Piezoelectric Energy Characterization: Materials and Utilization

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Abstract

This article exposes a new form of alternative and clean power generation. Being its objective to characterize, the models and use of the existing materials that comes to be more useful to generate energy. Bibliographic research was used as a method for data collection, through the study of existing articles that open the piezoelectric system. From the evaluation of the existing data, it was observed that to quantify the energy generation of these materials, besides simulating in software the amount generated is made the prototype for accurate measurement of the generated energy values. However, this is a task that requires a lot of study, so that, finally, it can reach usable values to supply the desired electrical systems. The results show that the amount of energy generated is different for each method used, which depends on the type of material and the harvesting procedures performed, among the most used materials is the "cantilever" being the best in relation to the generation of Therefore, it is evident that the present article seeks to demonstrate the existing modes of generation through the use of this piezoelectric effect. Thus, it is expected to draw attention to this type of electricity production.

Keywords: Piezoelectric effect; Alternative source; Renewable energy;

1. Introduction

Given the problems faced by the energy market, factors that remain evident is the search for new sources of energy generation given their environmental interface, thus, research continues to be conducted, focusing on alternatives on the use of natural resources.

The concept from the generation of renewable energy or alternatives related to this proposal arises from

the scarcity of fossil fuels and its relationship with climate change, where thus there is a need to seek the development of systems that take advantage of existing resources in the environment. or even products generated by humans, a technique known as “Energy Harvesting”. From this observation is the interest in piezoletric materials, a source of energy still little explored. This alternative uses piezoelectric transducers in the harvesting process associated with movements as a source of vibration causing deformation, which enables the generation of electrical energy [1].

In this way the vibrational energy resulting from our movements, made when walking on sidewalks, streets, squares, shopping malls, universities, etc., would be harnessed and converted from vibrational kinetic energy to electrical energy through the use of piezoelectric sensors enabling the harnessing of large amounts of energy lost in the form of heat and friction, as it can react to the mechanically generated deformation and in turn, convert the absorbed energy into electrical energy to be reused [2].

As noted by [3], the piezoelectric effect was discovered by brothers Pierre and Jacques Curie in the year 1880 and can be characterized by a property that certain crystals possess when subjected to an electric charge differential, first used by Paul Langevin in sonar in the first world war. Thus this innovation highlights the new search for clean, sustainable and alternative energy.

According to [4], piezoelectric materials have two electrical or mechanical power generation properties, depending on the state change, the direct piezoelectric effect corresponds to the electric power generation as a result of the application of a mechanical force; and the inverse piezoelectric effect is a mechanical change due to the application of an electric field.

As mentioned, [4] clarifies that piezoelectric materials generate electrical or mechanical energy because they have these properties in their crystalline structure when undergoing changes in their state. [5] mentions that the reverse effect was discovered by Gabriel Lippmann in 1881, where there were various applications in motors, transducers, sensors, actuators among other utilities, materials that have these conditions by nature are: tourmaline, quartz, topaz, sugar. cane and Rochelle salt.

According to [6] piezo comes from the Greek "piezein" which means to press, that is, electricity by pressure, being these piezoelectric materials built with quartz crystals and given some difficulties there was a need to improve them, creating synthetic materials in the 1940s. and 1950. The so-called PZT (lead zirconate titanate) piezoelectric ceramics have several variations, besides the quartz used to convert mechanical energy to electrical energy.

Thus, piezoelectricity can be considered a sustainable energy source as it does not use fossil fuels. It is important to consider that clean energy means to produce or consume energy without generating or generating in minimal quantities, waste and greenhouse gas and global warming [7].

The conversion of electrical energy to mechanics is found in: sound buzzers, microwave generators; ultrasound and electrotherapy devices. The reverse effect observed on spark generators on lighters or stove lighters and on the production of electricity. Virtually all applications are satisfied by synthetic quartz.

PZT-type ceramics have small crystals of Perovskite-like crystalline structure, with tetragonal symmetry, rhombohedral (A crystal with diamond faces) or simple cubic, depending on the temperature of the material [8].

The aim of this study is to analyze the models and processes of piezoelectric energy utilization, aiming to identify and characterize the existing methods and materials used in mechanical pressure energy generation,

demonstrating the amount of electrical energy generated by piezoelectric sensors.

2. Materials and Method

For the development of the present work we used the bibliographic research procedures that according [9] are elaborated mainly by sources such as books, magazines, newspapers, monographs, dissertations and theses, based on scientific publications of studies on the piezoelectric properties. Therefore in this way we seek to make this property more explicit.

We can conceptualize as a qualitative research. So one must assume that it is a method that aims at understanding people without worrying about numerical relationships. Certainly because it is an approach that seeks to explain the reasons and how the problems will be solved, with exploratory and descriptive objectives, since it is evident that this approach has the objective of clarifying an existing fact or phenomenon, that is, make a study about the object of observation [10].

Through consultations and analysis of scientific sources it is possible to demonstrate the electrical potential of piezoceramics, verified through a simulation in software with the help of experimental benches and through the assembly of prototypes used to measure power generation.

3. Results and Discussion

For a long time the piezoelectric effect has been used as, for example, in medicine in ultrasound and electrotherapy apparatus; transducers, sensors, actuators, in sound amplifiers, scales, among other utilities in which its application is useful. According to [11], zinc sulfide, sodium chloride, magnesium chloride, tourmaline, quartz, zinc carbonate, topaz, sugar, sodium potassium tartrate, barium titanate, lead zirconate titanium and fluorine polyvinyl are some. materials and crystals that suffer the piezoelectric effect.

There are several types of piezoelectric ceramics on the market that are characterized according to their structures. The Navy has created classifications of PZT composites that serve as a standard for all piezoelectric ceramic manufacturers and define the characteristics and performance of materials, which have been divided into six types [12]:

• ***Navy Type I:*** suitable for constant and repetitive conditions of medium and high power, producing large amplitudes and keeping dielectric and mechanical losses low, containing an active system in power generation, being applied in ultrasonic cleaning and sonars, under the tradename PZT-4.

• ***Navy Type II:*** It has high sensitivity, permittivity and time stability when used as a low power receiver or generator. Dielectric and mechanical losses make high-intensity excitation unfeasible, but can be applied to hydrophones, accelerometers, and flow and level sensors, bearing the trade name PZT-5A.

• ***Navy Type III:*** Used in high frequency applications with high mechanical qualities after converting twice the power and keeping mechanical and dielectric loss low. In addition, it has better power handling capacity, similar to Navy Type I, but less sensitive, having application in the ultrasonic welding and materials processing system, bearing the trade name PZT-8.

• ***Navy Type IV:*** Medium power application, consisting of BTs (Barium Titanate) becoming obsolete and replaced by Navy Type I. Its application is in the maintenance of old equipment, under the trade name Barium Titanate.

• ***Navy Type V:*** Used for high energy application and potential differential, being an intermediate composition of Navy Type II and VI, used accordingly in the application of impact detonators, under the trade name PZT-5J.

• ***Navy Type VI:*** Applications that demand large mechanical deformations, having very high permittivity, coupling and piezoelectric constant, but with low time stability. It can be applied to positioners and actuators, with trade name PZT-5.

Currently there are already some applications, both in Brazil and in other countries. In this context, to [12] claims to deal with a concept still little known, but widely used in everyday life, noting some applications of materials.

In Canada, two engineers inserted the energy-generating piezoelectric ceramics into car tires, covering the inner surface area of the rim 14 tire with the flexible PZT (lead zirconate titanate) elements, while driving 100 km / h 2 , 3 watts per tire [13].

Atelier DNA, New York's design laboratory, created for the planned city of the Emirates Masdar Abu Dhabi in 2010, a wind-powered electricity generator called Windstalk, which are piezo-coated ceramic rods and electrodes, all of which are connected, where when there is wind, there is also movement of the rods, which are forced by compression, generating current, and where a generator converts kinetic energy into electrical energy [14].

Piezoletric generators developed by Innowattech Company, used on train tracks in Israel, have shown that areas where ten to twenty trains per hour can produce up to 120 KW / H. The company also installed energy-producing road systems through a pilot project with the installation of piezo plates on roads, train tracks, airport runways and subway stations, noting that up to twenty cars pass an expressway. every minute and can generate 200 kW / h, enough to supply a home for a month. The founder of the organization, Haim Abramovich, explains that on an avenue less than a mile long, four lanes, which run about 1,000 vehicles per hour, can generate approximately 0.4 MW, enough to power six hundred (600) homes [16]

The Haifa-Israel-based company has developed a system based on piezoelectric generators that can be installed under concrete or asphalt layer in road, rail and pedestrian traffic. Thus, the busier the road, the more energy is produced, where the heavy vehicles produce more energy [17] from the conversion of mechanical energy to electrical energy, also for use in traffic lights, radars or grid connected.

Pavegen founded by London-based Laurence Kemball-Cook in 2009 works with floor development and manufacturing that converts steps into energy and data. One such project was called the internet of beings at a facility in Cambridge; Another analysis looked at 200 projects in 30 countries, with smart urban developments, retail destinations and educational institutions in countries such as Hong Kong, India, Korea, Thailand, United Arab Emirates, United Kingdom, and the USA. Customers include Abu Dhabi International Airport, BNP Paribas, Ellandi, Google, Siemens, Transport for London and Urban Renewal Authority [18].

In this context, [19] exposes that Pavegen created a soccer field using the conversion of energy from slabs that collect energy, in the hill of Minas Gerais / RJ, in 2014, in partnership with Shell.

Tables 1 and 2 present some bibliographies that use computer simulation and prototypes, using piezoletric materials generating usable electric energy.

Table 1- Power generation values by computer simulation.

Computational Program	Piezoelectric Materials	Frequency (Hz)	Deformation (µm / m)	RMS Electric Power (mW)	Author
ANSYS	Girder with PZT-C64	75	387,97	31,41	[20]
SIMULINK DO MATLAB	Commercial Device Q220-A4-503YB Piezo Systems Inc	68	_	1,3	[21]
ANSYS e LABVIEW	PZT Cylinder	285	_	2,5	[4]

Source: Own authorship, 2019.

Table 2- Power Generation Values Measured by Prototypes

Piezoelectric Materials (Un)	Pressure (kg)	Voltage (V)	Power (W)	Author
30 Discs of 35 mm PZT	92	6,82	1,52086	(22)
30 PZT-4 (Lead Zirconate Titanate) 35mm tablets	80	7,18	_	(23)
PVDF (Vinylidene Polyfluoride) LDT0-028k, MEAS, 25mm / 13mm	_	8,92	0,00074	(24)

Source: Own authorship, 2019.

From these authors it becomes evident that piezoelectric materials have the capacity to generate energy, arising from deformations in their structure. Therefore, it is undisputed that the application of these materials becomes very productive in relation to the production of alternative energy.

We sought to present an analysis of existing studies on the piezoelectric effect for power generation, showing the amount of energy generated according to the methodologies observed, being an effect widely used in the small-scale world, in relation to alternative energy. , bringing satisfactory results.

According to [20] it is clear that the beam with PZT is the most productive in relation to other materials, and it is also explicit the use of this study as a source for other research, such as the capture of piezoelectric energy by vibration from a rectangular metal beam (Figure 1), also known among the authors as "cantilever".

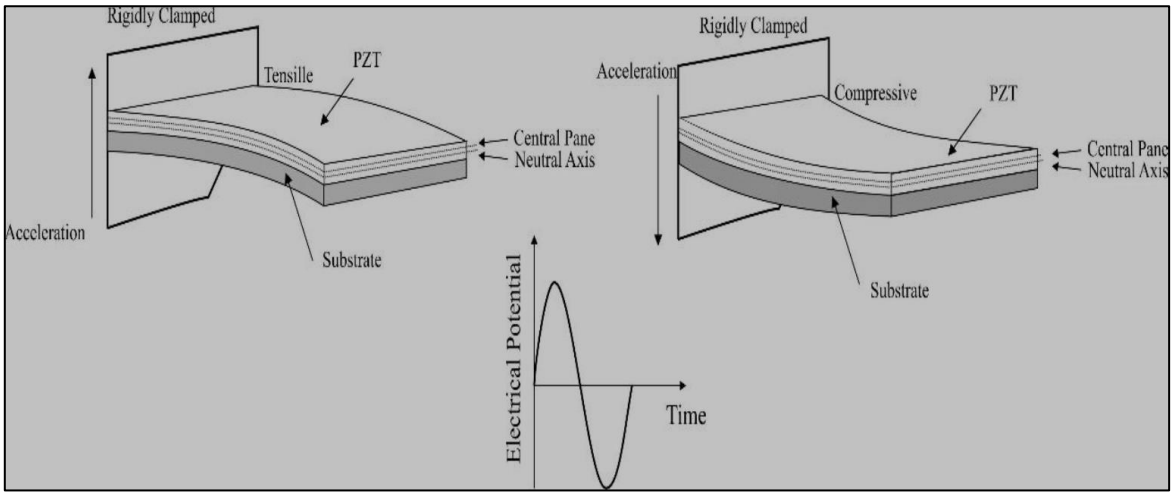

Figure 1: Basic configuration for energy capture through balance piezoelectric beams.
Source: Adaptation [12].

The best performance was observed in the use of 35 parallel interconnected 35 mm piezometric disks, with a positive pole of one ceramic with the positive pole of the other, where it is made with the negative pole, being the harvest by mechanical pressure. [22] There are other methods of linking the discs (Figure 2), which are used according to the purpose of each author, as topology has an influence on power generation.

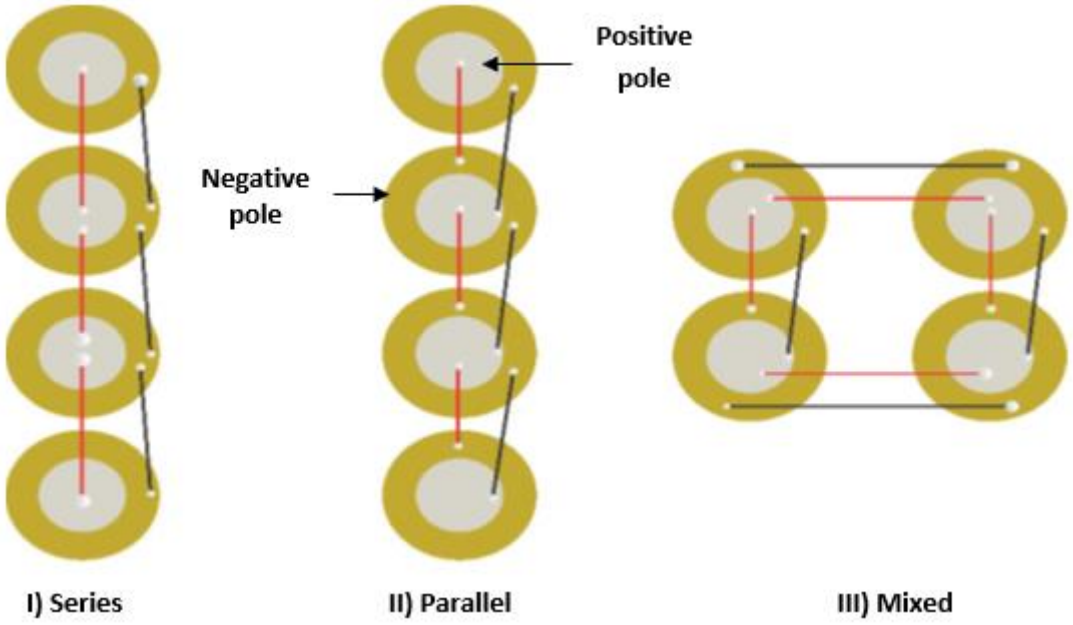

Figure 2: Electrical circuit topologies using piezoelectric
Source: Adaptation [25].

It is noteworthy that piezoelectric materials have limitations according to [26]: natural aging; property instability due to temperature variation and electrical and mechanical excitation limit. Knowing these limitations of properties and applications regarding commercial ceramics gives benefits in choosing the right material to use.

According to [27] relating the piezoelectricity generating sources to the main renewable energy sources, it

is noted that the piezoelectric effect does not depend on climate or specific geographical area, such as solar energy and wind energy, besides can be installed in urban areas near points of greatest demand, seeking to minimize transmission costs, which would not be possible with hydropower.

Also in this context, for [28] the use of these materials for power generation, has been gaining more attention from different communities, given the fact that it is mandatory to increase the demand for energy and consequently the search for alternative sources, given the impact caused over-exploitation over time and the impact on resources needed to generate this product. Thus, even though Brazil is dependent on hydroelectric dams, it has a great reference in the use of renewable sources.

4. Conclusion

Through the bibliographic review it was possible to analyze the contents about the use of the piezoelectric effect in the generation of clean electric energy, where when evaluating the different studies, still new within the research area, it was realized that there was a great potential regarding the diversification of the energy matrix.

Thus, it is concluded that piezoelectricity has evolved structurally and has several applicability in other areas, besides the production of electric energy, being exemplified its use in the areas of medicine, aerospace, electronics, etc.

In general, the application of this effect to energy generation can bring environmental benefits, without visual pollution, besides not using fossil fuels, considered a clean and alternative energy, which promises a promising source of energy generation. . In addition to being a sustainable solution, Energy Harvesting can be done anywhere that has a large flow of people as well as vehicles, reversing this condition into usable energy.

In this sense, the use of piezoelectric effect for energy harvesting through vibration or impact proved to be effective when analyzing the data from the sources in question. Attention is drawn to the fact that the study of these will be further studied and researched, since energy generation always aims at potentiality on a large scale.

Although feasible, further studies are needed on such properties of the materials used for piezoelectricity generation, which notes the existence of a difference in the generation potential.

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