Analysis and study of variable load and impact on a circular PZT-5H piezo electric disc for variable power generation

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Abstract

This paper is an analysis and study report of variable effects of load and impact acting upon the PZT-5H piezo electric plate. Each step of variable power generation from variable load and impact acting upon the piezo electric plate is analyzed and recoded. Graphs would be shown in between Variable loads and voltage and Variable impact and voltage, to find out the relation in between load/impact and voltage. The input parameters would be changed to see if it helps to efficiently make a Piezo electric plate mechanism for a new type of non-renewable energy harvesting system.

Keyword: PZT-5H, Piezo Electric Plate, Variable Load, Variable Impact Force.

Introduction

These days most of the research in the energy field is to source energy for the future. With the ever increasing and demanding energy needs, unearthing and exploiting more and more energy sources has become a need of the day. With oil resources being over tapped and eventually bound to end, what better time to look for renewable energy sources. Energy harvesting has been a topic since three decades.

Finding a new non-Renewable light, weighted, less maintenance required energy source is become essential in our present time. As we have limited types of non-renewable sources

To full fill the growing demand of power we need an alternative non-renewable source of energy. In present the basic non-renewable energy sources are solar, wind, hydro, nuclear etc . we can use the source of energy which is wasted in our daily life like pressure ,load, vibration, impacts.

we can use the source of energy which is wasted in our daily life like pressure, load, vibration, impacts. Peoples walking on streets on an average walk around 1000-2000 steps per day, when peoples walk, they lose energy in the form of impact on the surface. The load and impact energy which peoples and vehicles puts on the surface can be harvested. In this study, we are proposing to generate energy from piezo electric materials. This solution is green and durable. Piezo-electricity is a phenomenon which is exhibited by certain materials in which charge accumulates near the surface when variable load and impact is applied.

Proposed Method:

Proposed method proposes the analysis and study of variable load and impact forces on the piezo plate to have a number of graphs between forces and voltages, to modify the design of piezo to bear persons weights and generate maximum power, without breaking. One of the main focus of this paper is also on finding the breaking point of the plate by applying variable forces upon it.

Experimental Methods For Analysis Of Piezo Electric Plates:

    a) Hardware Experiments Analysis Methods :

    1) Using Hardware equipment's for Electrical output characteristics:

    1.a) oscilloscope for output   wave   patterns, voltage and current by a given specific weight and force.

    1.b) Multimeter for digital voltage and   current output.

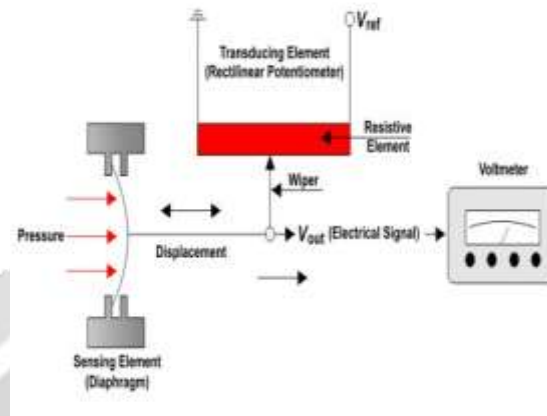**Block Diagram Of The Proposed Method:**

Figure 1: Measurement of power output   by variable pressure and forces
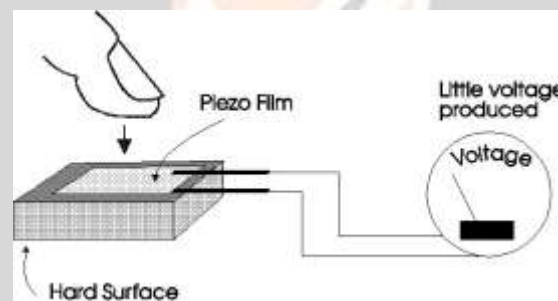

Figure 2 : Electric charge generation by Appling force from finger

Piezoelectric Energy Harvester (Power Supply):

Many researches have been given in to the material of piezoelectric and how it generates energy. The understanding behind the material is crucial to understand before jumping on to the conversion, to supply a device. The material itself generates power, the only way it generates power is when pressure is applied. The amount of power is proportion to the amount of pressure given. Another way to define piezoelectric is like a capacitor in itself or similar to a sponge that's full of water, once squished the water comes out.

When pressure is applied the chemicals inside the material create a reaction and therefore outputs energy. The power that it produces is in AC, again the amount of voltage and current is dependent on the amount of pressure applied. The material is very sensitive, it can either create energy by vibration or force applied to the material. The AC is not constant and therefore we would need to rely on the power conditioning in order to effectively supply a load, as many devices would need a constant flow of charge such that it will need to be in DC.

The reason for looking at the power supply of piezoelectric is because this is where my input parameters will take place. I have set 3 input parameters so that we can see the change. The first input of configuration would be the time at which we hit the material, the units which i would like to see is the number of seconds the system will hit the piezo. Second would be the force applied on the piezoelectric, the speed will affect the force but we are only considering a force of one impact. Third is the amount of deflection we will give on the element, as too much can break the material or too less can give low power. Changing the deflection would be alternating the

height from the surface to the system that hits the piezo. The reading which we will be recording would be in mm of how much the piezo bends.

Mathematical Analysis

$$force = Mass \times acceleration$$

From this main focal point my analysis of proportionality between force and power became to flourish. From the equation we would need the mass which we can easily weight, but calculating the acceleration would be near enough impossible unless we have an accelerometer to measure the acceleration. The reason why I didn't go in depth about this is because then we would need the change in velocity and change in time to make further progress in calculating the force.

In order to calculate the force it would be best to look at the conversion between Kg.f and newton's to reduce the time . Then when you have the units in newton's you can then divide the force by the area of force applied too. This will give us the pressure which is what we need for piezoelectric.

Piezoelectricity

Piezoelectricity could be a property exhibited by a definite material that also are emphasized as INTELLIGENT MATERIALS in several articles which regain their original form when the excitation is removed and also kind a vital category of TRANSDUCERS which rework one style of energy to different and since of this peculiarity, it's even used as an energy scavenger commutation the traditional generators and sources of energy. This technology is sort of scal- ready thanks to its torrential availableness in surroundings and conjointly considered the most cost effective energy supply. The specialty of this material is that it's a really sensible materialistic properties which can be mentioned very well during this chapter. Since it's terribly little in dimensions compared to its output, it's conjointly employed in MEMS technology that is currently trending thanks to its low insertion loss and high isolation on quick response (shorter switch spans) within the order of few microseconds competitory with the facility in physics technology. it's specied joined of the foremost efficient renewable sources of energy with an efficiency of thirty third. thanks to its outstanding response to vibrations, it's employed in acoustic guitars largely and conjointly in several different instruments.

Material Used

The piezoelectric effect through the spontaneous polarization of the dipoles happens thanks to spontaneous displacement of atoms below bound temperature that creates permanent dipole moments. The density of such dipole moments is understood as polarization. most of the electricity materials of current analysis are of per ovskite structure and are of the formula ABO_3 like power takeoff, BTO, BST and PZT. Here comes the demonstration of the perovskite structure of power takeoff material before transition temperature and then wherever the fabric undergoes shift in polygonal shape section leading to a non-Centro isosceles lattice and thence liable for the polarization.
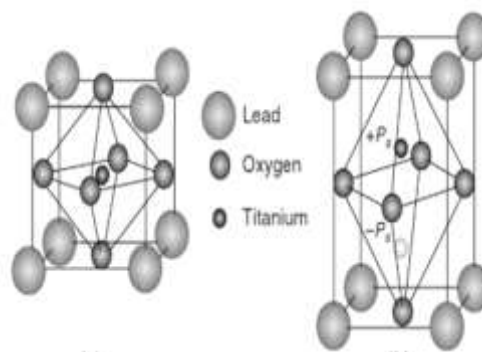

Figure 3: Lattice Structure

In general the axis of polarization may be several types. It may be either parallel to any unit edge, face diagonal or body diagonal as within the case of polygonal shape, orthorhombic and trigonal severally. The polarization is usually assisted by chemist strain or spontaneous strain, that is that the secondary parameter in piezo- electricity. This strain is really due the coupling of polarization vector with strain tensor through electrostriction. because of polarization usually the axis of polarization gets elongated and people perpendicular there to axis gets narrowed

therefore reworking from a lattice of high symmetry to that of low symmetry with reducing temperature as shown.

The transformation of piezoelectric material with polarization follows the Taylor Series expansion which can be represented as a free energy functional

$$\delta AL(P,T) = 0.5\alpha P^2 + 0.25\beta P^4 + 0.67\gamma P^6 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2.1)$$

Where α, β, γ are the materialistic coefficients of expansion out of which only is temperature dependent.

$$\alpha = (T - T_C)/\epsilon_0 C$$

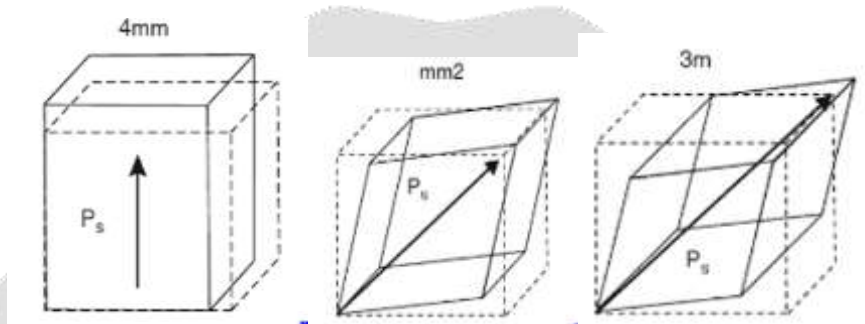where Tc and c are the curie temperature and constant respectively.

Figure 4. Transformation Of Crystal Due To Piezo-Electricity

Explanation

Direct piezo electricity is outlined because the tendency of a electricity material to get electromotive force across it's dimensions underneath abrupt changes in pressure input. it's associate intelligent material that responds to the deformations made thanks to the physical force. it's generally sculpturesque because the capacitance across the perimeters wherever it is heel stroke with relevance the virtual ground i.e., as a voltage supply. because it is mentioned within the historical summary, converse additionally exists which is common as in-direct piezo electricity within which the system takes alternating voltage as input and produces vibrations. the frequency of those vibrations depends on the input frequency. the simplestive advantage with this material although produces harmonics via direct electricity effect; it remains unaffected with the non-sinusoidal voltage within the converse effect. Hence, there's no heat generation not like typical devices owing to harmonics. Electricity materials additionally answer the thermal stress, that even accounts for the polarization of the fabric as seen earlier until Curie temperature and gets misshapen and loses its symmetry. however, the notable purpose regarding this material is that it responds less to converse result. therefore, it's sculpturesque because the network of a second capacitance in parallel to the terribly giant resistance in electrical domain. Here is that the picturing of the higher than effects.
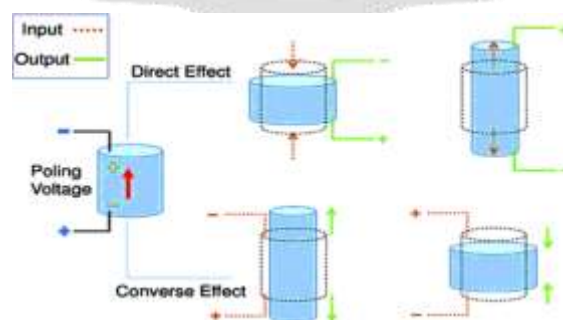

Figure 5. Piezoelectric Effect

Piezo Ceramics

Owing to the nuclear development within the recent years, oxides are in the market & within the markets at terribly high purity rates of ninety-nine. metallic element titanate that is treated because the prime electricity material is accessible within the powder type with a purity of ninety-eight. even the presence of impurities within the material diode to a similar ratio. Excess Ba within the material would cause a similar unsmooth microstructure and excess Ti in the fabric would lead to straightforward sintering method that successively ends up in crystalline matrix alignment of the material. The prime stuff of metallic element titanate is Sulphur that is answerable for the sick quality of the fabric and infrequently totally different burning processes are used within the refractory oven. Sulphur is answerable for the density and bloating. Now-a-days most of the makers of piezo ceramics are going for different oxides and carbonates rather than metallic element titanate. alternative of the inputs would decide the standard and performance. High grade zirconium oxide is yielded through the reaction of HfO_2 and ZrO_2 whereas metallic element titanate is obtained through the reaction of barium carbonate with mineral or anatase. Processes are developed that precipitates it from chloride, sulphate, nitrate associate in Nursingd pthalate solutions with an output purity of ninety-nine.7% yielding to the formation of lead zirconite with the prime contaminants of the fabric being metallic element and chemical element.

It is vital to understand what the impurities of the stuff are as a result of they decide the reactivity of fabric typically. The impurities could even be volatile therefore it'd be higher to understand their magnitudes. additionally the particle size plays a key role in determinant chemical stability equilibrium. therefore spectrographs are accustomed determine ion primarily based impurities and ignition loss is employed to work out ion based impurities and microscopes are used to determine particle size. It ought to be ensured that each one the constituents of the ceramic should be properly mixed and homogeneity should be maintained otherwise it leads to poor quality. There are several machines that perform this task and just in case of any improper combining, it will be resolved by oxidization to a tiny low extent. the fundamental purpose of oxidization is to get rid of any water presence within the material and any volatile impurities. additionally, to create a solution and to cut back volume shrinking at the time of ultimate ring.

Grinding could be a method to regulate the integrative variations of the fabric that resulted thanks to oxidization and improper commixture process. In general, grinding is allowed to a limit of one to ten micrometers. Coarser grinding could cause inhume granular voids and if its too fine, there are probabilities for mixture formation. additionally, it ought to be ensured that the machines that so ever will this job are subjected to light-weight wear otherwise they could confusion contaminants with the fabric. electricity materials are synthesized by precipitation of dissolved ions from solution either by wet precipitation or by ash heating the answer. Former is obtained by amendment in hydrogen ion concentration and ratio ought to be checked usually. The ash heating method ensures actual ratio however involves the usage of pricey liquids. Ceramic forming strategies just in case of piezo ceramics are: mud pressing, casting, centrifugal casting, isotactic pressing and extrusion. They involve binders and these mustn't be virtually organic which could either blow out or amendment the composition of ceramic material. Figure shows the multi-morph component by dipping threads. The composition of ceramic material. Figure shows the multi-morph component by dipping threads.

Losses In Piezo Ceramics Plates

Since piezo ceramics are hybrid materials, they are having losses revolving around three mechanisms: material because of the materialistic properties, physical property curve problems because of the fabric and piezo-electricity due to the electromotive force generated in a flash. These three losses together decide the standard issue of the fabric that successively decides dissipation rate of the system. Study of the loss mechanisms and loss reduction is very important for the look of high- potency devices and driving circuits, significantly for the cases of powerful transducers and devices for frequency choice. The magnitude of the vibration level within the high-octane usage is proscribed by heat generation in addition as a forceful modification in electricity properties, and it's restricted by temperature limit. The vibration level is diagrammatical by the effective vibration rate (v0), that could be a universal, pure mechanical parameter and is sometimes determined by the most vibration amplitude of the noble metal high at the resonance.

Piezo-Electricity Proved By Physical Laws

In physics, a stress on any elastic material causes proportional strain.

$$T = YS$$

Where T is that the stress exerted on the body and Y is its young's modulus and S is the proportional strain created. this can be known as direct piezo effect. Piezo-electricity is that the phenomena of creation of electrical charge with the strain given within the sort of capacitance. Since charge created is proportional to the force

exerted and because the force could be a vector, charge will be even negative reckoning on the force input. In terms of nonconductor displacement D (charge stored) will be outlined as

$$D = Q/A = dT$$

This is referred to as indirect piezoelectricity. a selected applied field of force E leads to equivalent strain S compression or growth counting on the polarity. The numerical constant d is same for direct and converse effects and may be calculated as

$$D = S/E = D/T$$

High d constant is needed for top vibrations and deformations and is employed in echo sounder and unhearable resonators. Another constant g is often used which supplies the electrical yield generated by the strain. Relation between g and d is given as

$$g = d/\epsilon = d/k\epsilon_0$$

High g constant is required high voltages to the mechanical stress applied as in phonograph pickup. Other constants are

$$T = -eE$$

$$E = -Hs$$

The actual definitions of these constants are:

$$g = -\left(\frac{\partial E}{\partial T}\right) D = \left(\frac{\partial S}{\partial D}\right)T$$

$$e = -\left(\frac{\partial T}{\partial E}\right) S = \left(\frac{\partial D}{\partial S}\right)E$$

$$h = -\left(\frac{\partial T}{\partial D}\right) S = \left(\frac{\partial E}{\partial S}\right)D$$

These constants disagree for an equivalent material from completely different axes attributable to its anisotropic nature. The simplest single mensuration to comment regarding the strength of piezoelectric effect is electro-mechanical coupling k. it determines the potency with that one variety of energy gets reworked to different type.

$$K^2 = \frac{OUTPUT\ ENERGY}{INPUT\ ENERGY}$$

K is 0.1 for quartz, 0.4 for Barium Titanate, 0.5-0.7 for PZT, 0.9 for Rochelle salt at its curie temperature. The piezoelectric equations in rectangular domain can be given as:

$$D = dT + \epsilon^T E$$

$$S = dE + s^E T$$

Material And Its Specifications

  Specification

•Resonance Frequency: 4.6Khz±0.5 Khz

•Resonance Impedance: 200 Ohms

•Capacitance: 20nF ± 30°% at 1 Khz

  Dimensions

•Piezo Plate Diameter: 27 mm

•Piezo Element Diameter: 19.7 mm

•Plate material: Brass

•Element thickness: 0.54 mm

•Plate Thickness: 0.3 mm

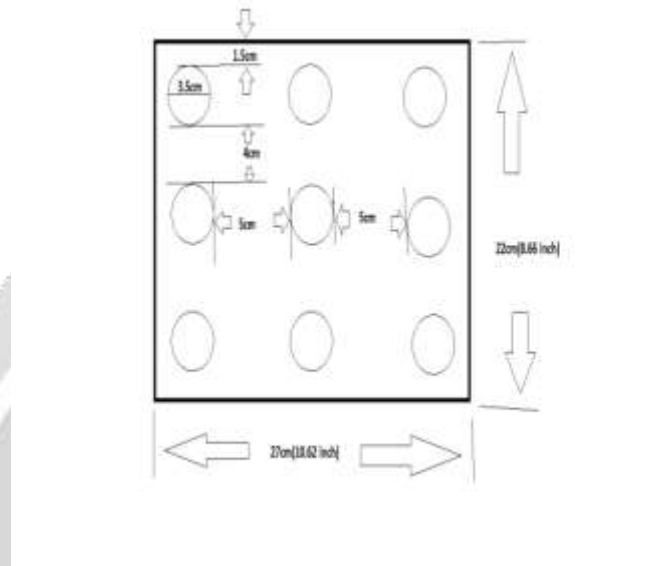**Result's & Discussion**

Base Dimensions Of PZT Plate :

Figure 6. Base Dimension

Piezoelectric sheet of 9 PZT-5H piezoelectric circular disk connected in parallel electrically to add up the current generating by multiple piezo disks at the same time. They are placed at certain distances apart from each other so that when foot pressure or any other pressure is applied on the pad it will distribute equally. On each piezo disk an small foam material is used so that it will absorb the heavy weight momentum to avoid breaking of piezo disk by direct contact of foot on disk surface(because the surface thickness of piezo disk is very thin)

In our thesis we will observe all the parameters and outputs of piezo disk, when we apply pressure on the disk pad.
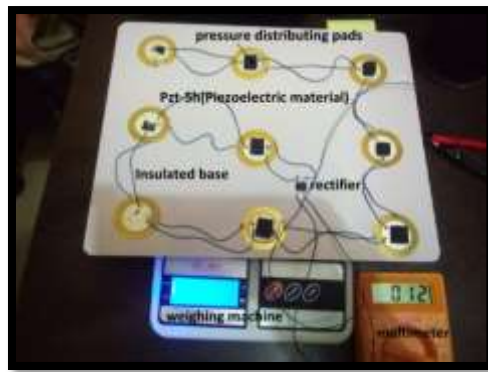
Figure 7. Pzt-5h Circular Piezo Disk Mounted On Insulated Wooden Sheet

Figure 8. Parts used with measuring   instruments

Figure 9. Parts used with measuring   instruments arrangement.

Methods used for data readings are as   follows: -

A) For Loads v/s Voltage

In order to determine the load on the pressure pad, weighing machine is used with voltmeter to read the load vs voltage output of the whole pressure pad. The outputs are in the graphs forms as
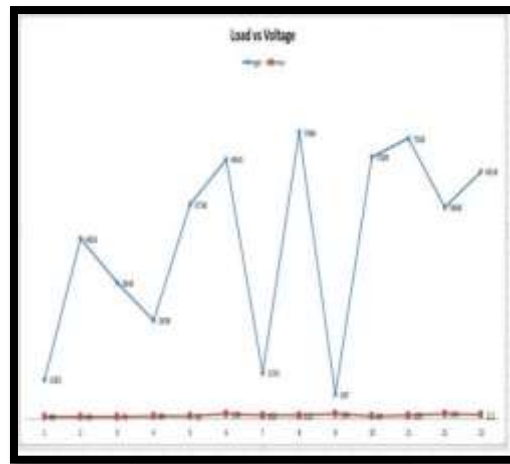
Figure 10. Load Vs Voltage Graph For Piezo Mounted Disk On Insulated Base.

Load v/s Voltage graph shows the output variable voltage when variable load applied on the piezo bed, as according to the load graph which is not linear, when maximum load under 10 kg is applied. For experimental output i.e., voltage which is random at random load this is due to the unequal distribution of load on each piezo disk.

Theoretically piezo disks will generate voltage according to the strike load force, which is linear in single disk case but in case of number of piezo disk on piezo bed, distribution of weight is an important aspect to generate approx. same voltage every time.

B) **For Timing Interval And Voltage Graph:**

To determine the time interval and voltage graph, Arduino based oscilloscope application is used to measure and time interval (frequency) and output voltage readings in the logged text form.

Foot load is applied on the pressure pad at different interval on different positions of the piezo bed, at every different interval different voltage spikes and generated due to unequal load distribution. Every time load is applied at different interval on different areas of piezo bed graphs shows different voltage spikes.
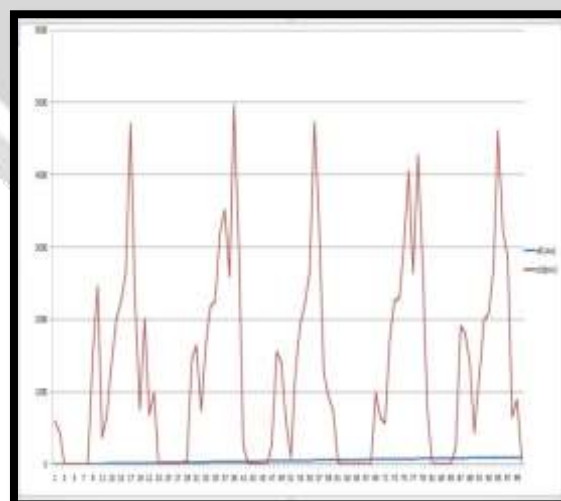

Figure 11. Time v/s Voltage graph

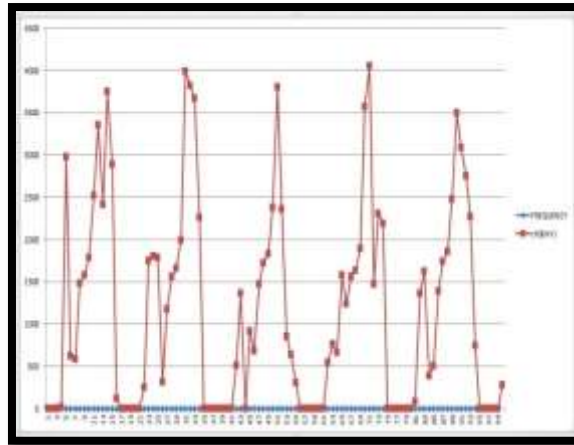C) **Graph Between Frequency and Voltage(mili volt)**

Figure 12. Frequency and Voltage graph for piezo mounted disk on insulated base

According to this graph more delay in frequency or load pressure time difference can also significantly change the output voltage, as delay in strike force of low frequency of load strike on piezo bed lowers the output voltage, if the frequency is moderate then maximum voltage is generated without the need of proper equal load distribution.

Scope And Applications

The rate of increase in population and new little physical science in market resulted in tremendous increase within the quantity of power demand which ought to be balance to keep up the availability and save the waste energy like human's potential and mechanical energy. The electricity energy has been wide in some countries like Brazil, Calif. etc. For generation of power by exploitation footsteps for instance to low street lights at midnight time, A 200-tile people-powered soccer pitch located within the "Morro First State Mineira favela", a underprivileged space in Brazil. because the youngsters run, their energy is hold on in batteries and used at required time. The electricity crystal/energy has been employed in medical sector, instruments etc. However, it's use has been restricted as a results of low potency and related to its price. The reversible time of battery is additionally additional thanks to its output however as per increment in power demand it ought to be possible and well economical. to extend its potency companies are progressing to use graphic symbol thanks to its superb property and corporations are operating to increase efficiency by exploitation hybrid composition of chemical materials. there's high scope of this technology in forthcoming future. Industrial applications of electricity energy has been used established like Engine Knock Sensors, Pressure Sensors, echo sounder instrumentality etc within the variety of sensors, These has been used like AN actuators conjointly. presently market is anticipated to grow due to increasing application in power generation by exploitation vehicles on road by implementing this technology.

Some firms and start-up like zero energy purpose and Pavegen already created these tiles and much they implement it to get power in Nagpur train station (India).

These devices are enforced by the East Japan Railway Company (un- der pedestrian terminus gates) and by Innowattech (under roads in Israel). Innowattech has publicized that these devices, if planted on a one-kilometer stretch of road, might give a median of four hundred kilowatt of power, enough to power 162 Western-U.S. homes.

13. Conclusion

From Load v/s Voltage:

As we can see that in load v/s voltage graphs at different loads voltages vary it may be high or may be low,

As according to my experiments on piezo base ,I have observed that according to the graph in time interval or every time I put pressure (load) on the piezo base voltage changes and every time I get different voltage readings. so according to experiments when pressure applied on different positions on the piezo base different voltage output comes. but as according to the graph the difference between the output output voltage is not very

high, so this pressure pad can generatemaximum5000mv(1000mv=1volt), means 5.0 Volt max (approx.) on every load strike, without breaking the piezo disks.

So as one single pad/base system can generate 5.0 Volt on heavy loads & ,my design of this piezoelectric base can withstand 90-150kg weight without breaking the disk.so in future a number of piezo bases can be arranged in parallel or bases can be used and connect with parallel to generate thousands of DC voltage which we can convert into A.C by inverters and use for the house hold and other applications as a best very cheap ,very low maintenance, renewable energy source for future use.

Future Prospects

The results showed that electricity is used as an alternate supply to get power to balance demand provide. The scope of this study was restricted however, with additional development in studies will enhance its potency to a bigger extent by varied the legitimate parameters. The potency is boosted by exploitation completely different composition of materials. the various results are seen with different inputs. Newer materials are being factory-made for improved potency. within the returning future, electricity can play a significant role. The potency of the projected model is improved by encasing the entire module and coating it with a fabric that may resist the strain applied like compound layers.

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