Paper ID: AM-07

Electricity Production from Piezoelectric Material Used in Traffic Road of Bangladesh

F. Rashid[1], F. Ahamed[1], R. Akbar[1]

[1] Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi

E-mail: frrashed10@gmail.com,ridwanul142071@gmail.com

Abstract

This paper presents electric power generation from piezoelectric material mainly use in traffic road at the junction point of traffic signal which is controlled by using programmable logic controller ((PLC). This electricity production is mainly based on vehicles load and load of the humans. The originality of this work is to produce electricity using piezoelectric material on the roads and the produced electricity is utilized to operate traffic light for traffic signal control. As a consequences, pressure on national grid in order to power traffic light is somewhat reduced as well as can back up during load shedding period. This paper also represents pollution-free energy source that is piezoelectricity generation technique based on human load in zebra crossing. In this paper, piezoelectric crystals are used for AC power generation (minimum 0.009V and maximum 5 V per single press on piezoelectric material) which is rectified to DC supply and store in a battery. This paper also summarizes the payback installation cost (require 1120 press with 338 kg load) and power calculation for a specific region of junction point for a traffic road in Bangladesh.

Keywords: Piezoelectric material, Piezoelectricity, Mechanical load, Electrical load.

1. Introduction

Now a day's scarcity of energy is one of the biggest problems in the world especially in under developing country like Bangladesh. In order to solve this growing demand of energy supply, new sources of energy are required to find out and apply in replace of conventional sources of energy which is diminishing day by day. For this reason researchers all over the world are trying to find green and pollution-free energy sources as an alternative source of energy. There are many energy sources like solar, windmill and geothermal energy sources which are the power harvesting technologies and are called macro energy harvesting technologies. However, macro energy harvesting technologies generate kW or MW level power. On the other hand, there is another type of energy harvesting technologies which is called micro energy harvesting technologies. Moreover, micro energy harvesting technologies are also pollution free energy source which uses mechanical stress and strain, mechanical vibration and friction sources in order to produce power. Micro energy harvesting technologies generate mW or µW level power. With the ever demanding and increasing energy requires of micro energy harvesting technologies which is introduced as an alternative of conventional energy sources [1]. In the last three decades, energy harvesting and production of new sources of energy has been a subject of research and piezoelectric material is one of the micro energy harvesting technologies which have some specific properties. However, materials that can convert the mechanical stress into electrical energy is called piezoelectric materials [2]. The piezoelectric phenomena and crystallographic structure was initially published in 1880 by Pierre and Jacques Curie [3]. The word which was derived from the Greek "piezo" means pressure, while electric means electricity or power [4].

This paper presents, electricity production from piezoelectric crystals which when are pressurized, an electric field is generated. Some of the biggest energy consumers on the earth are cars, trucks and ordinary people can generate energy by simply moving across the roadways and sidewalks over piezoelectric material. There are two effects in piezoelectric material one is direct effect which converts mechanical strain to electrical energy and another is converse effect which converts electoral energy to mechanical strain as shown in Figure 1.

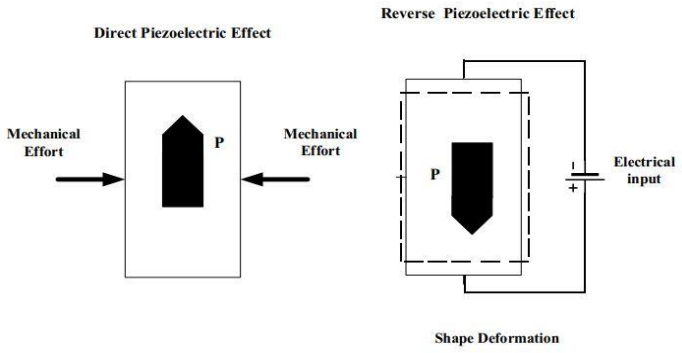

Fig. 1. Effects of piezoelectric material

This paper also represents that piezoelectric material in traffic road of Rajshahi, Bangladesh transform normally wasted mechanical load by vehicles into electrical energy. In general, asphalt (Tar) is used to make commercial roads on which several vehicles run and gravels, sand are used for laid the first layer of traffic road. In this system, a thin asphalt layer is used for the strong support of piezoelectric materials and finally quick drying concrete piezoelectric generator is placed on traffic road. Then wires are used to connect all the piezoelectric generators and the generators are connected in series to get maximum power output. For providing better adhesiveness bitumen sheet is used between asphalt and concrete. Finally, in order to complete the construction a thick layer of asphalt is laid on traffic road [5].

2. Methodology

For extracting energy from the load of the vehicles, piezoelectric crystal used in the roads shown in Figure 2 and Figure 3. First the layout and 3D modeling of the prototype was done. A piezoelectric material consists of many particles. The particles are negatively and positively charged. All the negatively charged particles and the positively charged particles are arranged in same central point and at under pressure both face of the crystals are moderately distort.

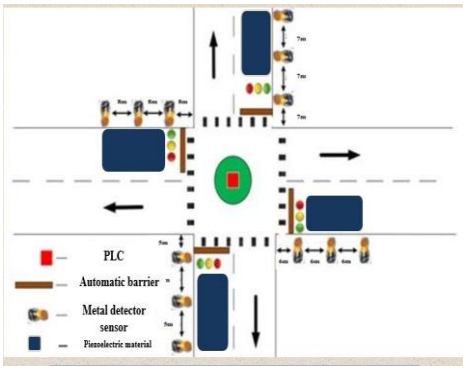

Fig. 2. Layout of proposed system use piezoelectric material

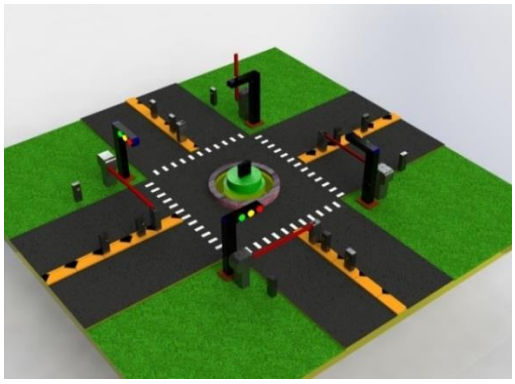

Fig. 3. 3D modeling of proposed system

The charge particle in the crystal is pushed out and so the position of the negatively charged particles slightly changes. Potential difference created between the positive and negative face.

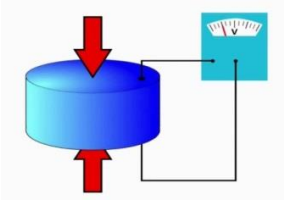

Fig. 4. Generating Energy when deformed

The voltage and power thus obtain is proportional to the amount of total pressure which is applied on the piezoelectric crystals. Here the pressure is applied by the weight of the vehicles and persons are standing or walking on it. Piezoelectric effect is use to produce piezoelectricity and the piezoelectric effect is shown in Figure 4.

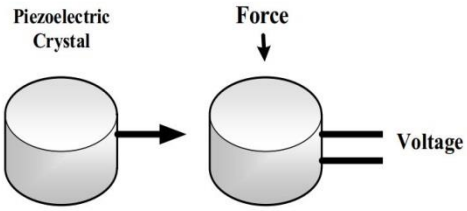

Fig. 5. Direct Piezoelectric Effect

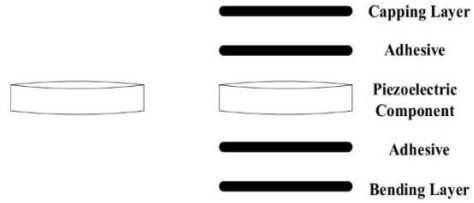

Fig. 6. Piezoelectric component structure

For single piezoelectric crystal the voltage obtained is in millivolts range and the watt obtain is in micrometer range. To obtain higher voltage the piezoelectric crystals are arranged in series. Lithium batteries or capacitors are used to store the output energy. Massive amounts of energy are generated due to the thousands of tons of vehicles passing over the piezoelectric crystals in each day as shown in Figure 5. A lithium battery is used to store the energy and from the battery energy is supplied to the traffic control system which is operated using PLC. The power from piezoelectric electric crystal is alternating current. To store the output voltage in the battery rectifier was used to convert AC current into DC current and this is followed by a capacitor. A switch is provided which gets close when the storage capacity reached to its maximum amount and then the current goes to the battery. The disadvantage of the capacitor is that it discharges the stored current very quickly and thus battery is preferable. Figure 7 shows electricity generation circuit for piezoelectric material.

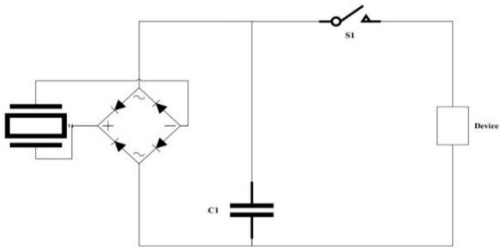

Fig. 7. Electricity generation circuit diagram

In this proposed system, two plates of dimension 3*2 square inch are used for hardware setup. Between these two plates the piezoelectric generators are placed. These piezoelectric generators convert the applied mechanical load into electrical potential. This generated electrical potential is in millivolts level which is measured by using multi-meter and overall flow diagram is shown in Figure 8.

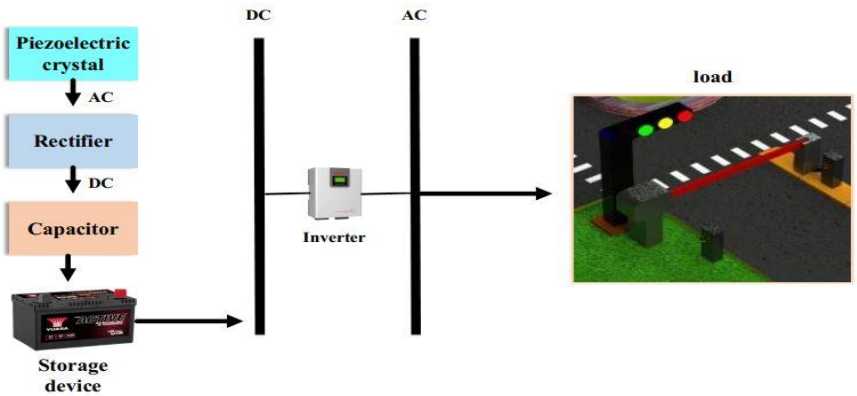

Fig. 8. Flow diagram of electricity generation from piezoelectric crystal and use in traffic lights

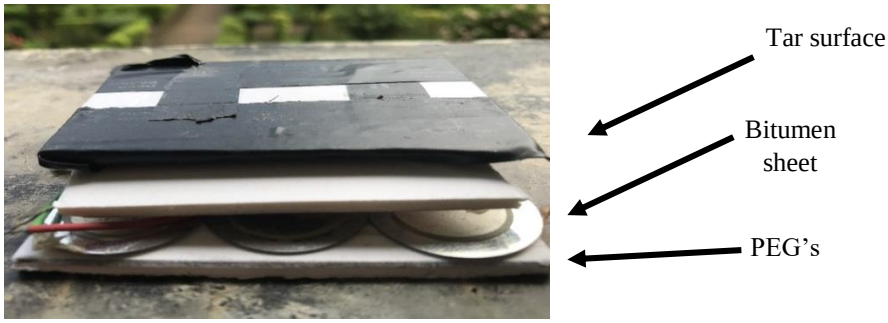

Fig. 9. Piezoelectric generator embedded roads

Figure 9 shows how piezoelectric material is set up in pavements below tar and bitumen sheet which is used for power generation by embedding the piezoelectric generators under the thin concrete slabs. Figure 10 represents electricity production circuit and from this circuit voltage, current is measured using multi-meter. On the other hand, Figure 11 illustrates electricity generation in traffic road using piezoelectric material and this traffic road signal is controlled using programmable logic controller (PLC). As a consequences, when vehicles are at the junction point and wait for green signal of traffic road then this load pressed on piezoelectric material and produce electrical voltage. In Figure 11, it is also seen that traffic signal is controlled using eddy current displacement sensor which have a range of 2-5 mm in the proposed prototype.

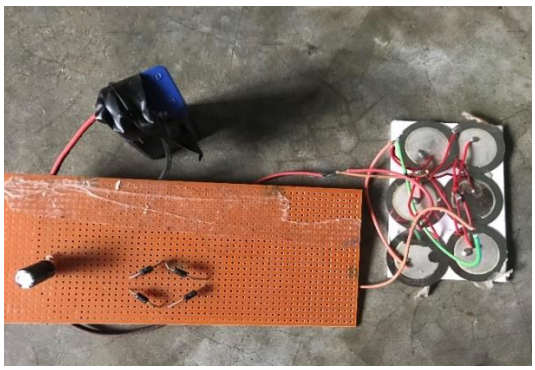

Fig. 10. Electricity generation circuit

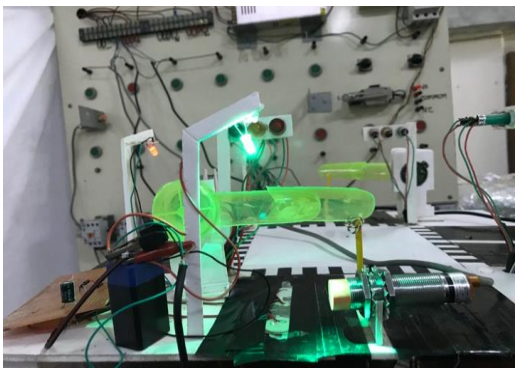

Fig. 11. Electricity generation from piezoelectric material in traffic road

3. Calculations

In, 3*2=6 square inch area, 6 piezoelectric generators are used. Piezoelectric generators voltage generation depends or varies with loads. Here, minimum 0.45 volt is obtained per press and maximum 5 volt is obtained per press of load. For pavement an average 50 kg average weight load is considered for single person.

For 1 volt charge in a battery it takes 1,778 steps and for 12 volt capacity battery to charge, it requires (12*1,778) = 21,336 steps. For 2 steps in 1 second, total time required = $\frac{21,336}{(60*2)}$=177.8 minutes = 178 minutes (approximately).

In case of vehicles, diameter of the piezoelectric generator, d = 0.027 m, length of the road, l = 15 m, width of the road is b = 3.7 m, area of the road = (l*b) = (15*3.7) =55.5m^2. Area of the piezoelectric generator = $\frac{\pi*d^2}{4}$= $\frac{3.1416*(0.027)^2}{4}$ = 5.726 *10^{-4} m^2.

Number of piezoelectric generators used = $\frac{\text{Area of the road}}{\text{Area of the piezoelectric generator}} = \frac{55.5}{5.726*10^{-4}}$ pieces =96926 pieces. For 1 kg load 0.009 volt is obtained per one press. Consider a car with average weight of 1352 kg. The weight of the car is distributed equally between the four wheels and so 338 kg weight is used for pressing. Total voltage obtained by pressing six piezoelectric generators = (338*0.009) volts = 3 volts. For 96926 pieces of piezoelectric generators total voltage obtained = $\frac{96926*3}{6}$ volts = 48463 volts.

The cost of one piezoelectric generator = 70 taka and so the total cost of 96926 pieces of piezoelectric generators = (70*96926) taka = 6784820 taka (installation cost).

However, cost required to charge a 72 volt capacity battery is 9 taka and so 48463 amount volt power produce from piezoelectric material in traffic road, so the saving amount is = $\frac{48463*9}{72}$ taka = 6057.87 taka.

To pay back the money which is invested for this installation setup = ($\frac{6784820}{6057.87}$) = 1120 presses is required with 338 kg load.

4. Results and Discussion

By pressurized piezoelectric materials different voltage was obtained and this is shown in Figure 12. Figure 12 shows relation between piezoelectric mass and output voltage. It is seen from Figure 12 that, when the load is increasing then the voltage is also increasing. As a result, it represents that when amount of load is applied to piezoelectric crystals then more voltage is produced.

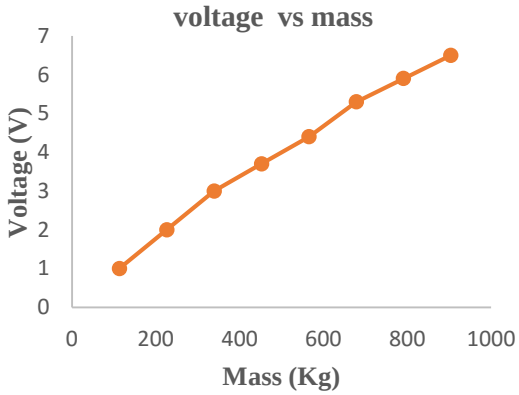

Fig. 12. Voltage vs Load graph

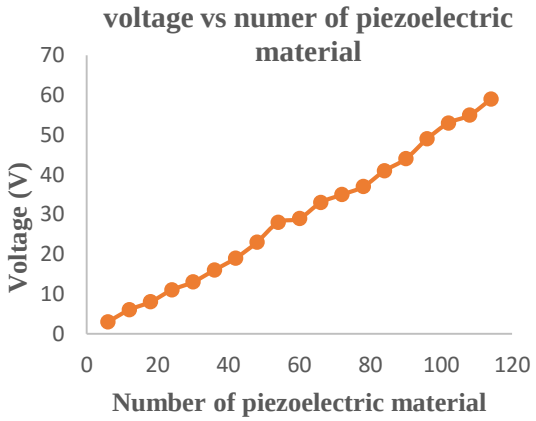

Fig. 13. Voltage vs Number of piezoelectric material

In this experiment six piezoelectric crystals were used and one voltage is obtained from these six piezoelectric crystals. On the other hand, if twelve piezoelectric crystals are used then the voltage output would be two volt and this is shown in Figure 13. From Figure 13, it is seen that if the number of piezoelectric materials increase then the output voltage is also increased and the voltage output mainly depends on the number and size of piezoelectric material. If the size of the piezoelectric material increases then the output voltage is also increased. In this system 0.45 V was obtained by pressurized one piezoelectric materials used in pavement and maximum amount of voltage was 5 volt if the press was in right place of the piezoelectric crystal material.

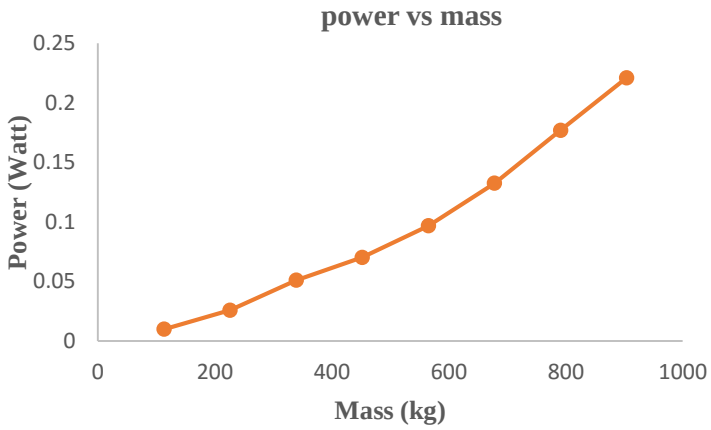

Fig. 14. power vs mass of piezoelectric material

Figure 14 shows, power production from piezoelectric material on the basis of mass on piezoelectric material and it is seen that, wattage value is increased with respect to mass on piezoelectric material.

From the cost and payback period calculation it is seen that, time required for piezoelectric material used in the pavement of traffic road junction in order to charge a 12 V battery was 178 minutes. From this, it is also seen that 72 volts capacity battery required power cost is 9 taka and for 48463 volts power production from piezoelectric material of traffic road the saving amount is 6057.87 taka. To pay back the money which is invested for this installation setup is 1120 presses required with a load of 338 kg.

This is one of the best alternatives of future power source as the production of electricity is high at low cost. It decreases the dependency on national grid as the traffic light and the road lights are getting power from the piezoelectric materials used in the roads. In this experiment quartz material was used and the voltage from piezoelectric material is high but the ampere of the current is very low. To use this current the AC voltage was converted to DC. For generating more voltage PZT (Lead Zirconate Titanate) materials can be used. If there is load shedding or any other reason for no current in that area, then the traffic control system must run with the current it produces using piezoelectric material.

5. Conclusion

An automatic traffic signal control using programmable logic controller and electricity generation using piezoelectric material system has been developed and manufactured. This system harvest energy from the road utilizing load of the vehicles and humans on piezoelectric material and it produces power to operate traffic light and other appliances of traffic signal. As consequences, it reduces pressure on national grid and this source is an ecofriendly source of generating energy and also an alternative of conventional fossil fuel. From this experiment it is seen that a large amount of electricity can be generated using piezoelectric material. However, efficiency is somewhat low but it can be increased if good quality piezoelectric material is used to produce electricity from piezoelectric material.

6. References

1. Nayan, H., Power generation using piezoelectric material. Journal of Material Sciences & Engineering, American International University, Dhaka. Bangladesh, 2015. 4(3).
2. Pratibha Arun, V. and D. Mehta, Eco-friendly electricity generator using scintillating piezo. International Journal of Engineering Research and Applications, 2013. 3(5): p. 478-482.
3. Manbachi, A. and R.S. Cobbold, Development and application of piezoelectric materials for ultrasound generation and detection. Ultrasound, 2011. 19(4): p. 187-196.
4. Kumar, A., Electrical power generation using piezoelectric crystal. International Journal of Scientific & Engineering Research, 2011. 2(5).
5. Ashish Dhokle, Amol Boke, Electrical energy harvesting from mechanical pressure of vehicles using piezoelectric generators.IOSR Journal of Electrical and Electronics Engineering,2017. p.46-49.