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An Insight into Harvesting Sustainable Electrical Energy from Sound Hazards Using Piezoelectric Materials †

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Abstract: The rapid growth of urban cities and industries has resulted in huge amounts of potentially harmful waste being released into the atmosphere. One form of hazard is noise/sound. Noise cannot be controlled in automobile industries and urban areas, which include traffic, railway stations, and markets. But it can be converted into a useful form through advanced material usage. One of the materials is piezoelectric material. Strain can be produced through vibration caused by sound, which, in turn, produces electrical energy. Hence, the objective of this research was to harvest electrical energy from hazardous sounds released from industries. Electrical energy was generated through systematic experiments using piezoelectric sensors. The experimental results revealed that the magnitude of 90 dB sound produced up to 2 volts through a single piezoelectric sensor. We can generate more energy by increasing the number of sensors as this material is cost effective. The numerical model was also effectively replicated and good agreement was obtained between the experimental and numerical frequency sound curves.

Keywords: noise; piezoelectric diaphragm; crystalline structure

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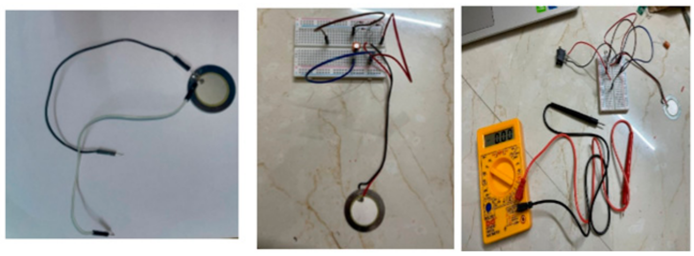
1. Introduction

Noise pollution is a hazard that needs to be reduced or converted into a useful form. Human events like learning, manufacturing, commercial processes, and community life are affected due to the high-level impact of noise pollution [1]. As per the third law of thermodynamics, mechanical energy can be transformed into electrical energy. Thus, sound, a form of mechanical energy, can be transformed into electric energy [2]. Sound energy can be transformed into electrical energy through heating and diaphragm through piezoelectric materials. Piezoelectric materials are a ferroelectric ceramics with a piezoelectric effect [3]. Due to the properties of Di-electricity [4], Elasticity, and Piezoelectricity [5], they have attracted many researchers to initiate research in piezo-electric materials for converting sound energy into a useful form. For instance, Alankrit Gupta et al. [6] explored a general idea of converting sound energy into electrical energy. They discussed various methods for converting sound into electrical energy. Vinu et al. [7] discussed the piezoelectric effect and the block diagram of the circuits. Nilimamayee Samal et al. [8] explained the classification of piezoelectric materials. They are categorized as Cantilever beam, diaphragm, Cymbal, and Stack type. They also discussed environmental energy sources other than sound which piezoelectric materials can be used for such as Vehicles, Machinery, Physical movement, and moving under the Mechanical category. Though many theoretical studies are available on the characteristics of piezoelectric materials, no experimental studies are available on exploring piezoelectric materials to convert sound into a useful energy form. Hence, this research addresses the experimentation for harvesting sustainable electric energy from sound energy. A blanking press in the automobile industry, which creates continuous non-stop noise while using a punching press, is one of the most common noises in the industry, Hence, a blanking press was chosen to do the experiments. A diaphragm-type single crystal piezoelectric material was used to convert sound energy into a voltage signal.

2. Experimental Procedure

2.1. Material and Circuit Construction

- The ferro ceramic piezoelectric material, Breadboard Switch, Multimeter, LED bulb, 14K resistors, IN 4148 diodes, and 25 V Capacitor were purchased from the local market for the experiments, which are shown in Figure 1. A diode bridge was constructed using a breadboard. Diodes permit current to move in only one path, making this a useful circuit for rectifying AC voltage. This can be used by the capacitor and LED. On the breadboard, diodes are inserted into sockets 1A, 1B, 5C, and 6A, with the diodes facing the same way as the black stripes. The diode from 1A is taken and the other end is inserted into socket 5A, the diode from 1B to 6B, the diode from 5C to 11C, and 6A to 11A.



(A) Piezo-Electric Materials **(B) Connction circuit** **(C) Tested circuit**

Figure 1. Experimental setup used for the study.

- The Piezo element is connected to the breadboard by inserting the black lead into socket 5E and the red lead into socket 6E and connecting the positive lead into socket 11E and the negative lead into 1E. The LED is connected to the breadboard and the piezo element is tapped to check whether the LED lights up briefly to ensure the circuit works.
- The capacitor is connected. Electrolytic capacitors have +ve and -ve leads, so direction matters. The +ve (longer) lead is inserted into socket 11E and the -ve (shorter) lead into socket 11H. The middle wire is inserted into socket 11J. The two remaining wires are inserted into sockets 1E and 15E and the breadboard jumper wire is inserted from socket 11B to socket 20E.
- The LED is connected by connecting the +ve lead from the LED to socket 20A and the -ve lead to 15A. The multimeter is connected by connecting the 11E into the red socket of the multimeter and the 11H into the black socket of the multimeter. The connections are now made to begin the experimental process.

2.2. Testing

- A noise was generated manually which resemblances the noise exhibited by the blanking press. A 99 dB noise was created and observed from a mobile application called DecibelX, which is shown in Figure 2. The experiment was conducted for 9 s, and the output voltage was calculated. The distance between the noise source and the piezoelectric material was set at 5 cm, above which the voltage generated is lower; by reducing the distance to less than 5 cm, the material may fail due to high fatigue stress due to continuous vibrations.

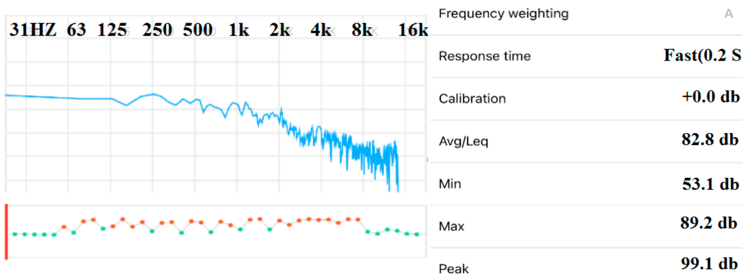


Figure 2. Time and noise measurements recorded through the Decimal X app.

3. Results and Discussions

The test results are tabulated in Table 1. From Table 1, it can be observed that, for a single piezoelectric material, we can get a maximum of 2 volts for 99 dB noise. This can be further increased by increasing the number of piezoelectric materials, and all the electric energy generated can be stored in a 25 V capacitor. From the above graph, it is noted that an increase in dB will increase the voltage output for a single piezoelectric material. The graph shows a linear increase in decibels. This experimental graph is for the piezo kept at 5 cm.

Table 1. Experimental results.

Sound (Decibel)	Voltage (Volts)
86	0.6
87	0.7
88	0.9
89	0.91
90	1.00
91	1.20
99	2.0

4. Cost Analysis

The total cost involved in generating 2 V is given in Table 2. When we use five piezo elements, which can each give 3 volts, a collective 15 volts can be generated for 9 s. Since the blanking machine in the automobile industry is operated 24 h in 7 days, we are able to get constant noise throughout its lifetime. For 15 volts, we can light a 1000-lumen LED light, which will cost INR 200 for 3 months. This might sound a little more expensive than the usual power source, but bear in mind that we are using a waste energy source in a usable energy form; though it is 10% more expensive than the former, we are able to use this form as a source of renewable energy. As it is in the nascent stage of development, it is a little expensive.

Table 2. Experimental Cost analysis.

Component	Cost (Rs)
Piezoelectric material, 4 pieces	150
Multimeter, switch	210
Capacitor-4 nos, LED-5 nos	20
14K resistor, 3 pieces	10
IN 4148 diode, 4 pieces	15
Breadboard, connecting wire	95
Total Cost	500

5. Conclusions

Noise can be used as a source of renewable energy as we can obtain desirable output voltage from the experimental process. The material used is ferro ceramic material, and with further developments improving or enhancing the quality of the material, we can increase even more the expected output results. The initial setup cost is found to be low but the process cost is slightly higher than a usual power source since it is in its nascent stage of usage. All renewable energy-producing devices like solar panels and windmills were expensive in their initial stage of development, but later on, due to research and development, researchers were able to produce more voltage. Hence, we are at a stage to replace a considerable portion of non-renewable sources of energy. But to date, the setup cost of other energy-producing devices has been high when compared to our research, which is considered a huge positive going forward in this research. Hence, from this research, we have successfully found a feasible solution from the gap identified in previous research papers and have proven that noise can be used as a source of renewable energy.

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