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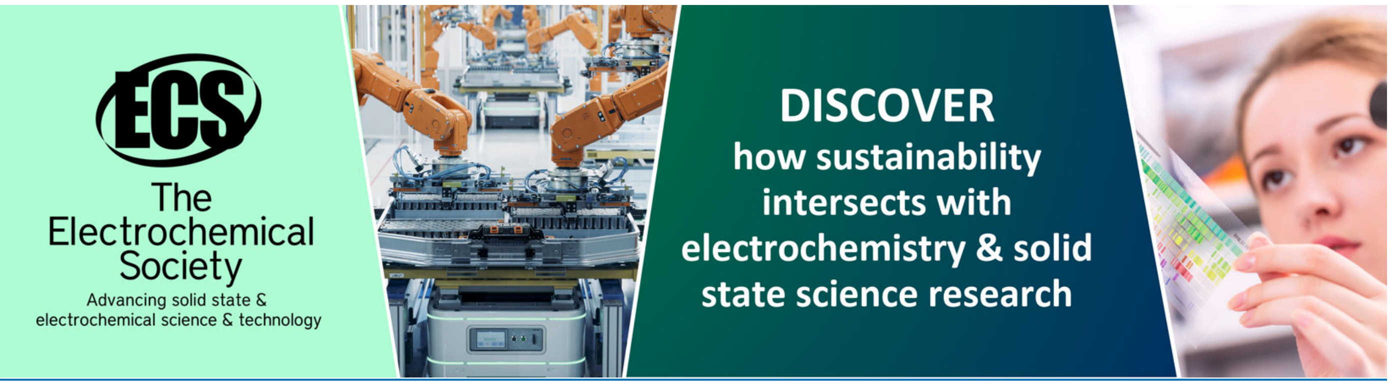

Piezoelectric transducer as a renewable energy source: A review

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Abstract: Green energy source has a vital role for production of electricity. Since present day, conventional fuel was considered as the core sources of electricity. In this paper, source of green energy discussed is very rare. Solar and wind power have been considered as inherent energy sources of electricity through solar cells and wind mill. Sound energy in the form of noise is comparatively unexplored source around us for generation of electricity. This noise can be successfully converted into electricity by using suitable transducer. Piezoelectric transducers has major role for noise to electricity. Multiple transducers can be used to produce electricity which can be stored and utilized further. The present object of this paper can offer renewable green energy source which can be beneficial in worldwide search of nonconventional source of energy.

Keywords: Noise, Piezoelectric transducers, electricity, renewable energy.

1. Introduction

Electricity is need of our day to day life for running most of appliances. Noise is one of the major pollution in the world out of four pollutions (i.e. Water, Land, Air and Sound). Today there is a lot of noise on roadways, factories etc. Noise can obstruct with challenging work, changes interpersonal relationships which leads to aggravation. The quality life of labors working in industries is very pathetic [1-2]. The most effective ways possible for conversion of environmental noise into electricity is most challenging because of its low power density. Therefore, noise conversion has created overemphasis among the explorers and professionals. The prime benefit of the noise conversion is the low maintenance which is appropriate in remote locations or to be organized widely. The devices basically sensors and actuators are fabricated using piezoelectric transducers and lots of work is carried out from many years. However, the use of these transducers has been considered as a source of energy. In urban environments, sound energy is popular and becomes attractive as a potential resource of energy for harvesting. It is extremely clean and endurable source of energy. Conversion of noise develop the major interest to reform surrounding energy into feasible and operable energy. Thus, use of transducer helps in generating electrical energy from noise.

2. Conversion of sound into electricity

Several kinds of sound are frequently generated in surroundings from numerous sources. These sounds makes no difference except making noises for us. Continuous noise might be the reason of neuropsychiatric disorders, mental pressure and depression in routine skipping any types of symptoms of acute or chronic disorder. Sound wave being a mechanical wave, it disturbs the particle of the medium, when it travels through a propagating medium. These particle disturbance could be used to produce electrical energy [3].In past few years, some sort of research has been carried out throughout the world on noise. For example: hypnosis, weeding, diagnosis, measuring temperature, refrigeration, dust removal and weapons and so on. All these phenomenon is carried out using noise. Charles Jokel provides a summary of the army noise surroundings for the non-expert. He provided the overall description of the noise by type of source and category of operation [4].Dong Zhou proved that sound accumulation has a considerable good effect to improve the efficiency of dust removal of the precipitators [5].Jinmei Liu demonstrated ITENG (an integrated triboelectric nanogenerator) with a 3D structure profiting for acoustic propagation and adsorption to efficiently convert sound energy with improved output functioning [6]. Timmer et. al. provided a summary of the recent technologies for converting acoustic energy into electric power (Fig. 1).

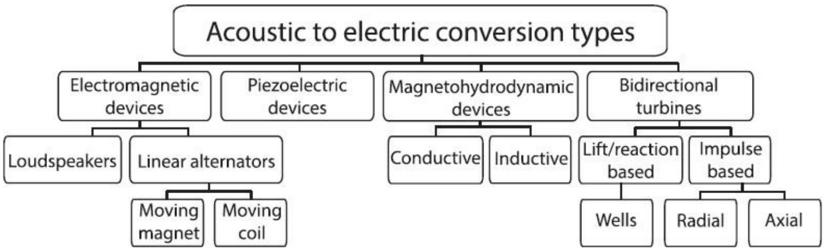

Figure 1. Summery of various methods for the conversion of acoustic to electric energy [7].

Timmer analyzed that for conversion of any sort of acoustic to electric energy, for a good performance, high power coupling between the field and the transducer would require. There may be the possibility of impedance mismatch due to acoustic reflections, results in redirected acoustic power that may create barrier for conversion of electricity. Timmer have shown methods which might be useful for making a good coupling to improve the performance of a thermo acoustic engine [7]. Wang presented noise conversion by using PVDF to convert the acoustic energy of low-frequency noise from speedy train into electric energy. The acoustic energy harvesting system is incorporated with the components mainly noise gathering input, a power storage, electric generator and a sound pressure amplification.

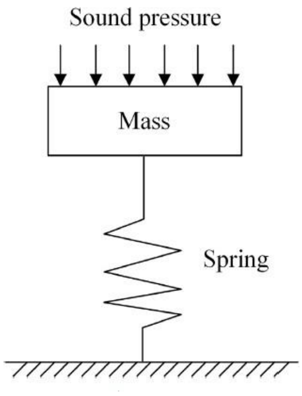

Figure 2. Mass spring model [8]

The pressure on the sound was increased in Helmholtz resonator, after that, Polyvinylidene Fluoride film could convert this amplified sound into electricity in the generator module with the help of mass spring model (Fig. 2). The power storage device stored the converted electricity in super capacitors that could be utilized in minor electronic appliances at railway stations [8].

3. Materials for conversion of sound into electricity

Harvesting energy is very important phenomenon in which a form of energy acquired from various sources can be transformed into usable electrical energy and can be stored for future use. The acoustic harvesters normally consist of a resonator, membrane and piezoelectric material (Fig 3). J. Choi et.al. provided a review on sound energy harvesting which is focused on the presentation of principles, examples and methods for the enhancement of energy harvesting system of sound[9]. Choi further introduced the mechanism of transducing and phenomenon of amplification of sound pressure.

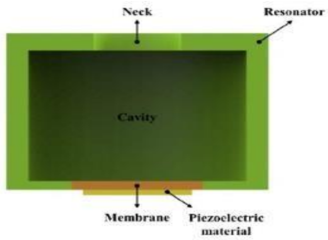

Figure 3. Representation of typical Acoustic energy harvester [9].

At resonant frequency, the resonator set off the sound oscillation. A membrane is fixed to a resonator from one side and a piezoelectric material is attached to other side where both vibrates with the vibration of sound, a form of mechanical energy, which would be converted into electrical energy by piezoelectric material. For amplification of the input noise pressure, the resonators are used due to low energy density. But mostly Helmholtz resonator is used by A. Yang [10], F. Liu [11], M. Yuan [12] and quarter-wavelength resonator is used by Li. A.[14] and B. Li [13] in many applications. The energy generation through piezoelectricity directly obeys piezoelectric effect. According to Zubair Butt et. al.,piezoelectric material has the loss of energy which is well described by mechanical quality factor. This mechanical quality factor and output voltage of piezoelectric material, PZT-4A (Lead Zirconate Titanate) is determined by varying different parameters [15].

4. Transducers for converting of acoustic energy into electricity

Acoustoelectric transducer is used for converting sound into electrical energy. The various approaches to the method are electromagnetic (inductive or moving coil), electrostatic (capacitive) or piezoelectric [16-18]. Moving coil type transducer is based on electromagnetic principle, when the voice magnetic coil in field of a ring magnet does cutting magnetic field line movement, it produces the induced voltage. The diaphragm is integrated with the voice coil in the transducer, vibration diaphragm brings voice coil vibration due to sound wave, and it produces the corresponding electric signal. Due to the vibrating membrane of moving coil type transducer is loaded with its a few hundred times the weight of the voice coil, so it is very complicated to make the noise power generation device. In general, the moving coil type transducer is commonly used in the production of microphones and high-fidelity headphones. Capacitive transducer has a fixed rear plate and an active diaphragm as the front plate, they are close to each other, and it is equivalent to a small variable capacitor. This transducer is the most common application, because it is inexpensive and compact. It is used for the common mobile phone built-in microphone and noise statistical analyzer. But it needs the additional power supply for the capacitor plate, because of its high sensitivity and wide frequency response, and can be used as auxiliary transducer. Piezoelectric transducer uses the piezoelectric effect of polarized material to turn the sound energy into electricity. It is the ideal choice for noise power transducer, because there is no need for additional power supply, voice coil and other auxiliary structures. After the invention of barium titanate and lead zirconate titanate which are basically the ferroelectric materials, the phenomenon of piezoelectricity has been applied in several materials as researchers there have been continuous research is going on for developing piezoelectric materials with different properties [19].

PZT which is basically a polycrystalline monolithic piezoelectric ceramic materials .The soft or hard piezoelectric materials can be formed by doping it with niobium or lanthanum, respectively. PZT is the prevalent material which contains lead due to which the large number of the new composition materials have been developed [20-23]. Within the recent past, Gao et al in 2018 [24] have developed a PNN-PZT with composition as (0.55Pb $(Ni_{1/3}Nb_{2/3})O_3$–0.135$PbZrO_3$–0.315$PbTiO_3$) ceramic with remarkable coupling coefficient of 1753 pm V^{-1}, which is greater than that of conventional PZT ceramics. The piezoelectric ceramics are comparatively affordable and brittle. It provide good coupling with high density. Muralt P. et. al describes many methods for fabricating high quality piezoelectric films and material deposition for 3D transducers, using low temperature synthesis with different substrate and improved texture of electrodes[25]. Also, piezoelectric polymers have been synthesized in order to make piezoelectric materials like PVDF material. As piezoelectric polymers are flexible and lightweight, much lower coupling than their ceramic version [26]. Pan et. al. prepared polyvinylidene fluoride film using a near field electro spinning technique for enhancing the coupling coefficient of these materials[27]. Recently, Shane Harstad developed a polyvinylidene fluoride polymers to enhance the coupling of material. This is done by fabricating Gd_5Si_4- polyvinylidene fluoride nanocomposite by the method of phase-inversion [28]. Aside from PZT and PVDF, the majority of piezoelectric transducer materials required for energy conversion can be classified into five groups, such as, high temperature piezoelectric, piezoelectric single crystals, piezoelectric nanocomposites, lead-free piezoelectrics, and piezoelectric foams.

5. Piezoelectric transducer for conversion of sound energy into electricity

For optimization of efficiency of energy conversion from the piezoelectric materials, it should be particularly organized with the transducer devices, which will be contributed for the sufficient absorption of mechanical energy from the acoustic energy source for required application. The simple and easy fabrication of cantilevered beam configuration of piezoelectric material (passive substrate beam on which active piezoelectric layer is pasted makes it appropriate for harvesting vibrational energy. The piezoelectric layer is bonded to a passive substrate for increasing the strain in the active material. In this configuration, the d_{31} piezoelectric strain coefficient is typically used to convert mechanical vibrational energy to electrical energy. The most efficient cantilever beam configurations is the unimorph and the bimorph. Erturk et al have widely discussed the behavior of these harvesters in the literature [29-30]. When piezoelectric materials are at excitation to their resonance, it shows a prominent performance of power generation [31]. There are various configurations existed in which by altering the structure of materials, the performance of piezoelectric energy harvesting may increase. For increasing the energy output and also the excitation of cantilever harvesters, the non- rectangular profiles, for examples-triangle-shaped beams [32-33] and trapezoidal cross section beams [34] can be used. Further, modified mechanical boundary conditions and various beam configurations, which includes the designs with a dynamic amplifier support have been described by many experts instead of a fixed end [35] , clamped-clamped boundary conditions with compressive load , an asymmetric tuned mass [36], multiple inertia masses[37-38], added auxiliary beam [39], cutoff two degree-of-freedom beams [40], and multiple beams [41]. The Applications of devices with beam generators are typically the rotary harvesters [42-43], acoustic resonator harvesters [44-45], and piezomagnetic nonlinear harvesters [46-47]. Pillatsch et. al. observed the due to formation of minute fracture in the stretched surfaces which degrade the stratified piezoelectric transducers in recurrent conditions [48]. Siqi Zhu Presented the noise power generation device software which includes five parts: DSP initialization, noise signal reception, converter, data processing, human-computer interaction. The software flow of the device for noise power generation is shown in figure 4 [49]. Apurba Das provided an approach to design and build a model of the energy harvesting techniques by regenerative transduction from wasted vibration source of vehicle horn using piezoelectric materials [50].

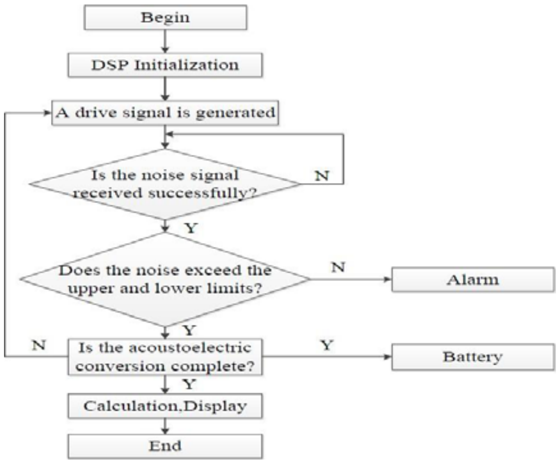

Figure 4. Software flow chart [49].

Yasser A. Farghaly utilized street noise from the bus stop of the different stations of Alexandria City of Egypt using piezoelectric materials for street lighting [51]. But the electric energy generated was so small that it cannot be utilized in an application. Piezoelectric materials can drive low voltage devices because of the small amount of voltage generation. Mehul Garg et. al. used a transformer and a speaker for conversion of noise produced by car horn into electricity. The output obtained was increased with the help of a step up transformer. In a same manner, this arrangement was set up at the motorbike exhaust pipe a having 350 cubic centimeter engine. The potential difference is obtained with the help of a digital multimeter. A sound level meter is used for measuring the sound in decibels (dB) [52]. Arnab et. al. proposed a noise conversion circuit. The test was conducted at the sources of sound of train wheels and and a better result from train wheels have been observed as compared with other sources using the same noise conversion circuit. Around 12 volts of output is obtained from this noise conversion device which can be utilize to charge the rechargeable battery. Also it can charge a nine volt dc battery within 30 minutes from electric power transduction [53]. L. Hui Fang described harvesting of noise and aspects of piezoelectric materials. The experiment was carried out at from 35 dB to 100 dB sound level range which is comparable with surrounding noise of level 50-100 dB. [54]. P. Kulkarni et. al. have discussed in his paper regarding the noise generated in sports stadium. Based upon this analysis, it has been proposed that noise generated at stadium helps in generation of electricity .It depends upon the number of audience present at there and maximum sound produced by them [55]. Fitria Hidayanti et. al. presented paper in which an experiment is carried out with the help of function generator. The result obtained is simulated with a variation of frequency. The obtained output voltage of the converting loudspeaker vibration was 5.56 volt for 10 hours [56]. Kyrillos K. Selim have utilized DJ as noise source which is the most popular arrangement in all celebrating functions.With the help of suitable piezoelectric transducer, noise from DJ was converted into electric energy. Selim Selim used a piezoelectric sensor which was connected in series, parallel, and hybrid combination. The output sound had 81, 84 and 87 dB sound intensity levels. The highest power is obtained at a distance from 1 to 5 meter in parallel circuits and it is found to be 4.96 mWatts. As distance from source of noise increased, the power generated decreased [57]. Shehab Salem had proposed a structure for AEH unit containing piezoelectric transducer as a main component. This AEH design process has two set up mainly open and closed circuit. Both the circuits helps in finding out the high frequency sound which is required for maximum power. When the noise of nearly hundreds of dB is applied at the frequency of 466.2 Hz, the results were found out to be 0.043 µW of power, 21 mV of voltage and 2.05 µA of current [58]. C. S. Salvador have used the piezoelectric transducer as well as the super-capacitor for generating the electrical energy. The setup were developed and installed at the crowded streets .Approximately 5.5 volts were generated from street creating the output average noise level of 75 dB which would further helpful for lightening the Light emitting diode by harvesting the sound pressure level with the help of the piezoelectric transducer [59]. Recently Hao Shao presented a paper on synthesis of PAN (electrospun polyacrylonitrile) which is the nanofibrous membranes that could convert low-mid frequency noise into electrical energy into the high voltage outputs. The device for acoustic to electric energy conversion can be prepared by sandwiching a thin layer of electrospun polyacrylonitrile film between the two plastic film electrodes which is coated by metal. The output produced the maximum power of 210.3 µW and the voltage generated is approximately 58 volts with the current of 12 µA when 117 dB sound is applied to this nanofiber device at the frequency ranging from 100Hz to 500 Hz.This power generated is highest amongst the other acoustoelectric appliances explored till now. Thus the electricity generated after processing can be utilized for running the commercial electronic devices [60].

6. Discussion

According to Safaei [19], piezoelectric transducers have been extensively explored for generation of power from vibration energy sources. Piezoelectric transducers have highest electro mechanical coupling than that of the electromagnetic and electrostatic transducers. Also it has higher power density. Yasser A. Farghaly [51] got very less amount of electric energy using piezoelectric transducer type QB220-503YB. Hao Shao prepared PAN which operates on 117 dB sound which gives noticeable electric output of 58 Volts. Salvador presented a prototype and collected average noise level of 75 dB which generates 5.5 Volts. L. Hui Fang has the found sound level on piezoelectric ranging from of 35 dB to 100 dB. Furthermore, it is found that, as the magnitude of noise is increased, the amount of converted electric energy may increase. Many Scientist have done research for piezoelctric transducers at lower sound levels at different frequencies for electronic applications, but for higher sound levels, still lots of effort is to be carried out yet. Therefore, more studies should be done for the synthesis of piezoelectric materials for different piezoelectric transducers of varying capacities ,as noise is investigated as a fast developing environmental hazards however a huge source of hygienic energy.

7. Conclusion

This paper aims to provide an information for literature study as the concept showed that sound or noise can be used as electrical energy and piezoelectric materials could be used as an acoustic transducer for generation electrical energy from noise. Energy potential wasted due to noise can be used as an alternative energy. Thus, such information will definitely provide the better understanding of piezoelectric materials as a transducer.

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