Electricity Generation Due to Vibration by Boots

Vaibhav Sharma[1] and **Mohini Preetam Singh**[2]
Vidya College of Engineering, Vidya Knowledge Park, Baghpat Road, Meerut 250002 UP India
vaibhav.sharma0105@gmail.com, mohinisingh2008@gmail.com

Abstract — **Mechanical energy that is generated by relative movement on the road is converted into electric energy by piezoelectric effect. Piezoelectricity is the electric charge that accumulates in certain solid material (notably crystal, certain ceramic and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. The aim of this research work is to make power generation more sustainable, economic and ecological by utilizing the advancement in technology.**

Keywords: Mechanical energy, piezoelectric effect, Sustainable power.

I. INTRODUCTION

AS piezo-energy harvesting has been investigated only since the late 1990s [1], it remains an emerging technology. When people walk or run, the piezoelectric materials under the boots vibrate and produce electricity in large amount [2]. Piezoelectricity is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various Proteins) [3] in response to applied mechanical stress.

Piezoelectricity was discovered in 1880 by French physicists Jacques and Pierre Curie [4]. The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry [5]. The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect (the internal generation of electrical charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect (the internal generation of a mechanical strain resulting from an applied electrical field) [6-9].

For example, lead zirconate titanate crystals will generate measurable piezoelectricity when their static structure is deformed by about 0.1% of the original dimension. Conversely, those same crystals will change about 0.1% of their static dimension when an external electric field is applied to the material. The inverse piezoelectric effect is used in production of ultrasonic sound waves [6, 8, 10].

Piezoelectricity is found in useful applications such as the production and detection of sound, generation of high voltages, electronic frequency generation, microbalances, and ultrafine focusing of optical assemblies. It is also the basis of a number of scientific instrumental techniques with atomic resolution, the scanning probe microscopies. Most piezoelectric electricity sources produce power [11-12] on the order of milli watts, too small for system application, but enough for hand-held devices such as some commercially available self-winding wrist watches. One proposal is that they are used for micro-scale devices, such as in a device harvesting micro-hydraulic energy. This paper is put up to provide the base for further improvements and considering the fact that failures faced in our work will guide future [15].

II. MECHANISM FOR PIEZOELECTRICITY

Many materials, both natural and synthetic, exhibit piezoelectricity. Crystals which acquire a charge when compressed, twisted or distorted are said to be piezoelectric. This provides a convenient transducer effect between electrical and mechanical oscillations: The generation of an electric charge in certain non conducting materials, such as quartz crystals and ceramics, when they are subjected to mechanical stress (such as pressure or vibration), or the generation of vibrations in such materials when they are subjected to an electric field.

Piezoelectric materials exposed to a fairly constant electric field tend to vibrate at a precise frequency with very little variation. The nature of the piezoelectric effect is closely related to the occurrence of electric dipole moments in solids. Of decisive importance for the piezoelectric effect is the change of polarization P when applying a mechanical stress. This might either be caused by a re-configuration of the dipole-inducing surrounding or by re-orientation of molecular dipole moments under the influence of the external stress.

Piezoelectricity may then manifest in a variation of the polarization strength, its direction or both, with the details depending on (*i*) the orientation of P within the crystal, (*ii*) crystal symmetry and (*iii*) the applied mechanical stress. The change in P appears as a variation of surface charge density upon the crystal faces, *i.e.* as a variation of the electrical field extending between the faces caused by a change in dipole density in the bulk. For example, a 1 cm^3 cube of quartz with 2 kN of correctly applied force can produce a voltage of 12500 V [13]. There is a magnetic analog where ferromagnetic material responds mechanically to magnetic fields. This effect, called magnetostriction, is responsible for the familiar hum of transformers and other AC devices containing iron cores.

Piezoelectric materials also show the opposite effect, called converse piezoelectric effect, where the application of an electrical field creates mechanical deformation in the crystal. Piezoelectric materials exhibit both a direct and a reverse piezoelectric effect. Figure 1 indicates conversion of vibration/mechanical energy into electrical energy and vice versa. The direct effect produces an electrical charge when a mechanical vibration or shock is applied to the material, while the reverse effect creates a mechanical vibration or shock when electricity is applied. Any spatially separated charge will result in an electric field, and therefore an electric potential. In a piezoelectric device, mechanical stress, instead of an externally applied voltage, causes the charge separation in the individual atoms of the material. Figure 2 indicates generation of piezoelectricity for polar crystals, for which $P \neq 0$ holds without applying a mechanical load, the piezoelectric effect manifests itself by changing the magnitude or the direction of P or both. For the non-polar, but piezoelectric crystals, on the other hand, a polarization P different from zero is only elicited by applying a mechanical load. For them the stress can be imagined to transform the material from anon-polar crystal class (P =0) to a polar one [14], having $P \neq 0$. Figure 3 shows mechanism of piezoelectric effect in quartz.

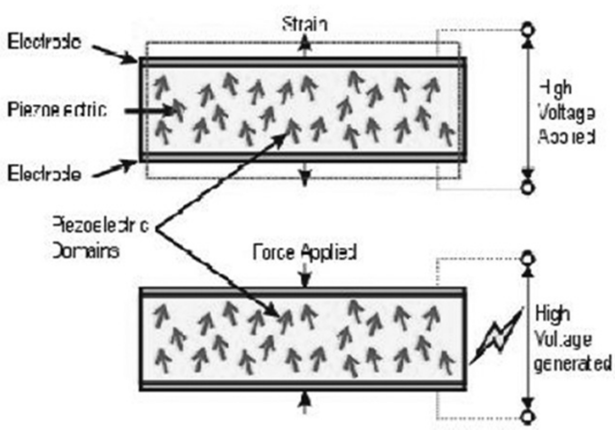

Figure 1. Conversion of Mechanical Energy into Electric Energy and vice-versa.

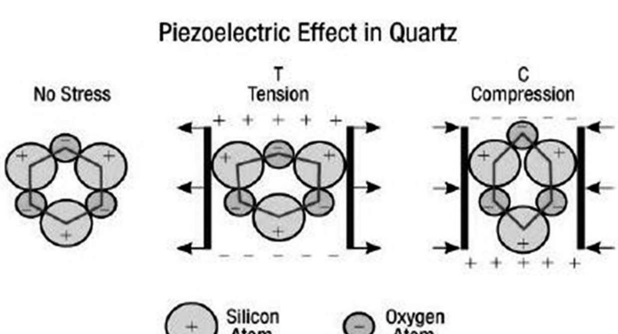

Figure 2. Mechanism of piezoelectric effect in quartz crystal.

III. SOURCES OF VIBRATIONS FOR CRYSTAL

Power Generating Boots or Shoes: In United States Defense Advance Research Project Agency (DARPA) initiated an innovative project on Energy harvesting which attempts to power battlefield equipment by piezoelectric generators.

Embedded in soldiers' boots. However, these energy harvesting sources put an impact on the body. DARPA's effort to harness 1-2 watts from continuous shoe impact while walking was abandoned due to the discomfort from the additional energy expended by a person wearing the shoes.

Power Generating Sidewalk: The piezoelectric crystal arrays are laid underneath pavements, side walks and other high traffic areas like highways, speed breakers for maximum voltage generation. The voltage thus generated from the array can be used to charge the chargeable Lithium batteries, capacitors etc. These batteries can be used as per the requirement.

Gyms and Workplaces: Researchers are also working on the idea of utilizing the vibrations caused from the machines in the gym. At workplaces, while sitting on the chair, energy can be stored in the batteries by laying piezoelectric crystals in the chair. Also, the studies are being carried out to utilize the vibrations in a vehicle, like at clutches, gears, seats, shock-ups, foot rests.

Mobile Keypad and Keyboards: The piezoelectric crystals can be laid down under the keys of a mobile unit and keyboards.

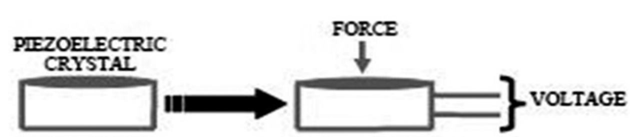

Figure 3. Principle of direct piezoelectric effect.

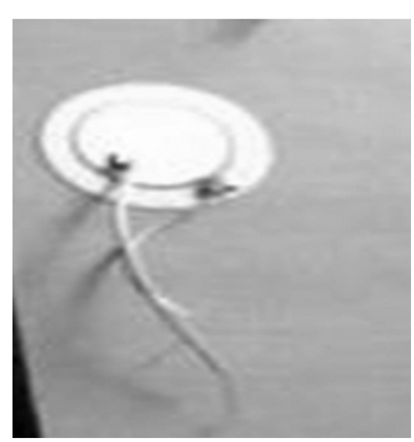

Figure 4. Single-Piezo Transducer.

With the press of every key, the vibrations created can be used for piezoelectric crystal and hence can be used for charging purpose.

Floor Mats, Tiles and Carpets: A series of crystals can be laid below the floor mats, tiles and carpets which are frequently used at public places.

People Powered Dance Clubs: In Europe, certain nightclubs have already begun to power their night clubs, strobes and stereos by use of piezoelectric crystals. The crystals are laid underneath the dance floor. When a bulk of people use this dance floor, enormous amount of voltage is generated which can be used to power the equipments of the night club.

IV. BUILDING SETUP

Initiation was started up by reading the concept of Piezo electricity. Then, after searching for the component (Piezo Transducer) required making the phenomena work, the working and connections were learned practically by using soldering, connecting wires and multimeter etc. Then, Searching internet and thinking led us to its various applications that could act as a free energy and a potential sustainable energy for future. For making the 'Walk N Charge Boot' the arrangement uses three sets connected in series of two parallel connected Barium Titanate piezoelectric transducers. Figure 4 shows sample of transducer used in experiment. Since these transducers produce Alternating Current, it needed to be converted to dc by using a bridge rectifier as shown in Figure 5 and gives 5V-15V as output. The output of bridge rectifier is connected to the charging wire of the power bank of 200mAH as shown in Figure 6.

Figure 5. Demonstration Setup.

Figure 6. Complete Built-in Arrangement.

Further it was experimented that this shoe while used in jogging will charge the 200 mAH power bank in 6 hours for 1 shoe out of a pair. These small piezo transducers could also arranged from buzzers used in scooter indicators, etc. Thus, almost all the material used in setup is almost free and could be arranged at inexpensive rates. Moreover, the discomfort caused with this setup in the shoes is just the elevated heel by half to one an inch.

V. COST EFECTIVENESS

The assembly developed using series and parallel combination of piezo-crystals is very cost effective. A single crystal costs around 23 – 25 Rupees when purchased in bulk of 10, and hence the cost of whole assembly including wires, base of setup, hard cardboard etc. is very less. It's just that u need a power bank to store the energy generated, and it will cost around 150 Rupees for 200 mAH. It is very encouraging to get a good voltage and current at such a low cost at the same time utilizing the waste energy. So, the assembly improves on the concern of cost effectiveness to a great extent and we are working on it to further improve upon the results of the system.

VI. FUTURE SCOPE

The proposed work portrays the concept of Piezoelectric Energy Harvesting and the results obtained after the implementation are very encouraging. Future work of the proposed idea encompasses further amplification of the crystal output to a greater extent. Future lies in the inclusion of advanced material used to design the piezoelectric crystal which further amplifies the crystal output in terms of voltage as well as current. A study could be carried out from the variety of piezoelectric crystals and after comparing the results, the choice of the optimum material for the best performing crystal could be devised. Further, amplifying the output by using the Operational Amplifier could improve the Efficiency.

VII. CONCLUSION

The amount of energy generated depends on the number of Steps taken during walking, intensity of footsteps and the pile of piezoelectric Transducers in the boot. Jogging and running produce slight more energy than via walking, but further research is needed to confirm this piezoelectric power generation system works successfully. It has tremendous scope for future energy/ power solution towards sustainability.

VIII. REFERENCES

[1]. White, N.M., Glynne-Jones, P. and Beeby, S.P. ‘A novel thick-film piezoelectric micro-generator’, *Smart Materials and Structures,* Volume 10, No. 4, pp. 850-852, 2001.

[2]. Abbasi, Aqsa. “Application of Piezoelectric Materials and Piezoelectric Network for Smart Roads.” *International Journal of Electrical and Computer Engineering* , Volume 3, No.6 , pp. 857-862, 2013.

[3]. Holler, F. James; Skoog, Douglas A; Crouch and Stanley R (2007). “Chapter 1”. Principles of Instrumental Analysis (6th ed.). Cengage Learning. p. 9. ISBN 978-0-495-01201-6.

[4]. Manbachi, A. and Cobbold R.S.C. “Development and Application of Piezoelectric Materials for Ultrasound Generation and Detection”. *Ultrasound,* Volume 19, No. 4 , pp. 187–196, 2001.

[5]. Gautschi, G. Piezoelectric *Sensorics: Force, Strain, Pressure, Acceleration and Acoustic Emission Sensors, Materials and Amplifiers*. Springer, 2002.

[6]. Katzir, S. (2012-06-20). “Who knew piezoelectricity? Rutherford and Langevin on Submarine Detection And The Invention of Sonar”. Notes Rec. R. Soc. 66 (2): pp. 141–157.

[7]. S. Trolier-McKinstry. “Chapter3: Crystal Chemistry of Piezoelectric Materials”. In A. Safari, E.K. Akdo˘gan. Piezoelectric and Acoustic Materials for Transducer Applications. New York: Springer. ISBN 978-0-387-76538-9, 2008.

[8]. Kochervinskii, V. “Piezoelectricity in Crystallizing Ferroelectric Polymers”. *Crystallography Reports,* 48 (4): 649–675, 2003.

[9]. Fotiadis, D.I; Foutsitzi, G., and Massalas, C.V (1999). “Wave Propagation Modeling in Human Long Bones”. *ActaMechanica*, 137: pp. 65–81.

[10]. Lee, BY; Zhang, J; Zueger, C; Chung, WJ; Yoo, SY; Wang, E; Meyer, J; Ramesh, R and Lee, SW. “Virus-Based Piezoelectric Energy Generation,” *Nature nanotechnology*, Volume 7, No. 6, pp. 351–356, 2012.

[11]. Gurdal, Erkan A.; Ural, Seyit O.; Park, Hwi-Yeol; Nahm, Sahn; Uchino, Kenji. “High Power (Na0.5K0.5) NbO3-Based Lead-Free Piezoelectric Transformer”. *Japanese Journal of Applied Physics*, Volume 50, No. 2, 027-101, 2011.

[12]. Website/ URL at www.merriam-webster.com

[13]. Sensor Sense: Piezoelectric Force Sensors, at www.Machinedesign.com

[14]. M. Birkholz (1995). “Crystal-field induced dipoles in heteropolar crystals – II. Physical significance”. *Z. Phys. B* , Volume 96, No. 3, pp. 333–340.

[15]. ‘Stop writers from writing; in the span, needs to be hidden from future’. — Mrs. Om Lata Singh.

Mohini Preetam Singh received Bachelor’s degree in Electronics and Instrumentation from UPTU, India and Master’s degree in Microelectronics from Subharti University, India. She received Academic Excellence award for research work in “NEGF Approach in Silicon Nanowire Transistors” in her Master’s. She is working as an Assistant Professor in Vidya College of Engineering since 2010. Her current work focus is on “Low power consumption techniques for embedded systems”.

Vaibhav Sharma is pursuing his Bachelor’s degree in Computer Science and Engineering from UPTU, India. Presently he is working on web and android based projects, along with soft computing, algorithms, networking, data compression etc.