MODULE FOR STUDYING THE USE OF PIEZOELECTRIC ELEMENTS FOR GENERATING ELECTRICITY

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Abstract: Today, most of the research on energy is focused on the development of alternative sources. Piezoelectric materials are being studied more and more, these having some unusual and interesting properties. This paper studies the necessary conditions to improve the electrical energy harvested from mechanical energy using piezoelectric materials. A laboratory module was created for studying the electricity generation using piezoceramic elements.

Keywords: piezoelectric, electricity, generation, piezoceramic.

1. PIEZOELECTRIC GENERATORS

Piezoelectric ceramics [4], [5], when mechanically driven by pressure or vibration, have the ability to generate sufficient electrical voltages to trigger a spark between the electrodes. Piezoelectric ceramics are commonly used for the ability to ignite a fuel source in lighters, gas stoves and welding equipment. In addition, everything, from quartz watches to computerized microphones, use piezoelectric components and the resulting piezoelectric effect, to increase their operational performance.

The damage caused to the world economy by corrosion reaches huge proportions, as an important amount of metal production is out of use due to corrosion. Damage due to corrosion is often related not only to direct metal losses but mostly to indirect losses through plant stagnation and repair or replacement of affected parts.

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1.1. Types of piezoelectric generators

Piezoelectric generators [2] represent an exciting breakthrough in electricity generation. Of course, we are still far from having a piezo generator to be used as a major source of energy, but when it comes to very stable and reliable power sources, experts believe that piezo generators can change the way we power electronic devices [6].

1.1.1. Single-layer piezoelectric generators

Two common applications of piezoelectric generators are in lighters (Figure 1) and in gas grills that many of us use daily. In these applications, pressing a button causes a mechanical actuation on a piezoelectric ceramic in the form of a rod. As a result of the piezoelectric effect, the ceramic element produces a voltage that creates a spark that causes the fuel source to ignite.

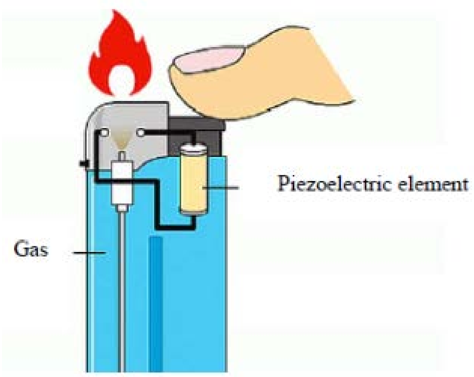


Fig. 1. Piezoelectric generator in lighter

Electricity in a rod-shaped piezoelectric generator that is released very quickly, has a very high voltage and a very low current. Piezoelectric ignition systems are small and simple, long lasting and require little maintenance.

1.1.2. Multi-layer piezoelectric generators

The multilayer piezoelectric generators consist of a stack of very thin (under one millimeter) piezoelectric ceramic plates alternated with electrodes (Figure 2). The electricity produced by a multilayer piezoelectric generator has a much lower voltage than that generated by a single-layer piezoelectric generator but the current is significantly higher.

As they do not create electromagnetic interference, multilayer piezoelectric generators are excellent batteries for electronic circuits.

Due to advances in microelectronic systems, many consumer devices have decreased in size. Smaller electronic systems require less energy to operate. As a result, solid state multilayer piezoelectric generators have become a viable energy source for some applications.

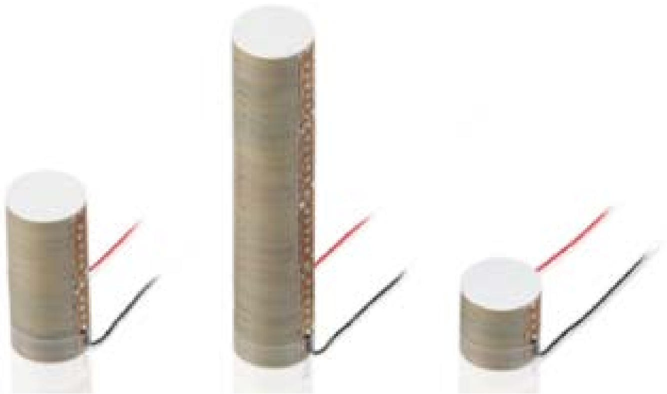


Fig. 2. Multi-layer piezoelectric generators

Current applications for multilayer piezoelectric generators are energy sources for ammunition and wireless sensors, such as pressure monitoring sensors in vehicles.

1.2. The future of piezoelectric generators

Recently, energy harvesting using piezoelectric power generation has become the focus of many researches [1].

Piezoelectric ceramics have limited power generation potential and therefore they are cost-prohibitive for feasible use in any large-scale energy harvesting application. On the other hand, the use of multilayer piezoelectric generators in smaller electronic devices with low power requirements provides a real opportunity for exploration.

In the case of existing piezoelectric materials, it is already possible to collect electricity and store it for later use. The problem is that piezoceramics do not generate enough electricity. Due to the relatively low power generation of piezoelectric materials, the ability to generate and store enough energy using this technology to power a machine, power consumer or any other large device is still far away.

Much has been thought of the ideas of walkways, stairs and roads that include piezoelectric materials that use the electricity generated for storage, but the technology is difficult to extend to generate adequate energy [3].

However, research continues, and improvements in piezoelectric materials, as well as energy production, have shown small but positive gains. Although it could never generate significant amounts of energy, the ability to convert mechanical energy into electrical energy will continue to expand the attraction of piezoelectric materials. Due to the reliability and correctness of the products that use piezoelectric materials, they will continue to be an integral part of the generation and conservation of electricity in a wide range of industries.

In the automotive and aeronautics industry, every chance of saving energy is worth pursuing.

The focus is not necessarily on finding a new revolutionary fuel source - it is about finding incremental savings in all systems and sub-systems. Here, piezoelectric materials will continue to play an important role in energy harvesting and utilization. If a piezoceramic material can generate enough energy to operate a sensor, there is no need to use the main power source.

A single piezoelectric generator may not represent significant energy or fuel savings, but as we begin to multiply, we begin to see a net gain.

2. LABORATORY MODULE TO STUDY ELECTRICITY GENERATION WITH PIEZOCERAMIC ELEMENTS

2.1. Achievement of the laboratory module

The electrical diagram of a piezoelectric generator is shown in Figure 3.

Operating on the basis of the direct piezoelectric effect, a piezoelectric generator can generate a small amount of electricity that can be stored in a capacitor or other battery and subsequently used. In order for such a generator to operate it is necessary that a force be applied to the piezoelectric element. The alternating voltage produced by the piezoelectric element it is rectified with a diode bridge.

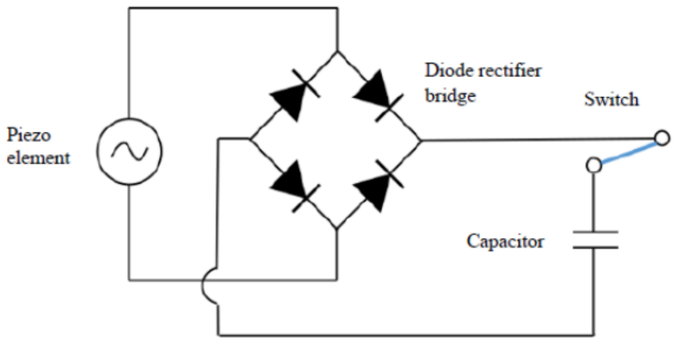


Fig. 3. Electrical diagram of a piezoelectric generator

We used 16 piezoelectric elements based on piezoceramics. The correct choice of the material is of great importance. In order to determine the most suitable material, the analysis of the most readily available piezoelectric materials was performed. The main selection criterion that was taken into account was a higher output voltage when applying different forces on the material.

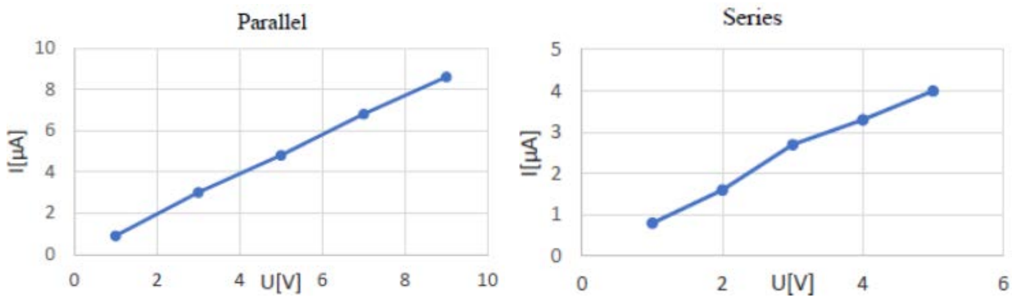
As a result of the measurements made, we concluded that PZT piezoceramics has better characteristics for use in this project.

In order to determine the way how the piezoelectric elements are connected in an electrical circuit that offers maximum voltage and current, two experimental connections were made, with three PZT piezoelectric sensors of the same model, connected in series and in parallel. We added a voltmeter and an ammeter to measure the values of the output. As a force was applied on the sensors, the corresponding voltage and current were observed (Figure 4.a), (Figure 4.b).

As a result of the measurements, we noticed that the parallel connection generates a higher current than the serial one.

A laboratory module has been developed to study electricity generation using piezoelectric materials (Figure 5). This represents a board with piezoelectric elements capable of generating up to 15 V and 35 µA when acting with a mechanical force. The energy generated by the system is subsequently used to power a red LED.

We made 4 parallel connections, each with 4 sensors mounted in parallel to obtain a higher current. Also, a LED has been used, with lowest opening threshold. For these reasons, a red LED was chosen as consumer with low electricity consumption. The positioning of the sensors was made as in Figure 6 so that, when mechanical actuation from outside is made, the mechanical stress is evenly distributed.



a. b.

Fig. 4. Output values for parallel (a) and series (b) connection output

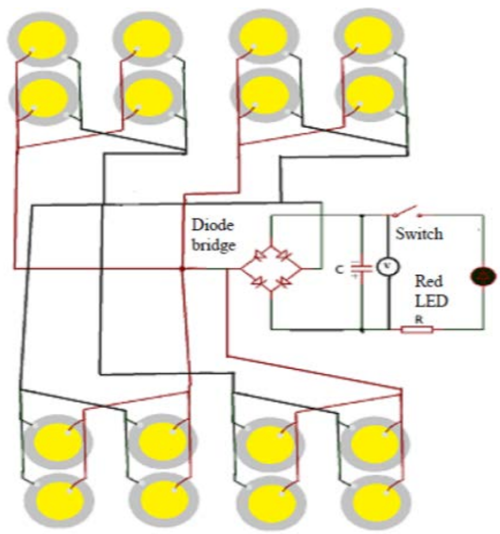


Fig. 5. Electric scheme of the module

2.2. Measurements and observations

The first measurements were performed on a single piezoelectric sensor connected via the bridge rectifier to a voltmeter and an ammeter. The following results were obtained:

- Maximum voltage - 2V
- Maximum current - 2.5 μA

During the experiments to determine the connection mode to give us the maximum current and voltage, we connected three piezoelectric sensors in series and three in parallel. As a result of the measurements made, we obtained results that differed from each other because it was difficult to operate with the same force on the three sensors simultaneously.

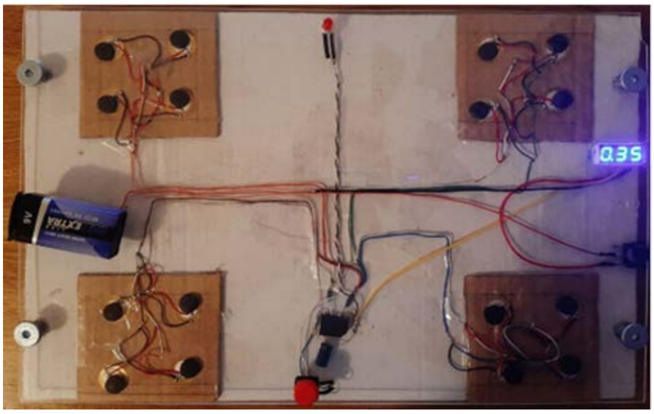


Fig. 6. Module achievement

In order to have a result as close to the truth as possible, we made several measurements and calculated the arithmetic mean, so the final values are:

✓ When connecting in series:
- Maximum voltage - 3.8 V
- Maximum current - 5.2 μA

✓ When connecting in parallel:
- Maximum voltage - 9.7 V
- Maximum current - 12.3 μA

The first variant of the project involved the connection of eight piezoelectric sensors, two groups of four sensors connected in parallel but due to the small number of sensors and their asymmetrical positioning mode, the current and the output voltage had low values. For this reason, we decided to double the number of sensors and their symmetrical positioning to allow uniform distribution of the force applied to all the sensors.

In the final module we used 16 piezoelectric sensors with a diameter of 15 mm. Because the generated electricity varies depending on the applied force, we performed measurements by applying two forces, a relative minimum of 10 N and a maximum of

350 N. We used these two forces to obtain a visible result and not to damage and depolarize the piezoelectric material.

Several measurements were made and we averaged the results. Thus, we obtained:

- Minimum voltage = 1 V at a force of ≈ 10 N
- Maximum voltage = 15 V at a force of ≈ 350N
- Minimum current = 1 μ A at a force of ≈ 10 N
- Maximum current = 35 μ A at a force of ≈ 350 N

When using an ordinary capacitor with the characteristics: U = 16 V and C = 220 μF, we obtain U = 6 V on the capacitor when operating for one minute, with a frequency of actuation on the sensors of ≈ 200 ac / min and a force of ≈ 300 N.

Following the measurements, we noticed that the output voltage and current are directly proportional to the force applied to the sensors. Also, a good response was observed at high frequencies which would allow the generation of electricity through vibrations.

When connecting the LED directly to the diode bridge terminals, there are low observable light pulses.

2.3. Measures to improve the results

Some measures to improve the results turned out to be:

- Piezoelectric sensors with larger dimensions and better characteristics
- Connecting more sensors.
- Using multilayer technology that would allow a much larger amount of electricity to be generated.
- Use of a supercapacitor as a battery.
- Coating the piezo ceramic with a wax layer or a polymer material that would reduce the influence of humidity.
- Use of flexible piezoceramics.

2.4. Source of errors

- Deterioration of the ceramics at microscopic level following the applied pressures - can affect the result reducing the amount of generated electricity.
- Depolarization caused by overpressures applied on the sensors - reduces the piezoelectric coefficient diminishing the generated energy.
- Purity of piezo-ceramics.

3. CONCLUSIONS

This module is designed for laboratory studies and does not withstand large mechanical stresses. But, if we consider similar systems that are achieved to use as a source of mechanical strength the weight of people and their steps, such projects could be used in public places like railway stations, schools, universities, offices. subway stations, airport etc. In such places, these devices can be placed at the entrances and exits. The obtained electricity can be used in street lighting, sensors or other low power devices supply.

However, piezoelectric materials have some disadvantages that limit their widespread use as sources of electricity. These disadvantages are: generation of a very low current, high prices of piezoceramics, sensitivity to temperature and humidity.

Due to contemporary trends in using alternative energy sources, more and more research is being done in the field of piezoceramics, which will allow in the future to create ceramics with superior electrical and mechanical properties.

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