied to it into electrical energy. The source of pressure from the weight of the people walking over it. The output of the piezoelectric material is not a steady one. So a bridge circuit is used to convert this variable voltage into a linear one. Again an AC ripple filter is used to filter out any further fluctuations in the output. The output dc voltage is then stored in a rechargeable battery.

The piezoelectric effect describes the material’s ability to transform mechanical strain into electrical charge. This effect is responsible for the materials ability to function as a sensor. A material is deemed piezoelectric when it has this ability to transform electrical energy into mechanical strain energy, and the likewise transform mechanical strain energy into electrical charge.

When a poled piezoelectric ceramic is mechanically strained it becomes electrically polarized, producing an electric charge on the surface of the material. This property is referred to as the “piezoelectric effect” and is the basis upon which the piezoelectric materials are used as sensors. Furthermore, if electrodes are attached to the surfaces of the material, the generated electric charge can be collected and used.

![Fig. 2: Dipole Alignment](image)

A. Design Objectives

1) Moving Stair Tread

This is the physical staircase that users will step on. There will be a moving stair tread which rebounds to its raised position via several springs under the moving tread plate. The tread plate will be hinged in the back to restrict the tread to one degree of motion. The tread will be limited in its vertical travel to about a half inch. We will be able to adjust the vertical travel of the stair via screw with an adjustable wing nut.

![Fig. 3: Moving Stair Tread](image)

2) Platform

Another piezoelectric setup will be installed on the crowded metro platforms, where the people will step while moving in and out from the metro trains. These piezoelectric slabs will be placed at those parts of platform which is highly influenced by the crowd like the areas just outside the openings of metro train gates.

3) Piezo-Electric Material

![Fig. 4: Piezo-Electric Material](image)
The Piezo-electric material placed in the gap between the tread plate and the base is used to convert the mechanical energy (Vibrations) into electrical energy with the help of Piezo-electric generator.

**Fig. 5: Mechanical & Electrical System**

4) **Energy Harvesting**

The Electrical energy thus produced can be used to power different electrical lights, etc. depending upon the amount of power produced.

### III. PREVIOUS RESEARCHES AND DISCUSSIONS

According to two architecture students at the Massachusetts Institute of Technology, Cambridge, Massachusetts, James Graham and Thaddeus Jusczyk, their design – which won a prestigious award from the Holcim Foundation for Sustainable Construction in Zurich, Switzerland? They figured that the stomp of every footfall gives off enough power to light two 60-watt bulbs for one second. Furthermore, 28,527 footsteps could power a train for one second and interestingly 84,162,203 paces could launch a space shuttle.

Also, layers of piezoelectric biopolymer with strong positive charges on the inside and negative charges on the outside that transforms pressure into power can be used at a large scale for energy harvesting in large-scale projects.

#### A. Advantages of Piezoelectricity

1. It is totally unaffected by external electromagnetic fields.
2. It is a green renewable source of energy.
3. It is very easy to maintain and replace.
4. The power that is created is used locally, rather than needing to be transmitted.

#### B. Disadvantages of Piezoelectricity

1. The piezoelectric crystal is prone to crack, if overstressed.
2. It may get affected by long use at high temperatures.

### IV. CONCLUSION

The field of piezoelectricity, not only demonstrates the capabilities of electronics engineering, but also relates the world with green and sustainable energy. It is a very useful application of piezoelectricity that we can use in Delhi Metro and has greater future aspects. In this paper we mainly focused on empowering Delhi metro for its energy needs. With all our efforts and the cooperation from DMRC, we can produce electricity from nowhere in the upcoming days. By using just microwatts, we can save kilowatts of energy that would have gone to waste.

### REFERENCES