International Conference on Mechanical, Industrial and Materials Engineering 2017 (ICMIME2017)
28-30 December, 2017, RUET, Rajshahi, Bangladesh.

Paper ID: ET 136

Electricity Generation from Treadmill Using Piezoelectric Transducer

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Abstract

The invention of electricity is one of the greatest achievements of scientific wonders . Although the generation of electricity by conventional technologies has environmental impacts, it is impossible to replace them. The objective of our research is to reduce the dependency on the conventional electricity generation. This paper emphasizes on using a pollution free electrical energy source and utilizing the wasted energy of human footstep by piezoelectric energy harvesting method. This project utilizes crystalline piezoelectric components where deformations produced by human weight are directly converted to electrical charge via piezoelectric effect. This project specifically concerns the generation of electricity from treadmill incorporating piezo transducer when a person is running on its track. This construction will enable the setup to store power in a battery and thus empower small power consuming devices.

Keywords: Footstep, piezoelectric transducer, treadmill, electrical energy.

1. Introduction

Energy has been always considered a vital thing for the sustenance and well-being of human being. Among them electrical energy is one of the most important blessings that science has given to mankind. Due to the pollution caused during the production of electricity with conventional sources the exploration of alternate sources of energy and its sustainable use is being highlighted nowadays. Human population all over the world and hence the energy demand is increasing day by day linearly. So harvesting power from human motions can be a feasible method. The idea of harvesting power from human locomotion is not a new concept. Over the past two decades, there has been significant interest in converting mechanical energy from human motion into electrical energy [1]. Footstep power generation using piezoelectric transducer has become popular in the last few years. This technology is based on the principle called piezoelectric effect, in which certain materials have the ability to build up an electrical charge from having pressure and strain applied to them [2].

2. Fundamental properties of piezoelectric material

Piezoelectric materials are crystals which basically consist of atoms with positive and negative ions. Although the specific repeating units (also called unit cells) in these materials are not symmetrically arranged, they are electrically balanced. When stress is applied upon them, it upsets the balanced positive and negative ions and causes net electrical charges to appear [3].

These materials exhibit two effects known as direct piezoelectric effect and reverse piezoelectric effect. Direct effect can be defined as the property of generating electric charge on their surface when mechanical stress is applied on them. On the contrary, the reverse effect can be defined as the property of generating mechanical stress when an electrical field is applied [4].

The piezoelectric materials which are available as quartz in nature don’t possess the required properties for the generation of electricity. Whereas synthetic piezoelectric materials such as PZT (Lead Zirconate Titanate) have superior characteristics [5].

3. Footstep as an energy source

At present footstep is being considered as a significant source for power harvesting. The energy exerted by the footstep will be totally wasted if not utilized is the main reason behind the significant interest in converting this source of energy into electrical energy. Among all the body parts footstep offers the largest range of motions and dynamic forces [6]. The movement while walking or running produces kinetic energy which can be converted into power by necessary setup. Footstep has already been used as an energy source for generating electricity through vibration, piezo transducer, ratchet mechanism, rack and pinion mechanism etc. [7].

4. Design and Required Components

The whole system consists of a wooden board with ten piezoelectric transducers and cork pieces housed in a treadmill infrastructure. The design was done in such a way that the load was to be applied on the transducer could be converted to electrical output through pinpoint enforcement by cork pieces. The length of the running surface of the treadmill is 45 inches and the width is 16 inches. While running on the surface, it has been found that the footsteps by a person only cover surface length of 18 inches of treadmill. Among them 14 inches of length gets maximum pressurized heel strike and it also covers 12 inches of width of total 16 inches of the treadmill width. Finally it has been concluded that a running surface of 14 inches by 12 inches will get the maximum pressure from footsteps of a running person. Moreover a piezo element has a diameter of 3 cm. Five transducers in a row with 3 cm of clearance at each other consumes 27 cm or 10.5 inches of space length. 2 inches of clearance has been provided at each end of the row. Two rows of piezo element with each row consisting of five transducers were finally installed on the wooden board. A single foot pressurizes intermittently a single row of transducers. To gain suitable output, the implemented devices on the setup were:

1. Piezoelectric transducer,
2. AC-DC rectifier (1N4007),
3. Capacitor (2200 μF),
4. Battery (3.7 V),
5. Connecting wire,
6. Cork pieces.

A CAD design developed in Solidworks software shows the bottom view of the infrastructure in Fig. 1 incorporating all the required components.

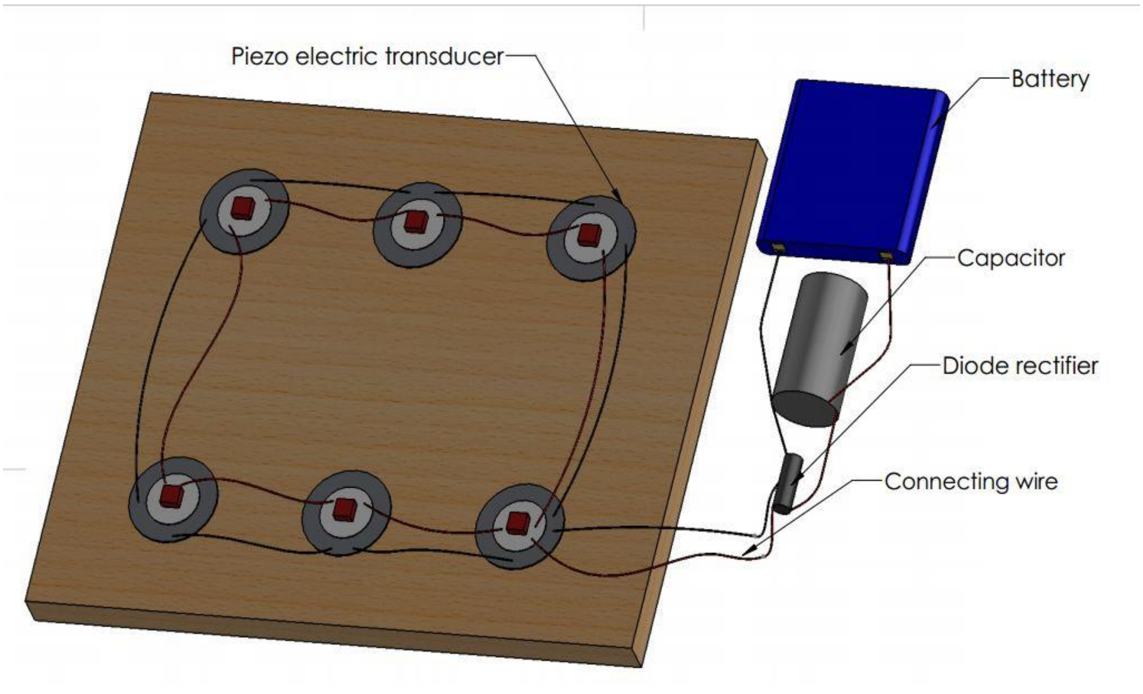

Fig. 1. Design of experimental setup (bottom side of board).

5. Experimental setup & working procedure

Fig. 2 shows the block diagram of this power harvesting process which depicts the method of producing electrical energy from the footstep through piezoelectric transducer. Fig. 3 shows an experimental setup of the piezoelectric transducers for producing electrical energy from footstep while running on the treadmill. The piezoelectric transducers were placed upon the wooden board. Then the board was placed on the treadmill bed after grooving the bed in the required dimensions mentioned above. As the power output from a single transducer was very low so a combination of ten piezoelectric transducers was used. When a person runs on the bed of the treadmill, the weight downwards on the setup lying on the bed brings about a deflection on the piezoelectric material which will create voltage difference across that material. For getting the maximum deflection and potential difference, cork piece was used for pinpointing the applied pressure.

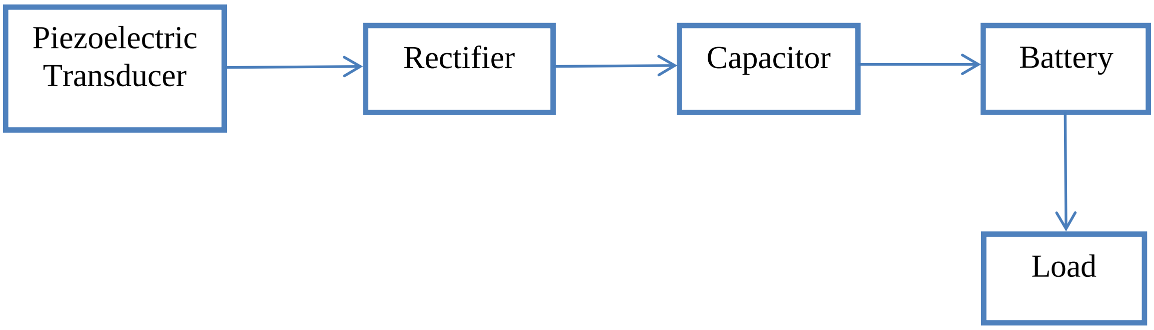

Fig. 2. Block diagram of setup.

Fig. 3. Experimental setup and circuit connection.

For getting the maximum deflection and potential difference, cork piece was used for pinpointing the applied pressure .The Electrical output of the piezoelectric transducer is of alternating in nature. So before feeding it to any electrical equipment it is needed to be converted into direct current. A rectifier was attached to the setup for converting the AC to DC. But the converted DC output was of pulsating nature. So a capacitor was provided for the conversion of the pulsating DC voltage into constant DC voltage. To keep a device running constant power is required and thus a battery is used.

6. Data Collection and Calculation

The output voltage which is fluctuating in nature varied from 3.0 to 6.2 volt for different kinds of load. At the same time the current gained also varied from 1.1 to 2.1 mA. Due to this small amount of current in mA range, the output power was also very small. The power was obtained from the equation:

$$P = IV \tag{1}$$

Where,
P = output power, I = current, V = voltage.

Table 1. Data table for current, voltage and power of different loads

Observation no.	Voltage (V)	Current (mA)	Power (mW)
01	3.0	1.1	3.3
02	3.2	1.2	3.84
03	3.3	1.2	3.96
04	4.17	1.3	5.421
05	4.36	1.4	6.104
06	4.7	1.5	7.05

Observation no.	Voltage (V)	Current (mA)	Power (mW)
07	4.72	1.4	6.61
08	4.96	1.7	8.432
09	5.19	1.7	8.823
10	5.52	1.8	9.936
11	6.2	2.1	13.02

The relation between output voltage and output current is shown in Fig. 4. Person with weight varied from 50 kg to 70 kg were made to run on the treadmill bed to test the voltage generating capacity of the setup. The relation between variable load of different persons and power generated was plotted in Fig. 5.

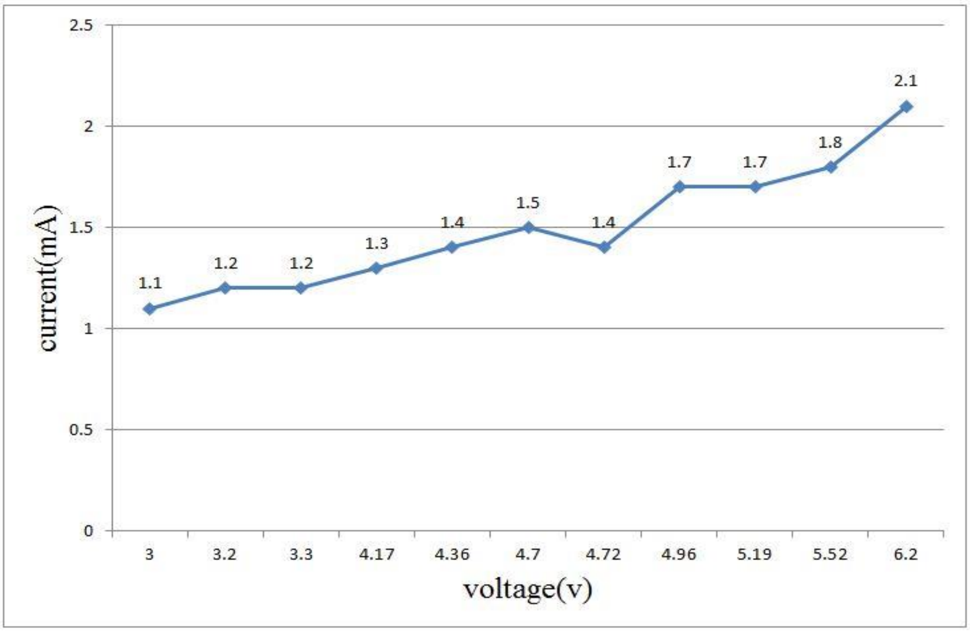

Fig. 4. Voltage vs current curve.

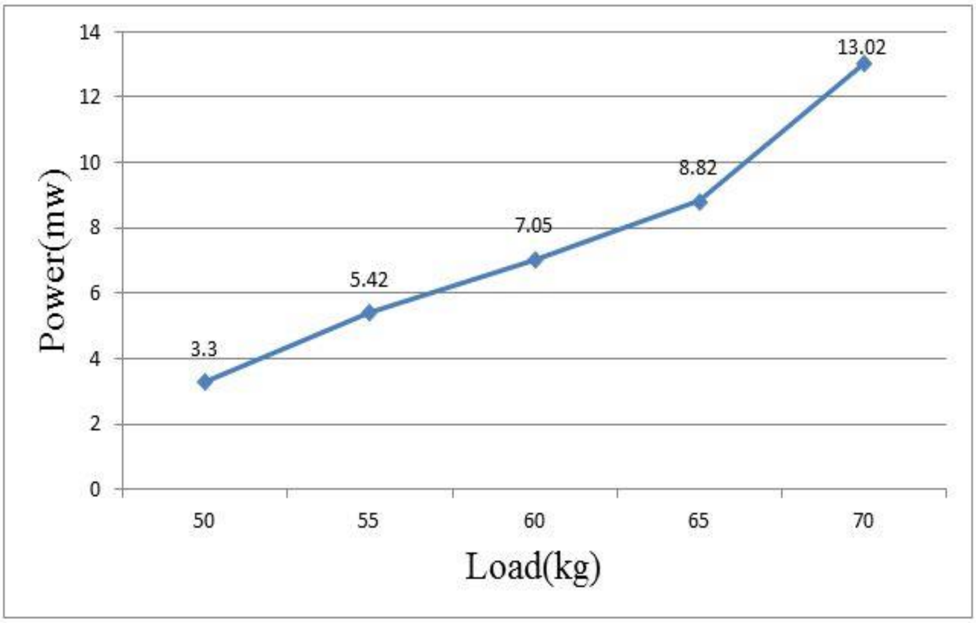

Fig. 5. Power vs load curve.

From the graph it can be seen that, maximum power is generated when maximum load is applied. Thus, maximum power of 13.02 mW is generated across the bed when a weight of 70 Kg is applied on the board. Let us assume that there are 40 steps on the board per minute which gives the amount of maximum generated energy per hour:

Energy = P × 40 × 60
= 0.01302 × 40 × 60
= 31.248 Wh
= 5040 mAh

7. Results and Output Analysis

This experiment revealed that the installation of PZT on a treadmill gave the maximum output power of 13.02 mW per step for 70 kg load. It is also expressed that the maximum output energy is 31.248 Wh or 5040 mAh with suitable design and proper implementation of load. Moreover, it is needed to recharge a battery of 3.7 V and 2000 mAh capacity with continuous supply of output power for 24 minute in optimum operating condition

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8. Conclusion

Human population all over the world has been increasing day by day and so do the energy consumption rate. Energy management is a very big challenge for a developing and over populated country like Bangladesh. As millions of people move every day in cities, significant amount of electricity can be generated by installing these devices at places where public walk everyday like railway stations, shopping malls, roadways, densely populated public spots etc. Although the power output from this project is low, this piezoelectric system can be a practical product for capturing footstep power. So the idea of utilizing the wastage energy from human locomotion is of great significance for our country.

9. References

[1] A. Adhithan, K. Vignesh, M. Manikandan, Proposed Method of Foot Step Power Generation Using Piezoelectric Sensor, *International Advanced Research Journal in Science, Engineering and Technology*, Vol.2, No.4, pp. 25, April 2015.

[2] K. Boby, Aleena Paul K., Anumol C.V., J. A. Thomas and Nimisha K. K., Footstep Power Generation Using Piezo Electric Transducers, *International Journal of Engineering and Innovative Technology (IJEIT),* Volume 3, Issue 10, pp. 264, April 2014.

[3] The Piezoelectric effect, https://radiologykey.com/the-piezoelectric-effect/

[4] Fundamentals of Piezo Technology, From the Physical Effect to Industrial Use, https://www.piceramic.com/en/piezo-technology/fundamentals/

[5] A. Rahman and M. E. Hoque, Harvesting Energy from Sound and Vibration, *International Conference on Mechanical, Industrial and Materials Engineering 2013 (ICMIME2013)*, pp. 194, 2013.

[6] C. J. Kendall, Parasitic Power Collection in Shoe Mounted Devices, *Massachusetts Institute of Technology*, pp. 5-6, 1998.

[7]M. M. H. Akanda, H. Barua, Parasitic Power Collection in Shoe Mounted Devices, *Rajshahi University of Engineering and Technology*, pp. 6, April 2010.