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Generation of Electricity by Vibrating Piezoelectric Crystal in Staircases

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Abstract

A number of renewable or non-renewable sources of energy present these days are not able to meet our need of power. The need of power is increasing day by day as the population is increasing so we are finding different ways to generate power. In this paper we are generating power by walking on the stairs and the power which is generated can be stored for the further use. We can use this system in malls, homes, schools, companies, college, metro etc. When the group of people walks on these stairs, power is generated by the continuous movement of the persons. Here mechanical power is converted into electrical power. The power which is generated can be used to charge mobile.

Keywords: *Piezoelectricity, Renewable, Electrical power, Mechanical power, Green energy*

1. Introduction

A recent innovative step for energy harvesting is Piezoelectric Energy Harvesting. It comes under micro scale energy harvesting as small voltages can be obtained from piezoelectric crystals.

The Piezoelectric effect refers to a change in electric polarization in certain crystalline materials called piezoelectric materials when mechanical stress is applied on them [1, 2]. This stress dependent change in polarization appears as potential difference across the material. The higher the applied stress the higher will be the output voltage.

Some examples of piezoelectric materials are quartz, Rochelle salt, tendon, barium titanate, potassium nicobate etc [3], [16]. These crystals lack centre of symmetry. A unique characteristic of these crystals is their ability to work in reverse manner as well i.e. when voltage is applied to them they tends to change dimensions. A single piezoelectric crystal generates output voltage in the range of millivolts, so to produce higher voltages piezoelectric materials should be placed in series. The energy hence derived can be stored in capacitors or lithium batteries [17].

Energy for piezoelectric materials can be obtained from heavy weight machines, walking humans, vehicles running on roads, soldier boots, etc. Moreover, these movements are untapped and go unutilized. So our work involves utilizing the movement of humans to produce an efficient energy source [5, 6]. These crystals can be used to generate electricity in places which are crowded and involves human movement like stairs in metro stations, malls, laptops etc. Here we have made use of Matlab simulation in order to show how the electricity is generated while walking on a flight of stairs up and down.

2. Background Survey

2.1. Pressure Sensors

The most common example of piezoelectric crystal is gas igniters (Figure 1). Piezoelectric ceramic when subjected to applied mechanical stress generates a very high voltage that can cause sparking and ignite the gas. The mechanical force can be applied in two ways, either by a frequent pulse application or by a more frequently continuous increase.

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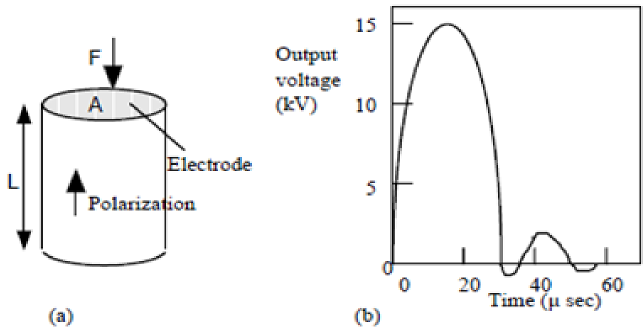

Figure 1. (a) gas igniter (b) output voltage

Piezo-ceramics pertains direct piezoelectric effect [4] and as a results used as stress/acceleration sensors. Figure 2 shows a 3-D stress sensor constructed by Kistler. Substituting the combination of a significant number of crystal (Quartz) plates (extension and shear type) the multiple layer device can reflected 3-D stresses.

Figure 3 signifies a cylindrical shaped gyroscope commercialised by Japan. The cylindrical structure has 3 separated pairs of electrodes, representation of each pair as the axial location (or X, Y, Z) one pair is used as excitation system there of the fundamental bending vibration mode, while the other two pairs are used for detection of the accelerating medium. The voltage generated on the electrode when the axis of this gyro is subjected to rotational acceleration is modulated by Coriolis force. A voltage directly proportional to accelerating mode can be deduced by making difference in the signals between the pair of two electrode sensors.

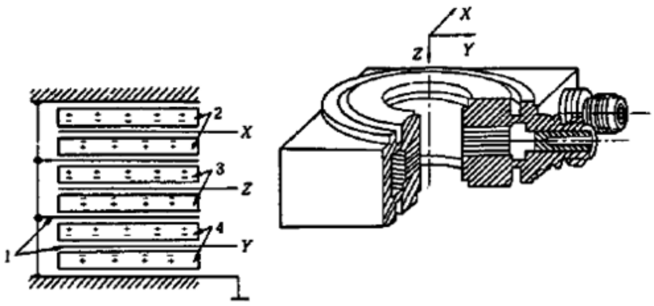

Figure 2. 3D stress sensor by (Kistler)

The effect of gradient with respect to pressure applied sensed by the potential change. The change in potential referred to the varying potential gradient field defined by the divergence theorem.

Gradient (ϕ) = $-\Delta V$
$d\phi_x/dt + d\phi_y/dt + d\phi_z/dt = -ive$ Δgradient of voltage.

The negative gradient referred to the rise in potential in the case of conservative force, which depends upon the initial and final position but not the path of traversal. Electrostatic field is also the conservative force field, the work done against the direction of field.

The stress dependency concise on the primitive is also used in stress sensor. A measuring system which differentiate the static capacitive value of two dielectric medium (ie ceramic plates), which has been stated by changes in capacitance of the top and bottom plates have opposite signs for unaxial stress and same sign for temperature (but here is the concept of pressure) deviation [7, 8]

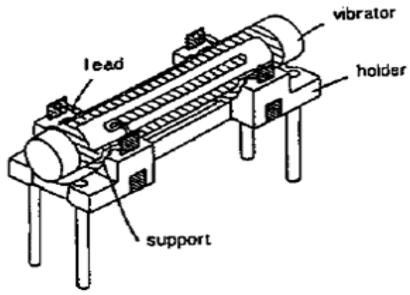

Figure 3. Cylindrical Gyroscope

Energy transmission coefficient = λ_{max}

Not all the stored energy can be used, and the amount of work done depends on the mechanical load. At zero mechanical loads or at no strain the work done is zero work.

$$\lambda_{max} = \frac{(Output\ mechanical\ energy)_{max}}{(Input\ mechanical\ energy)_{max}}$$

Or

$$\lambda_{max} = \frac{(Output\ electrical\ energy)_{max}}{(Input\ mechanical\ energy)_{max}}$$

Considering the case where an electric field E is applied to a piezoelectric defined by constant value external stress X < 0, because a compressive stress is necessary to work to the outside. As shown in Figure 1, the output of a system is calculated by work done.

$$\int (-X)dx = -(dE + sX)X$$

while the input electrical energy is given by

$$\int Edp = (\varepsilon_o \varepsilon_r E + dX)$$

We have to choose an optimal load to expand the energy transmission coefficient. From the most maximize state of

$$\lambda = -\frac{(dE + sX)X}{(\varepsilon_o \varepsilon_r E + dx)E}$$

The expression has been obtained with the help of following relation

$$\lambda_{max} = \left[\left(\frac{1}{k}\right) - \sqrt{\frac{1}{k_2} - 1}\right]^2$$
$$= \left[\left(\frac{1}{k}\right) + \sqrt{\frac{1}{k_2} - 1}\right]^{-2}$$

Notice that

$k_2/4 < \lambda_{max} < k_2/2$

Depending on the value of k. For a small k, $\lambda_{max} = k_2/4$, and for a large k, $\lambda_{max} = k_2/2$.

It is additionally important that the most extreme condition expressed above does not concur with the condition which gives the greatest yield mechanical vitality [9, 10] The most extreme yield vitality can be acquired when the load output is half of the maximum generative stress: - (d E - s (d E / 2s)) (- d E / 2s) = (d E)2/ 4s. In this case, since the input electrical energy is given by $(\varepsilon_o \varepsilon_r E + d\left(-\frac{dE}{2s}\right))$

$$\lambda = \frac{1}{2\left(\frac{2}{k_2}-1\right)}$$

The following value is nearest to the value λ_{max}, but has other than that is predicatively concluded theoretically.

2.2. Matlab Simulation

The model that we designed is a hybrid combination of electrical as well as mechanical model. The model consists of PID controller, Quantizer, Repeating sequence stairs, Simulating PS converter, Simulating SP converter, Rate transition block, Position valve, Display, scopes and permutes dimensions.

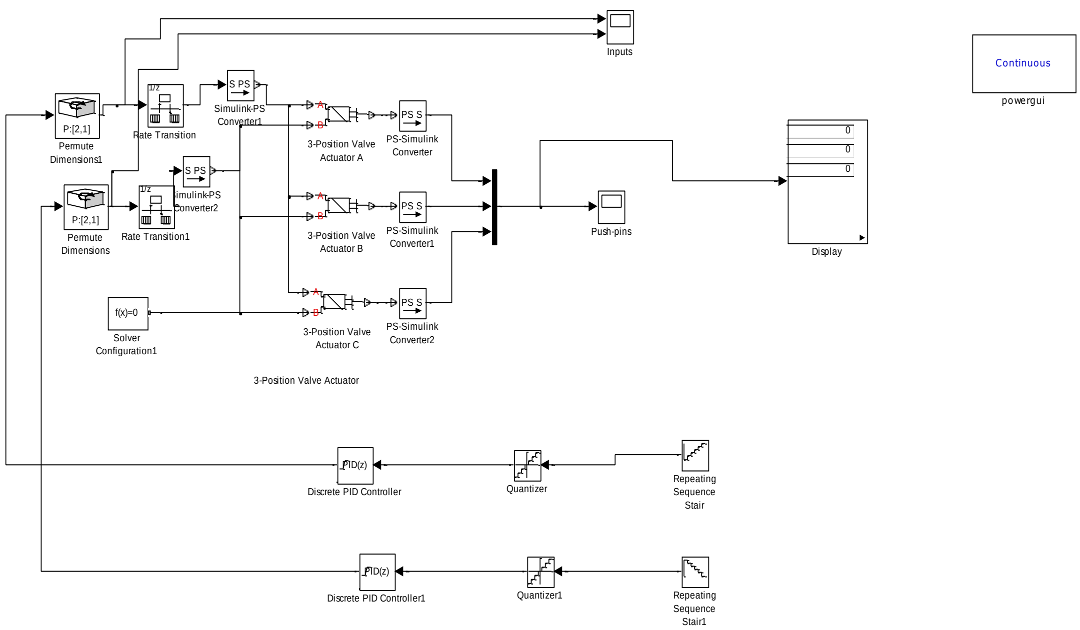

Figure 4. Simulink Model

In this simulation (Figure 4) we can produce electrical energy from everyday motion of people travelling up and down in the stairs and can be stored for further use. When pressure is applied in the stairs case, electrical energy is generated which is then passed to PID controller which reduces the number of harmonics to get better output [15], [18, 19]. Maximum pressure is applied in the middle of the stair so that maximum energy is produced.

3. Results

The input given to the block diagram.The output of the push pin shows that the electricity produced in the middle of the stairs is of great importance than that of any other step. The input to the system is well defined in Figure 5 and the output is calculated by the push pin system the negative gradient is shown. Which give conversion process that converts stress into electrical electricity generation? The generated energy can further stored in secondary device like battery.

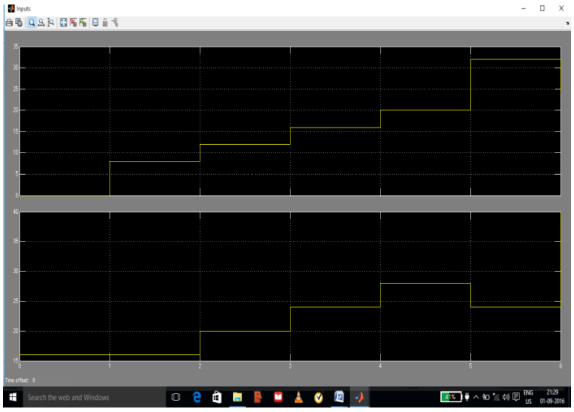

Figure 5. Input

Figure 6. The output of the push pin

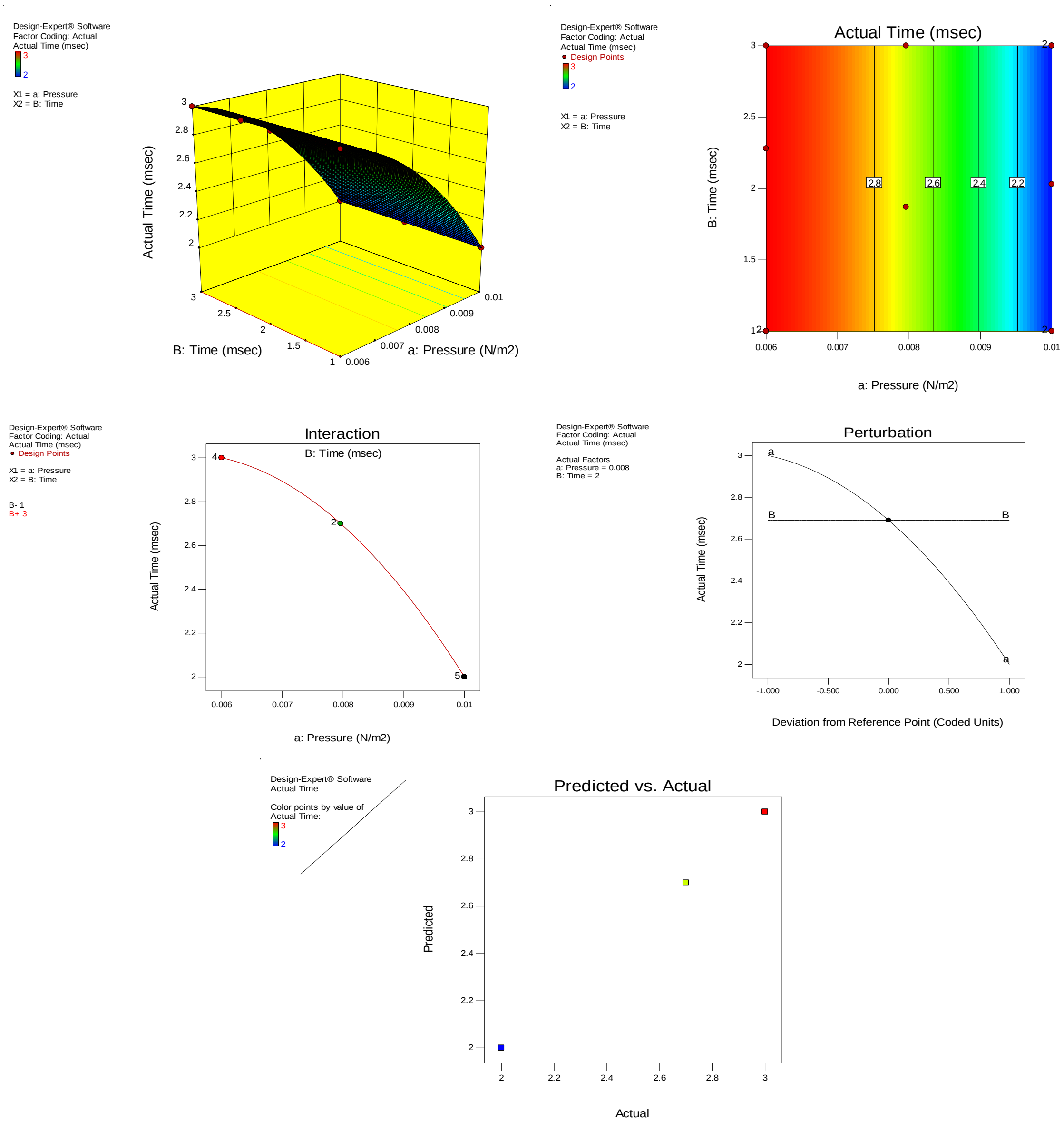

Figure 5. Input System

Table 1. Pressure and Time for Generation

Factor 1 A: Pressure N/m^2	Factor 2 B: Predicted Time msec	Response Actual Time msec
0.01	2	2
0.01	3	2
0.01	1	2
0.006	2.3	3
0.006	1	3
0.01	1	2
0.01	3	2
0.006	3	3
0.006	1	3
0.008	3	2.7
0.008	1.9	2.7

The above result shows the time of the actual response which lies between 2 to 2.7msec. The most precise value of time calculated comes out to be 2 msec.

4. Conclusion

The demand of green energy is increasing day by day so the electricity demand through non conventional energy sources is also increasing. Green energy is the demand of upcoming sector. The new method employed is of great interest for upcoming sectors. This energy is not only renewable but also it's a pollution free source of energy. The use of piezo-electric crystal requires less maintenance and gives better output in terms of clean electricity generation.

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