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ELECTRICITY GENERABLE TILES USING PIZEOELECTRIC TRANSDUCER

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ABSTRACT: In last few years low power electronic devices have been increased rapidly. The devices are used in a large number to comfort our daily lives. With the increase in energy consumption of these portable electronic devices, the concept of harvesting alternative renewable energy in human surroundings arise a new interest among us. In this project we try to develop a piezoelectric generator. That can produce energy from vibration and pressure available on some other term (like people walking). This project describes the use of piezoelectric materials in order to harvest energy from people walking vibration for generating and accumulating the energy. This concept is also applicable to some large vibration sources which can find from nature. This project also represents a footstep of piezoelectric energy harvesting model which is cost effective and easy to implement

I. INTRODUCTION

E-TILES means Electricity generable tiles, this tile has capability to produce electricity with help to foot step. This tile can be used in making of pathway, Gym and in any places that covered under human footstep. The basic objective would be to study the techniques of footstep generation and to successfully compare the methods that followed for each power generation used in conventional manner. Modeling of this system and interfacing the electrical hardware would be the prime importance. After designing, the obtained parameters and design values (results) will help to implement it on hardware. In the coming decades, the green energy potential of smart surfaces will be multiplied when they can draw from more than one kind of renewable energy at a time. An E TILE Floor that also housed a bendable solar panel could be 66% as efficient as a standard solar panel but could also continue generating electricity when the sun went down.

[A] piezoelectric sensor: -

A piezoelectric sensor is a device that uses the piezoelectric effect to measure pressure, acceleration, strain or force by converting them to an electrical signal. Piezoelectric sensors have proven to be versatile tools for the measurement of various processes. They are used for quality assurance, process control and for research and development in many different industries it was only in the 1950s that the piezoelectric effect started to be used for industrial sensing applications. Since then, this measuring principle has been increasingly used and can be regarded as a mature technology with an outstanding inherent reliability. It has been successfully used in various applications, such as in medical, aerospace, nuclear instrumentation, and as a pressure sensor in the touch pads of mobile phones. In the automotive industry, piezoelectric elements are used to monitor combustion when developing internal combustion engines. The sensors are either directly mounted into additional holes into the cylinder head or the spark/glow plug is equipped with a built in miniature piezoelectric sensor. The rise of piezoelectric technology is directly related to a set of inherent advantages. The high modulus of elasticity of many piezoelectric materials is comparable to that of many metals and goes up to 10e6 N/m^2Even though piezoelectric sensors are electromechanical systems that react to compression, the sensing elements show almost zero deflection. This is the reason why piezoelectric sensors are so rugged, have an extremely high natural frequency and an excellent linearity over a wide amplitude range. Additionally, piezoelectric technology is insensitive to electromagnetic fields and radiation, enabling measurements under harsh conditions. Some materials used (especially gallium phosphate or tourmaline) have an extreme stability even at high temperature, enabling sensors to have a working range of up to 1000°C. Tourmaline shows piezoelectricity in addition to the piezoelectric effect. This is the ability to generate an electrical signal when the temperature of the crystal changes. This effect is also common to piezo ceramic materials. One disadvantage of piezoelectric sensors is that they cannot be used for truly static measurements. A static force will result in a fixed amount of charges on the piezoelectric material. While working with conventional readout electronics, imperfect insulating materials, and reduction in internal sensor resistance will result in a constant loss of electrons, and yield a decreasing signal.

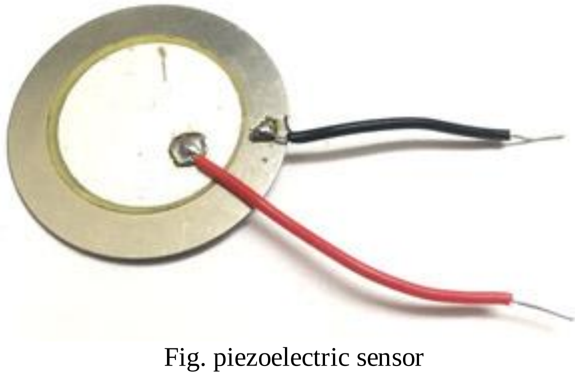


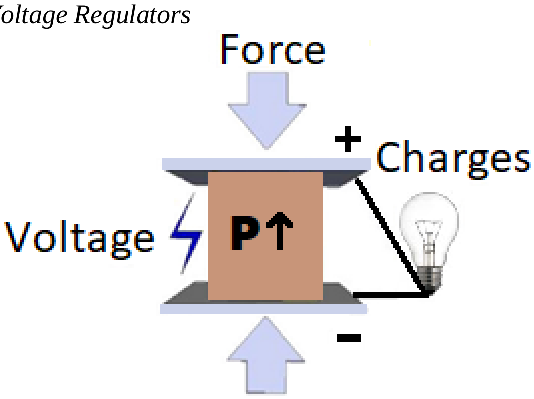
Fig. piezoelectric sensor

[B] Battery Connection

Lead-acid batteries are normally available in blocks of 2V, 6V or 12V. In most cases, to generate the necessary operating voltage, many batteries have to be connected together in parallel and/or in series.

[C] Rectifiers

[D] Voltage Regulators



Microcontroller

This project is used to generate voltage using footstep force. The proposed system works as a medium to generate power using force. This project is very useful in public places like bus stands, theaters, railway stations, shopping malls, etc. So, these systems are placed in public places where people walk and they have to travel on this system to get through the entrance or exist. Then, these systems may generate voltage on each and every step of a foot. For this purpose, piezoelectric sensor is used in order to measure force, pressure and acceleration by its change into electric signals. This system uses voltmeter for measuring output, led lights, weight measurement system and a battery for better demonstration of the system. whenever force is applied on piezoelectric sensor, then the force is converted into electrical energy. In that movement, the output voltage is stored in the battery.

The output voltage which is generated from the sensor is used to drive DC loads. Here we can use microcontroller to display the amount of battery get charged and average energy produced by one foot step.

II. LITERATURE REVIEW

Pierre and Jacques Curie brothers (1880), examined the piezoelectric effect on crystal materials, (quartz, Rochelle salt) which have the ability to produce electrical charges in response to externally applied forces. This effect they named as "Piezoelectricity", after the Greek word “piezein”, which means to squeeze or press. Lippmann (1881), deduced mathematically the converse piezoelectric effect from the fundamental thermodynamic principles. This phenomenon illustrates that the application of an electrical field creates a mechanical stress. Cady’s (1946), worked on development of piezoelectric devices. These developments led to numerous ceramic materials with better piezoelectric properties. The discovery of piezoelectricity in PZT in the late 1960’s increased the number of applications for industrial use. Hagood and Bent (1993), developed an alternative actuators to existing commercial actuator by combining the interdigitated electrodes (IDEs) with piezoceramics. The circular cross-section PZT fibers of the Active Fiber Composite (AFC) had very little contact area between the interdigitated electrodes and the fibers. Due to this the transfer of the electric field into the PZT fibers is inefficient and also the AFC operates at very high voltage. 8 Bent et al. (1994), developed the first generation of piezocomposite actuators. They are the remedy for the significant drawbacks of monolithic piezoceramics. Piezo Fiber Composite (PFC) combines piezoceramic materials and additional inactive components in a specific structure to form an overall actuator/sensor package. Adriaens et al. (2000), presented An electromechanical piezo model, based on physical principles. In this model, a first-order differential equation is adopted to describe the hysteresis effect, and a partial differential equation is used to describe the mechanical behavior. Wilkie et al. (2000), developed the Macro Fiber Composite (MFC) at NASA Langley Research Center. The MFC is a piezoelectric fiber composite which has the rectangular cross-section and unidirectional piezoceramic fibers embedded in the polymer matrix and uses the interdigitated electrode. Unlike the AFC, the rectangular PZT fiber of the MFC ensured the maximum contact area between the PZT fibers and the interdigitated electrodes.

FE FORMULATION WITH PIEZOELECTRIC COUPLING-

A REVIEW Allik and Hughes (1970), presented a finite element formulation which includes the piezoelectric and electroelastic effect. The dynamical matrix equation of electroelasticity was formulated by them to develop tetrahedral finite element. Macneal (1978), formulated a four-noded quadrilateral shell element, called QUAD4, which was based on isoparametric principles with modifications which relax excessive constraints. Naganarayana and Prathap (1989) reported on force and moment corrections for the warped four-node quadrilateral plane shell element. The element stiffnesses were generated for a ‘mean plane’ equidistant from the four nodes, and are corrected by introducing equilibrated forces and moments. Chandrashekhara and Agarwal (1993), presented a finite element formulation for modeling the behavior of laminated composites with integrated piezoelectric sensors and actuators. This model they validated for both continuous and segmented piezoelectric elements that can be either surface bonded or embedded in the laminated plate. Samanta et al. (1996), formulated a generalized finite element procedure for active vibration control of a laminated plate with 10 piezoelectric laminas. They derived an eight-noded shear deformable plate element. Also the vibration control was studied by them with a simple feedback control strategy. Varadan et al. (1996), Discussed the three dimensional finite element model to predict the effects of both active and passive damping of a vibrating structure. A cantilever structure made of viscoelastic core sandwiched between piezoelectric actuator and sensor was considered by them for the closed loop control analysis. They have showed that the hybrid concept introduces better damping than purely passive or active system. Chang et al.(1996), derived general finite element formulations for piezoelectric sensors and actuators by using the virtual work principle. The amplitude-frequency and the phase-frequency characteristics of the closed-loop system were studied by them. Chen et al. (1997), employed a plate finite element to model the structural system parameters and used a negative velocity feedback control law to demonstrate the active vibration control by piezoelectric actuators. Using state-space equations, damped frequencies and damping ratio were derived by them numerically. Han et al (1997) experimentally studied active vibration control of composite structures with a piezo-ceramic actuator and a piezo-film sensor using the classical laminated beam theory and Ritz method, an analytical model of the laminated composite beam with piezoelectric sensors and actuators. 11 Benjeddou et al. (1997), presented a finite element model for adaptive sandwich beams to deal with either extension or shear actuation mechanism. For both configurations, an electric field is applied through thickness of the piezoelectric layers. Saravanos (1997), developed mixed laminate theory for piezoelectric shells in curvilinear coordinates that combines singlelayer assumptions for the displacements. Mechanics for the analysis of laminated composite shells with piezoelectric actuators and sensors were presented. Baruch and Abramovich (1997), extended the formulation of Miller et al. (1995) to include the material and geometric variation. The piezoelectric actuator forces were represented as equivalent mechanical loads in the equations of motion in a generalised form so that the solution could be found using well-established approximate methods. Batra and Liang (1997) presented an analytical solution for the vibration control of a simply supported rectangular plate expanding displacement functions as Fourier series. Clinton et al. (1998), studied coupled structure-actuator-sensor interactions and developed both analytical and numerical models to realize the so called smart or adaptive structures. 12 Liu et al.(1999), presented a finite element formulation to model the dynamic as well as static response of laminated composite plates containing integrated piezoelectric sensors and actuators subjected to both mechanical and electrical loadings. The formulation was based on the classical laminated plate theory and Hamilton's principle. A four node non-conforming rectangular plate bending element was implemented by them for the analysis. The influence of stacking sequence and position of sensors/actuators on the response of the plate was evaluated. Dogan and Vaicaitis (1999) developed analytical model for active control of nonlinear flexural vibrations of cylindrical shells under random excitation. A velocity feedback control scheme was integrated into the governing equations of motion using discrete surface-bonded piezoelectric materials as collocated sensors/actuators. Benjeddou (2000), has conducted survey on the advances and trends in the formulations and applications of the finite element modeling of adaptive structural elements focusing on the development of adaptive piezoelectric finite elements. Azzouz et al. (2001), have developed a triangular piezoelectric shallow shell element for analyzing structures with MFC/AFC actuators and compared the performance of the MFC actuator with 13 that of the traditional PZT actuator. Developed element was used to investigate the effect of PZT fiber orientation on acoustic and structural vibration control of plate and shells. Wang et al.(2001), investigated the vibration control of smart piezoelectric composite plates and the effect of the stretching-bending coupling of the piezoelectric sensor/actuator pairs on the system stability of smart composite plates. Based on first-order shear theory and consistent methodology, a smart isoparametric finite element was formulated and the classical negative velocity feedback control method is adopted for the active vibration control analysis of smart composite plates with bonded or embedded distributed piezoelectric sensors and actuators. Balamurugan and Narayanan (2001), proposed the mechanics for the coupled analysis of piezolaminated plate and piezolaminated curvilinear shell structures and their vibration control performance. A plate/shell structure with thin PZT piezoceramic layers embedded on top and bottom surfaces to act as distributed sensor and actuator was considered. Chad Landis (2001), presented a new finite-element formulation for the solution of electromechanical boundary value problems. As opposed to the standard formulation that uses scalar electric potential as nodal variables, this new formulation implements a vector potential from which components of electric displacement are derived. 14 Bernadou and Christophe (2003), developed a two-dimensional modelization of piezoelectric thin shells the approximation of the second formulation by a conforming finite element method was analyzed. Singh et al. (2003), described Some efficient strategies for the active control of vibrations of a beam structure using piezoelectric materials. The control algorithms have been implemented for a cantilever beam model developed using finite element formulation. Lee and Yao (2003), experimentally studied the active vibration control of structures subject to external excitations using piezoelectric sensors and actuators. A simply supported plate and a curved panel were used as the structures in experiments. The Independent Modal Space Control (IMSC) approach was employed for the controller design. Raja et al. (2004), modeled a coupled piezoelectric field with an expansion strain in the numerical formulation to analyze piezohygrothermoelastic laminated plates and shells. Finite element actuator and sensor equations are derived using a nine-noded field consistent shallow shell element. Robaldo et al. (2006), presented finite element for the dynamic analysis of laminated plates embedding piezoelectric layers based on the principle of virtual displacements (PVD) and a unified formulation. 15 The full coupling between the electric and mechanical fields was considered. Numerical results have been given by them for the free- vibrations frequencies of simply supported plates embedding piezoelectric layers. Balamurugan and Narayanan (2008), presented formulation of a nine-noded piezolaminated degenerated shell finite element for modeling and analysis of multilayer composite general shell structures with bonded/embedded distributed piezoelectric sensors and actuators. Guennam and Luccioni (2009), developed a piezoelectric multilamina shell FE to model for thin walled structures with piezoelectric fiber composites polarized with interdigitated electrodes (PFCPIE). A new scheme for the interpolation of the electric field was presented. Ivelin V. Ivanov (2011), modelled Active Fibre Composites (AFC) by piezo-electric Finite Elements (FEs) and their effective properties are determined by FE analysis. Dynamic behaviour of a smart composite structure was simulated by them in Finite Element.

VIBRATION CONTROL USING MFC ACTUATOR

Balas (1978) and Meirovitch et al. (1983), were among the first to present the vibration control procedures for the large flexible structural systems. Aubrun (1980), presented the collocated or localized interconnection concept for structural vibration control with distributed actuators and sensors. Meirovitch (1983) proposed coupled control. A unique and globally optimal closed-form solution to the linear optimal control problem of the distributed structure was presented. Crawley & Luis (1987), presented the analytical and experimental development of piezoelectric actuators as an element of intelligent structure. Tzou (1987) proposed a distributed active piezoelectric damper and evaluated using analytical, experimental, and finite element techniques for active vibration control of flexible structures via converse piezoelectricity. Baz and Poh (1988), presented the utilization of piezoelectric actuators in controlling the structural vibrations of flexible beams. A Modified Independent Modal Space Control (MIMSC) method was presented for selecting the optimal location, control gains and excitation voltage of the piezoelectric actuators. Lammering (1991), focused on the finite element analysis of shell structures with piezoelectric layers bonded on the surface. A 17 finite element formulation taking the piezo-electric effect into account was given and a finite shell element was presented. Clark & Fuller (1991), have studied on panels, the vibration control and its effect on the reduction of sound radiation. Active structural acoustic control (ASAC) using conventional fine mass dampers and PZT activators are currently emerging as a popular solution for vibration induced noise control problems. Hwang & chul park (1993), presented FE formulation for vibration control of a laminated plate with piezoelectric sensors/actuators. Classical laminate theory with the induced strain actuation and Hamilton's principle are used to formulate the equations of motion. Tzou and Hollkamp (1994), proposed a scheme based on collocated spatially distributed actuators/sensors assembly to achieve independent control of natural modes of a structural system. The actuators/sensors were spatially shaped to capture the response and control of a particular mode of a laminated cantilever beam. Miller et al. (1995), developed a selective modal control strategy based on Lyapunov's second method for piezolaminated anisotropic thin shells. The proposed scheme was used to demonstrate simultaneous sensing and actuation of a particular mode with arbitrarily chosen modal participation factors. 18 Baz and Poh (1996), proposed an active control scheme based on Independent Modal Space Control (IMSC) for a flexible beam with optimally placed piezoelectric actuators. Yang and bian (1996), experimentally demonstrated that, without sacrificing the structural advantages, the piezoelectric element embedded in composite laminated structures can be applied both as the in situ vibration sensor and as the vibration suppression actuator. Del Rosario et al. (1998), reported a study on vibration control of thin shells with piezoelectric layers. The shell governing equations were derived based on Donnell-Mushtari theory. Closed form solutions of the shell dynamics and controls were presented using Galerkin expansion and LQR based control strategy. Jung Woo Sohn et al. studied active vibration control of smart hull structure using piezoelectric composite actuators. Kim et al. (2000), designed distributed sensor and actuator for the active vibration control of shell structure. To prevent the adverse effect of spillover, distributed modal sensor/actuator system was established by optimizing the electrode pattern and the lamination angle of polyvinylidene fluoride (PVDF). Bevan (2001), has proposed a modified GA based optimal placement scheme for MFC actuator using LQR control strategy. 19 Further he has examined the performance of the MFC actuator in vibration and acoustic control of carved and flat panels. Jha and Inman (2003), modeled the dynamics of a lightweight, inflatable shell structure commonly used in telecommunications satellites and other space-based structures and also experimentally investigated the suitability of using the MFC for structural vibration applications. Williams et al. (2004), investigated the mechanical properties of the MFC using the classical lamination theory. Nonlinear mechanical behaviors of the MFC were studied by the experiment, and the linear mechanical properties of the MFC were compared with the result of the analytical method. In addition, Williams measured the nonlinear actuation properties of the MFC under various loads. There are also some researches for the application of the MFC to the structure. Ruggerio et al. (2004), used several MFCs as both actuators and sensors to measure the dynamic behavior of the inflatable satellite structure and to control its vibration. The flexibility of the MFC made for convenient attachment to the doubly-curved surface, and it was found that MFC outperformed the other actuators. Schultz and Hyer (2006), used the flexibility and high force output of the MFC to snap-through an unsymmetric composite laminate from one stable configuration to the other. 20 Kovalovs et al. (2007), demonstrated experimentally the application of MFC actuators in vibration control of aluminum beam and metal music plate. The MFC'S are used, one as an exciter and other as an actuator. ANSYS was used to model the structures with thermal analogy for including the piezoelectric actuation. Ro et al. (2007), adopted a LQR based feedback control strategy using MFC actuators to suppress the flexural vibration of cycle handle bar to establish the natural frequencies and mode shapes. Shon and Choi (2008), used GA to optimally place MFC actuators on cylindrical aluminum shell and conducted active vibration control experiments. A Lagrangion based theoretical formulation was made by them to capture the dynamics of the shell including the electro-mechanical couplings of MFC actuators. Kwak et al. (2009), performed theoretical and experimental investigations on aluminum cylindrical shell vibration control using the MFC actuators. The theoretical model was developed by them using Rayleigh Ritz approximation and the strain displace relations are established based on Donnel-Mushtari theory. First three modes of the cylinder are successfully controlled by a positive position feedback, implemented in DS1104. Rolf

Paradies and Paolo Ciresa (2009), implemented Piezoelectric macro fiber composites (MFCs) actuators into an active composite 21 wing. Dynamic tests were also performed by them on a sandwich wing of the same size with conventional aileron control for comparison. Eliza Munteanu and Ioan Ursu (2010), obtained control law LQG/LTR (Linear Quadratic Gaussian/ Loop Transfer Recovery).The robustness characteristics of the optimal control LQR (Linear Quadratic Regulator) are recovered by the Kalman filter applying a special construction for the estimator. Alibeigloo and Kani (2010), studied vibration problem of multilayered shells with embedded piezoelectric layers. An approach combining the state space method and the differential quadrature method (DQM) was used for shell vibration control

BUCKLING AND SHAPE CONTROL OF COMPOSITE CYLINDRICAL SHELL PANELS

Sobels et al. (1976), studied buckling of cylindrical panels under axial compression. The effect of boundary conditions and panel width on the axially compressive buckling behavior of un-stiffened, isotropic, circular cylindrical panels was investigated. Becker et al. (1982), conducted experimental investigation on the instability of composite cylindrical panels. A detailed description of test methods and analytical procedures used to evaluate the buckling of composite curved panels are presented. Zhang and Matthews (1983), studied Initial buckling of curved panels of generally layered composite materials. An initial buckling analysis for cylindrically curved panels made of generally layered composite materials was presented. The influence of curvature, fibre angles, stacking sequence and panel aspect ratios on buckling was investigated. Reddy (1984), reported on exact solutions of moderately thick laminated shells. Static and dynamic behavior of shell was captured. An extension of the Sanders shell theory for doubly curved shells to a shear deformation theory of laminated shells was presented. 23 Jun and Hong (1988), presented formulation of the geometrically nonlinear finite element procedure based on an updated Lagrangian on the buckling behavior of laminated composite cylindrical panels under axial compression. Sheinmany et al. (1992), developed PBCOMP program for buckling and post buckling of stiffened laminated curved panels. The program was based on the von Karman kinematic approach and uses the eigen functions of an isotropic beam in the longitudinal direction and finite differences in the lateral direction. Sai Ram et al. (1992), studied hygrothermal effects on the buckling of laminated composite Plates. The effects of moisture and temperature on the static instability of laminated composite plates are investigated. Geie and Singh (1997), studied some simple solutions for buckling loads of thin and moderately thick cylindrical shells and panels of laminated composite material. Mandal et.al. (2000), conducted experiments on the buckling of thin cylindrical shells under axial compression. Simple experiments such as self-weight buckling of thin, open-top, fixed-base, small-scale silicone rubber cylindrical shells are presented. 24 Girsh, and Ramachandra (2008), studied the stability and vibration behavior of composite cylindrical shell panels under axial compression and secondary loads. The influence of initial geometric imperfection, temperature field, and lateral pressure loads, and mechanical edge loads on the static response and vibration behavior of the shell panel. Himayat Ullah (2009), reported on buckling of thin-walled cylindrical shells under axial compression. He concluded that the effects of non-Linearity and geometric imperfections are responsible for the mismatch between theoretical and experimental results. Raja et al.(2011) studied the use of surface bonded and embedded piezoelectric composite actuators through a numerical study by applying the isoparametric finite element approach to idealize extension-bending and shear-bending couplings due to piezoelectric actuations for deflection and vibration control of laminated plates.

III. CONCLUSION

Electricity-generating Tile flooring is a key component of smart city concepts. Surveys says that (survey reference: -Google) a dozen tiles could power a street lamp for a whole night. By strategically placing kinetic tiles in key areas of a city, we would have on-demand lighting, mobile phone charging stations at bus stops and interactive displays powered by foot traffic alone which would also make them energy efficient. When it comes to city likes Delhi let us calculate for an area just 250 m2 .

Area covered	250 square meters
Average Footfall	35,000 people
Around 70% of the people step on our Tiles	
Effective Footfall	24,500 People
An average person walks 250 steps in an area of 250 Sq. m.	
Total steps	24500*250 = 6125000 steps
One step generates	$2.73*10^{-3}$ W
Total energy	$6125000*2.73*10^{-3}$= 16721.25 W
Power Produced (when used upto10 hours)	16721.25*10 = 167.212 kwh
Efficiency of Tiles	70%
Output Power	117.048kwh

Power generated (For an area 250 m^2)

Cost of Electricity per unit	Rs.8
Cost of Electricity produced by E Tile	117.048*8 =Rs 936.39
Electricity saved in one Day	Rs 936.39
Electricity saved in one Month	Rs 936.6*30= Rs 28,091
Electricity saved in one Year	28,098*12= Rs 3,37,092
Electricity saved in Five Year	3,37,176*5 = Rs 16,85,460

Money saved (for an area just 250m^2)

Adopting this technology would save Approximate Rs 16,85,460 in Five year and also prevent huge amount of CO2 (approximate 244 ton of co2) entering the atmosphere.

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