Design and Development of Piezoelectric Tile Prototype for Energy Harvesting from Footsteps

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Abstract: The **objective of this research is to design a piezoelectric tile for harvesting energy from footsteps and to optimize the system for harvesting maximum energy. The piezoelectric materials easily break when they are directly subjected to energy generated by human movement, we have developed a prototype model as the basic research in this investigation where we have chosen a plywood sheet instead of ceramic tile or concrete tile inorder study preliminary design criteria. Here we have designed a plywood sheet that employs indirect energy transmission through springs and a tip mass. We aimed at making the mechanical resonance frequency of the tile with that of the piezoelectric module. The power output of piezoelectric module is 3V and power output delivered from our piezoelectric tile was 10V. we have harvested volts power by connecting 8 piezoelectric modules in series and parallel. From the developed prototype tile, we got satisfying results and hence we will be developing a commercialised piezo tile in our future work.**

***IndexTerms*–Pizoelectric effect, Piezo-Tiles, Energy.**

I. INTRODUCTION

Piezo electric material is the one which has the ability to convert mechanical energy to electrical energy. it has many large-scale applications; one such application includes Floor tile where electrical energy is harvested from the pressure exerted by the footsteps. In one of the Japan's Tokyo subway station they have used Piezo-tiles to power nearby lights. Our focus is to harvest underutilized piezoelectric energy.[1]

Piezoelectric materials have two main functions. The first function is the direct piezoelectric effect, where the mechanical strain is transformed into electrical charge [3]. The second function, called the converse piezoelectric effect, takes an applied electrical potential and converts to mechanical strain. Therefore, an electric field can be applied to induce an expansion or contraction of the material and vice versa. The piezoelectric effect occurs due to the material's electric dipoles. Dipoles are represented as vectors pointing from the positive to the negative charges. Groups of aligned dipoles are called Weiss domains. In a piezoceramic material, which are materials that are not inherently piezoelectric like naturally occurring piezoelectric crystals, but rather can be manipulated to exhibit piezoelectric behavior, the Weiss domains are not aligned, and the overall material has no net polarization. After applying an electric field, the domains align themselves in the direction of the field, creating a polarization. When the field is removed, the material cannot return to its original structure, but rather a more organized structure which allows for the material to exhibit the piezoelectric effects like a normal crystal [4]. Applying mechanical stress to this newly piezoelectric material disrupts the orientation of the dipoles, realigning them as they were during polarization with the applied electric field and bringing about a polarization which creates a potential difference across the material. This voltage drop allows charge to flow between the two poles in order to realign the dipoles, thus generating a current.

Additionally, the applied pressure and the generated energy have a direct relationship in which increasing the pressure will also increase the energy output. The piezoelectric charge coefficient, dXX, gives the amount of electrical charge to the strain applied in units of picocoulombs (10-12 coulombs) per Newton in one of the six directions. The d33 value gives the charge on the top and bottom of the piezoelectric when a force is applied to the top of the piezoelectric. Natural piezoelectric crystals, such as quartz, typically have lower piezoelectric charge coefficients than synthetic piezoelectric materials. Team Piezo's touchscreen prototype uses one of the most common and efficient synthetic Weiss domains before during and after polarization. Balance of charges is disrupted to create a potential difference 3 piezoelectric materials, lead-zirconate-titanate (PZT) ceramic. A frequent application of this material is a PZT stack, which is made by mechanically assembling several PZT wafers in series and then connecting the electrodes so that the wafers are in parallel electrically. The wafers are polarized in the same direction along their thickness. This uniaxial polarization means that the stack exhibits the piezoelectric effect only in the vertical direction. When a voltage is applied across the electrodes, the stack elongates in this vertical direction. Conversely, when the stack is vertically compressed or elongated, an electric current is generated [6].

The most commonly used piezoelectric materials are quartz, polyvinylidene fluoride (PVDF) and lead ZirconateTitanate (PZT). In this investigation an attempt has been made to develop a Piezo tile to harvest electrical energy. In our research PVDF was the piezoelectric material chosen because it possesses very good resistance to solvents acids, hydrocarbons and is very economic [7]. In this regard the following objectives were framed

- To fabricate the piezo electric transducer.
- To develop a Piezo-tile from which electrical energy could be harvested.
- To measure the power output obtained from the fabricated tile.

II. EXPERIMENTAL DETAILS

The PVDF piezoelectric material was used to develop a piezo electric transducer. Then the transducer was mounted on the plywood sheet inorder to test the prototype model. The hardware components include wires, 12V battery, one multimeter, plastic bushes and lighting device. The detailed specifications of the developed PVDF transducer is depicted in the table 1.

Table 1: Piezoelectric transducer specifications

Piezoelectric material	PVDF
Weight	50g
Output	3-4CV
Height	10mm
Width	50mm

III. RESULTS

(3.1) Modeling:

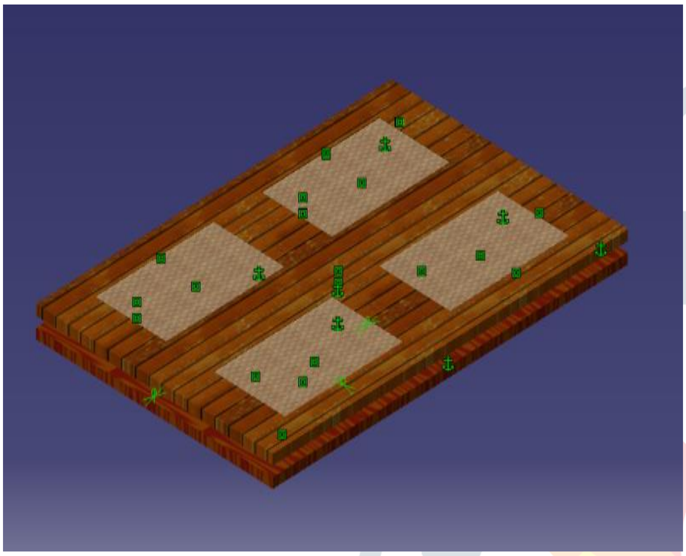

Figure1: Catia 3d model

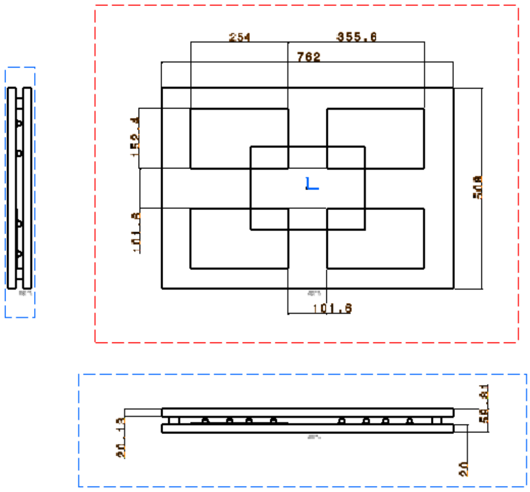

Figure 2: 2d model

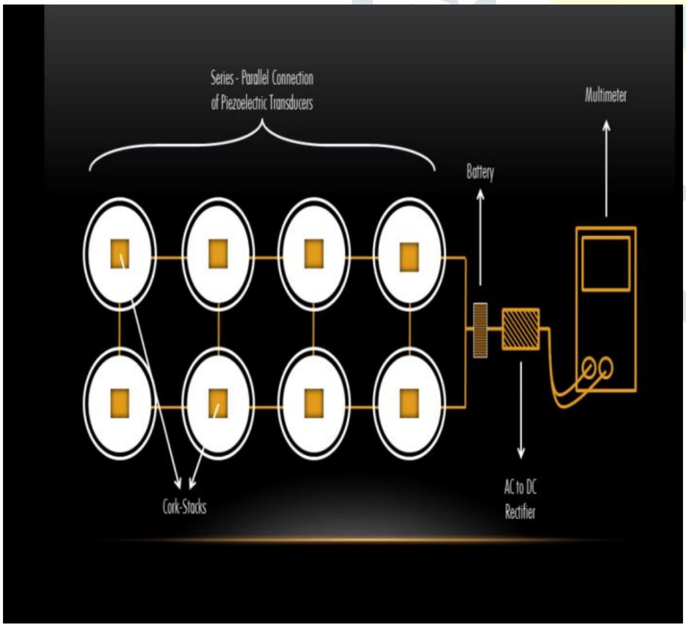

Figure 3: visualized circuit

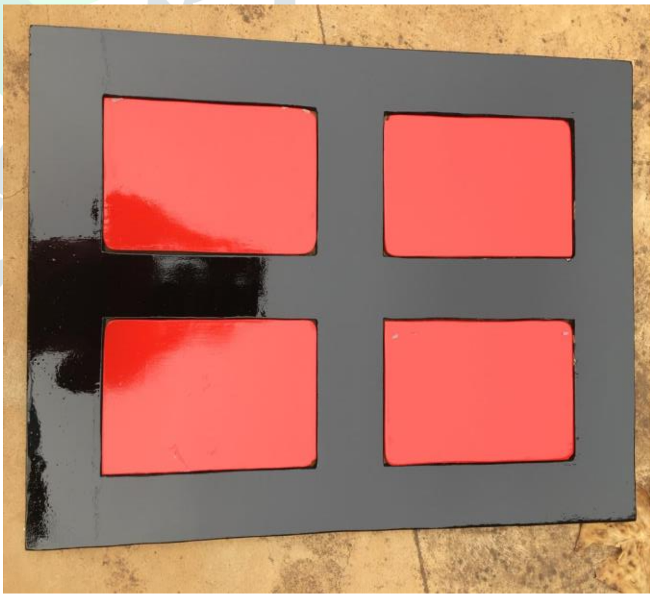

Figure 4: final model

A 3d model of the wooden base with circuit was prepared as shown in the picture. This 3d model was developed using the software CATIA V5. The figure 1 shows the 2d CATIA model of the wooden tile. The wooden tile was then fabricated according to the dimensions in the CATIA model of figure 2.

The tentative 3d model a circuit for the successful conduction of the Piezo transducers was prepared as shown in Figure 3. The conceptualized circuit was then implemented, i.e., piezoelectric transducers was connected as shown in the Figure 3. Both series and parallel circuits were tested. But inorder to get maximum power output transducer circuit of four series connections were made in parallels shown in Figure 3. According to circuit connections were made and then they were mounted on the wooden tiles to the required dimension. In a whole wooden base four separate wooden pieces were cut as per dimensions. Bushes were mounted to two of the four wooden pieces as seen in the figure 4 inorder provide proper gripping action. The Transducers in series with parallel connections were fixed to the wooden panels according to the circuit diagram.

As we know the pressure is directly proportional to amount of power generated

$$P \alpha Wt$$

Here we take the constant of proportionality as Ⱪ, then the equation becomes

$$P = Ⱪ Wt$$

Where, Ⱪ is Constant of proportionality
Wt.is weight and
P-power
From calculations for wt.=50kg, we get the value of voltage V=4V and I =0.015A
Then P=V*I=4*0.015=0.06w,
From which we can conclude that if 50kg pressure is exerted on one tile by one step on the developed prototype tile we can harvest 0.06W

From this we can find the value of Ⱪ

Ⱪ=P/wt.=0.06/50=0.0012

When a force is applied on piezo material, a charge or potential difference is created in the tile. Thus, it can be assumed to be an ideal capacitor. Thus, all equations governing capacitors can be applied to it. In this project we have connected 8piezo- transducer in series. 4 such series connections are connected in parallel. Thus when 4 piezoelectric discs are connected in series, its equivalent capacitance becomes:

$$\frac{1}{Ceq} = \left(\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}\right)$$

We know that,

$$Q = C * V$$

So,

$$C = \frac{Q}{V}$$

Hence,

$$\frac{Veq}{Q} = \left(\frac{V1}{Q} + \frac{V2}{Q} + \frac{V3}{Q}\right)$$

Thus,

$$Veq = V1 + V2 + V3$$

Hence, the net voltage generated in series connection is the sum of individual voltages generated across each piezoelectric disc. Output voltage from 1 piezo disc is 6V.
Thus,

$$Veq = V1 + V2 + V3 + V4 = 6 + 6 + 6 + 6 = 24$$

Thus, theoretically the maximum voltage of 24V can be harvested from one tile under ideal conditions. The table 2 depicts the calculated amount of energy which can be developed from one tile and the amount of time required to turn ON one 100W bulb.

Table 2 : calculation of Energy to be harvested from one tile to glow 100W bulb

Number of foot steps	Duration of lighting a 100W 230V bulb	Total energy (J)	Energy/Step (J)
250	6	600	2.4
500	12	1200	2.4
750	18	1800	2.4
1000	25	2500	2.5

Figure 5 depicts the experimental results which is plotted in a graph of Load v/s Current. From the graph we can conclude that as the pressure exerted on the Prototype Piezo model more the energy harvested from the tile.

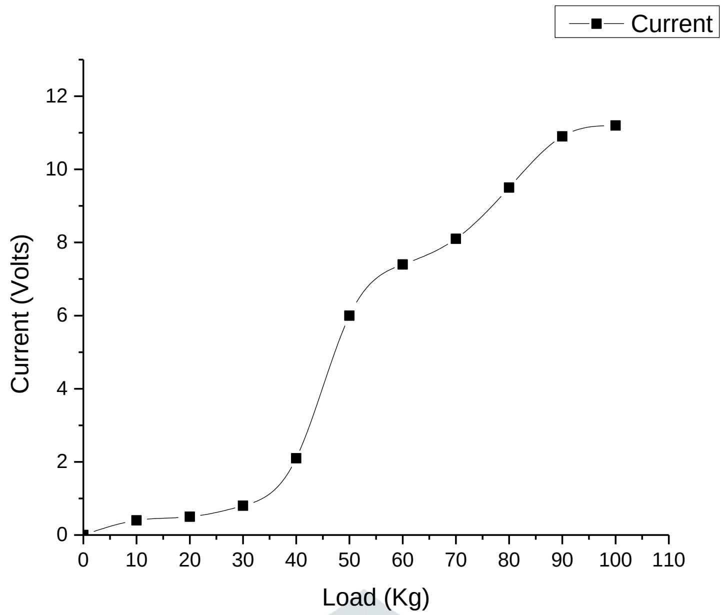

Figure 5: Load v/s Current

IV. CONCLUSIONS

The following conclusions were made in this investigation:

1. 8 PVDF piezo electric module was incorporated in one slab to develop one piezo electric tile.
2. From the results we can conclude that the transducer connected in series with parallel yielded higher output.
3. A prototype tile was developed which has the capability of generating 3.25 V for a pressure of 60Kg.
4. The developed prototype if it is commercialized by using a cement or ceramic tile can harvest green energy in large scale.

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