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Getting Electric Power For Piezoelectricity

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ABSTRACT

This work presents the design and the implementation of a floor tile piezoelectric to obtain electric power and to feed a system of low power. To obtain the electric power across the floor tile, it is necessary to know the phenomenon called the piezoelectric effect, which is used as way that produces the electric power to a material ceramic call PZT-4 that operates as a generator, which produces the electric power for the application of mechanical energy to the material, that is to say, on having deformed the material piezoelectric for the mechanical action this one generates electric power.

Keywords: *Electric Power, Piezoelectricity, Piezoelectric Effect, Ceramic PZT-4, Floor Tile.*

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I. INTRODUCTION

The use of the electric power is indispensable in the modern life, difficultly we might imagine our lives without her. Across the electric power we have to our disposition machines that make the tasks much easier in the home, public system of illumination in shopping malls, parks, highways etc., tools and machines that are used for the technological development in many aspects like the possible automation of forms of production, advances in medicine, all thisis in order to do the most pleasant life.

At present, the generation of electric power depends in the main in the burning of fossil fuels like the coal, oil, and natural gas or for the consumption of radioactive material which produce a high index of pollution in the environment and can put in risk the human life in case of some fault in the case of the radioactive materials.

And due to the increasing demand of electric power and the destruction of the environment there has been stimulated the investigation of new alternatives to obtain electric power. One of these new forms of obtaining energy is by means of the piezoelectricity, that is to say, of the piezoelectric effect, which is a physical phenomenon that some crystals present when they surrender to a mechanical deformation that which makes appear a potential difference to the exit of piezoelectric material PZT-4.

For such a motive, in this article there appears the design of a prototype of piezoelectric generator that transforms the mechanical force of pedestrians compression into electric power to feed a system of lighting of low power.

II. PIEZOELECTRICITY

The piezoelectricity is the property that there possess some not conductive, crystalline substances, of presenting electrical loads of opposite sign in his faces when they are deformed. For the comprehension of the piezoelectricity, it is necessary to know the piezoelectric effect and for define it, it will be necessary to be considered the microscopic structure of the piezoelectric material.

A material that is capable of presenting a polarization in his faces is considered like a piezoelectric material. The polarization of the material happens inside the crystalline structure that it composes it; one speaks about a dipolar moment, that it arises from the existence of two loaded particles, located in two different points from the space and that it is defined mathematically as the product of the load by the distance that separates them. Then, if one speaks about a material with natural piezoelectric characteristics, this one was presenting the piezoelectric effect, when there applies him an effort on the contrary, if one speaks about a material with artificial piezoelectric characteristics, one speaks about a material induced to exhibit these properties [1].

The piezoelectric effect, also known as "direct piezoelectric effect", is the ability of certain materials (minerals, ceramics and some polymers) to produce an electric load in response to an applied mechanical stress. This effect takes place if an elastic deformation of a solid which is accompanied by an asymmetric distortion of the distribution of the positive and negative loads in the material.The inverse piezoelectric effect occurs if an electric field is applied to the material and this causes a distortion of the distribution of the loads since geometric distortions are generated, manifested as mechanical stresses [2].

III. PIEZOELECTRIC GENERATOR.

The generator to be designed for electric power generation consists of a series of floor tile piezoelectric that seek to replace the existing inert floor tile. The remarkable difference is that they have the capacity to generate electrical energy through the mechanical deformation of a group of piezoelectric disks.
For the complete analysis of the floor generator (floor tile), which is constructed from piezoelectric ceramic materials, it will be necessary to consider the parameters of this material. Which are listed below.
Type of piezoelectric material.
Piezoelectric constant.
Dimensions of the piezoelectric.
Level of deformation.
Loss of load.
Static capacitance of the piezoelectric.
Force exerted on the material.
Resistance of piezoelectric transducers
For purposes of this generator, from the above list of the total properties of a piezoelectric material, only the fundamental parameters of said material will be considered; being these, the piezoelectric diameter at the deformation level reached, the force exerted on the material and the resistance of the piezoelectric transducers.

Electrical stress due to deformation. In order to calculate the electric voltage generated from the deformation of the piezoelectric ceramic, it is necessary to know the constant of the piezoelectric correspondent to the material. This constant defines the ratio between the dimensional variation Δl of the piezoelectric material in meters and the potential difference applied in Volts. It defines the generation of electric loads in Coulombs and the force applied in the material in Newtons [3].
The equation 1 defines the voltage generated by a mechanical load acting on a determined area of a piezoelectric PZT [4].

$$V = \left(-g33 * h * \frac{f}{A}\right) = -\left(g33 * h * \left(\frac{f}{d^2 * \frac{\pi}{4}}\right)\right) \quad (1)$$

Where:
VIs the expected peak strain due to deformation of the material.
g33It is the piezoelectric constant (Vm / N).
hThe length or thickness of the piezoelectric.
fForce that is printed on the piezoelectric ceramic (N).
dEffective diameter of the piezoelectric ceramic.
AArea of the piezoelectric ceramic.
The force applied on this area is also called the stress level of the piezoelectric material. "In this case, for a disk PZT (Lead TitaniumZirconate) of 27mm diameter in itsdiaphragm and 20mm in diameter in theceramic, thepiezoelectricconstantis of theorderof :$25x10^{-3}$Vm/N" [7].
The piezoelectric generation elements, being connected in parallel, retain an equal output voltage, regardless of the number of elements that are connected. However, the current varies depending on the number of connected elements besides the impedance presented by them.
By their nature, the devices used have a high impedance, approximately 400Ω. Apparently it is not a considerable amount, however due to the characteristics of the material, it is considered a high resistance. Because of this high resistivity presented to the electric power flow, the current values are too low. These values oscillate in the scale of the milliamperes; for the case of ceramic devices a base current of the order of 1mA is considered.
The power generated from the generator drive is defined as the product of the output voltage by the current. This power is calculated through equation 2.

$$W = (V)(I) \quad (2)$$

Where:
WIs the power generated in watts.
VIs the voltage that flows through the circuit in volts.
IIs the current in Amps.
To base the operation of the generator, whose pillars are the piezoelectric elements, is made based on the mechanical properties applicable to them.

Force applied to piezoelectric disks. For the calculation of the force exerted or applied on the ceramic discs, equation 3 will be used.
The applied force is estimated considering the average weight of the world population; This is an approximate weight of 80 kilograms and the force of gravity of the land at sea level [8].

$$f = m * g \qquad (3)$$

Where:
mIt is the mass of the object that activates the piezoelectric, in this case a person.
gCorresponds to the constant of gravity equivalent to 9.81
m / s^2.

Effective area of disk action. The effective area of action for the piezoelectric disk is that area where the participation of the ceramic material is concentrated. Equation 4 allows to calculate this area according to the diameter of the disc [9].

$$A = \frac{(\text{Ceramic area}^2)(\pi)}{4} \qquad (4)$$

From the theoretical bases that were presented, the calculations were developed corresponding to the tension generated by each floor tile from the force applied to it and also, from the characteristics of the piezoelectric devices in use.These calculations refer exclusively to voltage values and are developed with the objective of displaying in the corresponding section the voltage values that theoretically must be presenter for each floor tile.
The calculation of the generated voltage is:

$$V = -\left(g33 * h * \left(\frac{f}{d^2 * \frac{\pi}{4}}\right)\right) \qquad (5)$$

Assigning the values to each of the variables; You have:

$V = ¿?$

$g33 = 25x10^{-3}\ Vm/N$

$h = 0.33mm$

$f = (80Kg)(9.8m/s^2) = 784N$

$d = 20mm$

Substituting these values, we form the equation and get:

$$V = \left(25x10^{-3} * 0.00033m * \left(\frac{784N}{0.02m^2 * \frac{\pi}{4}}\right)\right) = 20.58V$$

IV. TEST AND RESULTS

Electrical Testing on the Piezoelectric Element. Two independent basic electrical tests were performed on a piezoelectric element sampling. The tests carried out on each element have the purpose to evaluate and verify the electrical properties that theoretically they must present.
The tests performed on the piezoelectric elements are listed below:
1. Voltage generated by direct impulse.
2. Current generated by direct impulse.

Voltage generated by direct impulse. The voltage value generated, presented by each piezoelectric element oscillates between 13.24 and 17.11 volts. The actual voltage in each disk was obtained by connecting a digital multimeter to the ceramic and metal terminals of the said disk; And in turn, exerting on it a mechanical force capable of deforming it. Fig. 1.

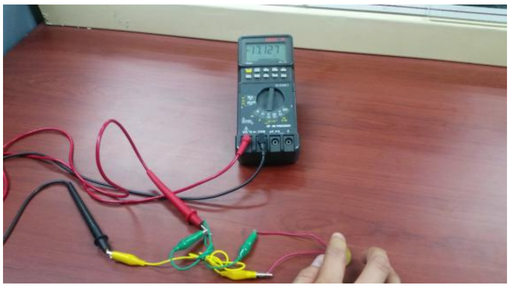

Fig. 1.Measurement of voltage on a piezoelectric disk.

Current generated by direct impulse. The current generated by each of the disks due to the direct mechanical impulse equals 11.49 μA. Fig. 2.

Fig. 2. Measurement of current in a piezoelectric disk.

For the development of the calculation of the voltage that can be generated by the piezoelectric elements under the action of a mechanical load. By collecting the theoretical properties that they possess and making a substitution of them in the variables of the equation, we have ideally that the piezoelectric elements, applying them a weight of approximately 80 kg, must be able to present in their terminals a potential difference of approximately 20.58 Volts. This result differs somewhat from that obtained experimentally; When the piezoelectrics are subjected to that level of deformation, we obtain a maximum reading between 13.24 and 17.11 Volts, this is due to a series of factors that can alter or diminish the performance of these elements. As for example: an error in the application of the deformation force, a mechanical overprotection, a measurement error, defects of factory etc.

V. IMPLEMENTATION OF PIEZOELECTRIC GENERATOR TO OBTAIN ELECTRIC POWER.

For our design to operate properly, we must use electronics to bring 100% of its total operation to the piezoelectric tiles. Since the greatest strength of piezo floor tiles is the generation of voltage, ie, it is an element that generates comparatively high levels of voltage but a very low current.
The deficiency that it presents in the generation of current, is what forces to make use of the electronics. It should be remembered that for the operation of any electrical device, not only the presence of the required voltage level is sufficient, but also the current demanded by it must also be considered.
The piezoelectric floor tile is capable of providing voltage levels, but will hardly support current levels.This disadvantage forces us to use elements that help us to strengthen this weakness.
Next, the electronic circuit used to transmit and store the energy obtained from the piezoelectric tiles is shown.

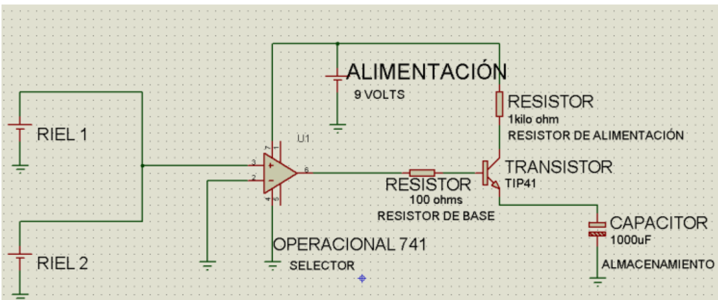

Fig. 3. Electronic circuit for transmitting and storing electrical energy.

Based on the electronic circuit, we proceeded to the physical elaboration of the circuit, all the elements were assembled in a perforated phenolic table.

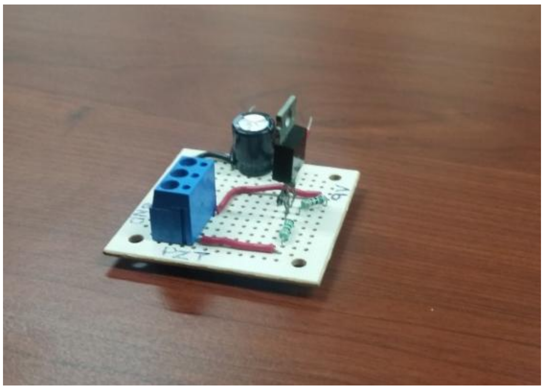

Fig. 4. Physical Circuit

In order to finish implementing the design, we proceed to assemble the prototype with the tile to be able to do the tests, this is shown in fig. 5.

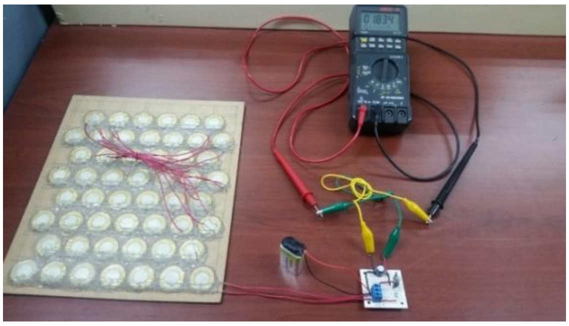

Fig. 5.Resting state of the electronic circuit.

Different stimulation tests were performed on the piezoelectric tile to give a broader picture of how it obtains better results in loading and unloading time of the energy obtained by the floor tiles.
The energy obtained in the capacitors will be consumed by strips of 6leds, calculating the time in which they consume the energy.
One of the tests is to vary the force to which the tile is subjected to fill the capacitors and take record of the time it takes to do so to later take record of the time in which the LED strips consume this energy to have a panorama of the time that the energy stored in the capacitors can supply the load of the LED strips.

Proof.Unique deforming factor 83 kg on a single leg. The force that deforms the piezoelectric disks that integrate the tile is that of a person weighing 83 kg, concentrating its weight in a single leg.
In the Fig. 6 is shows the person submitting his force to the tile with a single leg, it is observed that the footprint covers a minimum part of the piezoelectric tile which leaves several disks unused.

Fig. 6.Proof.

In the Fig. 7, the discharge process is observed, the led strip is observed and the voltage drop on the multimeter.

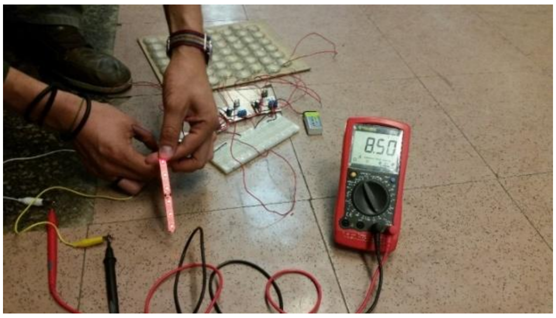

Fig. 7. Download in the Test. Energy obtained applied to the system of low consumption (6 leds).

The results obtained for the charge of the capacitor to a voltage of 8.79 volts are shown in table 1, as well as the results obtained at the end of the discharge of the capacitor by the strip of 6 leds.

Table 1. Results of the test.

Load		Discharge	
Volts [V]	Time [s]	Volts [V]	Time [s]
8.79	155.88	1.7	20.11

VI. CONCLUSIONS

Thinking of a mode of electric power generation that can support and power a lighting system, as presented by the Tokyo metro, or Bernabéu stadium in Spain, is impressive and it is more impressive to observe the way Which they do, step on, store and use. Stepping the piezoelectric elements, storing all the charge in the batteries and finally using it, is the context with which this work was developed.

On the other hand, it can be observed with the tests, that the design and the implementation work with the help of the electronics and was fulfilled with the objective of the work.

They changed the capacitors that stored the charge for a battery that would give the energy needed to illuminate the low power system, thus achieving the purpose of the job.

Finally, this type of generation can be recommended since the piezoelectric generation systems are clean and reliable, they have a long life and do not require some directed excitation like the big generators, however, their construction is relatively high for the Level of electrical energy obtained.

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