[Patel, 3(11): November, 2014]

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

A Review on Optimization of Piezoelectric Power Generation in Taper Cantilever Beam at Different Tip Mass Position

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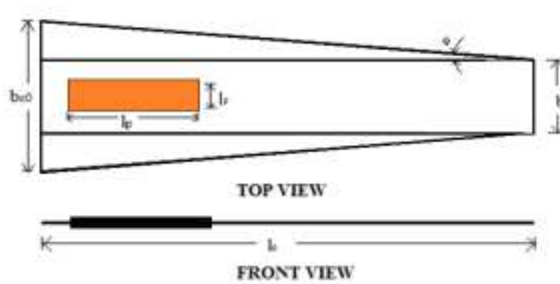
Abstracts
Energy supply from piezoelectric material using environmental vibrations is very attractive because they possess more mechanical energy for conversion into electrical energy and can withstand large amount of strain also. Such vibration energy harvester extracts maximum energy from environment when natural frequency of taper beam matches with natural frequency of environment. This paper presents a review on power generation in taper cantilever beam at different tip mass position. In this paper we reviewed the work carried out by researchers on piezoelectric power generation.

Keywords: Mechanical Vibration, Tip mass, Resonance, Power Output, Frequency.

Introduction
Energy harvesting or the process of acquiring energy from the surrounding environment has been a continuous human and endeavor throughout history. Need of energy harvesting due to growing need for renewable energy source. It also reduces dependency on battery power and increases popularity of wireless network as it suitable for remote devices.

Piezoelectric cantilever beam energy harvesters are commonly used to convert ambient vibration into electrical energy. When pressure (stress) is applied on piezoelectric materials it creates a strain or deformation in the material and strain in the material creates electrical potential difference, a voltage. The effect is reversible, when an electrical potential is applied across two sides of a piezoelectric material, it strains. The piezoelectric effect is found in materials with a specific electrical crystalline structure. Some piezoelectric materials are Berlinite ($AlPO_4$), Cane sugar, Quartz, Rochelle salt, Barium titanate ($BaTiO_3$) Leadtitanate ($PbTiO_3$)Lead zirconate titanate (PZT) Potassium niobate (KNbO3) Lithium niobate (LiNbO3) Lithitantalate (LiTaO3) Sodium tungstate (NaxWO3)And poly vinyledene fluoride (PVDF) etc.



Many methods have been reported to improve the harvested power of micro-generators. Some methods are selecting a proper coupling mode of operation and by changing the device configuration. This is accomplished by adding multiple pieces of piezoelectric material to the harvester. Harvesting efficiency can be increased by reducing beam thickness and attaching proof mass at the tip of the beam, Due to the less thickness and proof mass fundamental frequency of beam decreases. In the process of energy harvesting from environmental vibration shape of beam has great influence. Many researchers have showed that the triangular shaped cantilever beam with a small free end can withstand higher strains and allows more deflection resulting in higher power output.

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Literature review

[1] DEEPAK KUMAR CHAKARBORTY (2014) proposed the comparison between analytical and experimental studies of a taper cantilever piezoelectric beam with one input base excitation. This has demonstration the design, fabrication and measurement of piezoelectric taper cantilever with quite low resonant frequency for the energy harvesting application. The output voltage of different taper angle of beam is measured and discussed. The resonant frequency increases as the taper angle increase. Obtained the maximum voltage output at taper angle 1.6365 for the respective taper beam. It is found that the maximum power output of beam is at the taper angle 1.6365.The results obtained offer a possible for practical application in low frequency situation. Moreover the geometry is very easy to manufacture. Optimizing the dimension of the beam is expected to further increase power.

[2]YADRAM SINGH (2014)proposed that for uniform cantilever beam power transfer depends on piezoelectric material properties and other matching operating conditions. Increasing tip mass decreases the resonant frequency and Output power increases. After certain limit; increasing tip mass decreases the power output due to the increasing of the damping effect. The position of tip mass has a great effect on the effective mass of the harvesting cantilever and also its resonant frequency. The position of the tip mass has the great effect on the power output and resonant frequency .the tip mass position change from the free end of the cantilever beam ,the power output increase and resonant frequency decrease after certain limit power output decrease and resonant frequency increase due to damping effect. The value of the resistive load is increase of internal impedance of the PZT material then the Maximum power transfer occurs when harvester's internal impedance matches the resistive load.

[3] Lei GU(2010) they presented a low- frequency piezoelectric energy harvester based on impact vibration assembled with a compliant driving beam and two rigid generating beam. The advantage of this is to increase power density of harvester. This operate at low frequency around 1-30 Hz.

[4] Huicong Liu, Chengkuo Lee, Takeshi Kobayashi, Cho Jui Tay, Chenggen Quan (2012) they proposed a FUC cantilever stopper for converting random and low-frequency external vibration to self-oscillation of a FUC stopper at high resonant frequency. This is broadens the frequency range and increases the output voltage and power.

[5] Huicong Liu, Chengkuo Lee, Takeshi Kobayashi, Cho Jui Tay and Chenggen Quan They have analytically and experimentally investigated the wideband frequency response of a PEH system with stoppers on one side and two sides. The key parameters for the frequency response, including base accelerations, damping ratios, frequency characteristics and stopper distances, have been studied based on their mathematical model.

[6] Huicong Liu, Cho Jui Tay, Chenggen Quan, TakeshiKobayashi, and Chengkuo Lee They have investigated energy harvesting from the aspects Of widening the operating frequency range and frequency up-conversion. The unique impact mechanism including scrape-through and release between the two piezoelectric cantilevers is presented.

[7] Lokesh Dhakara, Huicong Liu, F.E.H. Tay, Chengkuo Lee. (2013) they have made the polymer piezoelectric bimorph beam (made of polyethylene terephthalate) which they called soft spring that is mechanically connected to longitudinal direction.

[8] Huicong Liu , Chengkuo Lee ,Takeshi Kobayashi , Cho Jui Tay , Chenggen Quan(2012) In this paper, a new S-shaped piezoelectric PZT canti-lever was successfully micro fabricated with small device size and extremely low resonant frequency. An S-shaped PZT cantilever is designed for achieving an extremely low resonance of 27.4 Hz. It would be more applicable to ambient vibrations at low frequency and low accelerations.

[9] Wahied G. Ali, Sutrisno W. Ibrahim (2012) they find the necessary conditions to enhance the extracted AC electrical power from vibrations energy using piezoelectric materials. The effect of tip masses and their mounting positions are investigated to enhance the system performance. The optimal resistive load is estimated to maximize the power output.

[10]Kuok H. Mak, Stewart McWilliam n, Atanas A. Popov, Colin H.J. Fox(2011) A theoretical model has been developed to analyses the performance of a piezoelectric cantilever energy harvester impacting a bump stop. The model estimates the contact force and predicts the dynamical and electrical responses of the harvester. Experiments have been carried out to validate the theoretical model of a piezoelectric energy harvester with and without the bump stop.

[11]M.N. Fakhzan, Asan G.A.Muthalif (2012) investigated the voltage production of piezoelectric cantilever beam when subjected to base excitation, with and without attached proof masses. The beam is modeled using Euler–Bernoulli, also known as thin beam theory. As such, the model obtained here is applicable for micro- and Nano-beams. The frequency response function (FRF) that relates the output voltage and transverse acceleration is identified for multi- mode vibration. These analytical predictions are then compared with experimental results and good agreement is obtained

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[12]Huicong Liu, Cho Jui Tay et al (2011) proposed a piezoelectric MEMS energy harvester (EH) with low resonant frequency and wide operation bandwidth was designed, micro fabricated, and characterized. The MEMS piezoelectric energy harvesting cantilever consists of a silicon beam integrated with piezoelectric thin film (PZT) elements parallel arranged on top and a silicon proof mass resulting in a low resonant frequency of 36 Hz. The whole chip was assembled onto a metal carrier with a limited spacer such that the operation frequency bandwidth can be widened to 17 Hz at the input acceleration of 1.0 g during frequency up-sweep. Load voltage and power generation for different numbers of PZT elements in series and in parallel connections were compared and discussed based on experimental and simulation results. Moreover, the EH device has a wideband and steadily increased power generation from 19.4 nW to 51.3 nW within the operation frequency bandwidth ranging from 30 Hz to 47 Hz at 1.0 g. Based on theoretical estimation, a potential output power of 0.53 μW could be harvested from low and irregular frequency vibrations by adjusting the PZT pattern and spacer thickness to achieve an optimal design.

[13]Bin Yang, Chengkuo Lee (2009) investigated a novel non-resonant energy harvester with wide band frequency is proposed for collecting energy from ambient vibration at low frequency. A free-standing magnet is packaged inside a sealed hole which is created by stacking 5 pieces of printed circuit board (PCB) substrate sn with multi-layer copper coils made on double-sides. When the energy harvester is shook from 10 to 300 Hz at 1.9g acceleration along longitudinal direction of hole, a 65 Hz flat-band-like output voltage of 4.5 mV at the case of only one side with drilled air holes on acrylic plate is generated within 35 to 100 Hz. The output power from the coils is measured as 0.1μW under matched loading resistance of 50 Ω within this flat band range under 1.9 g ambient vibration.

[14] Andrew Townley (2009) proposed utilizes AlN due to its ease in processing and potential for on- chip integration. By operating at a MEMS scale, the benefit is that arrays of piezo generators can be placed on the same die. With the process advantages of AlN, a long term goal of an integrated power-harvesting chip becomes feasible. Theoretical results of scaling predict that raw power output and even power per unit volume will decrease with scaling.

[15] Jae-yun Lee, Sanghwan Kim et al (2009) investigated optimal environments and specimens for an energy harvesting system using resonator. An important thing is the correlation of the resonant frequency of diaphragm and piezoelectric elements in experiments. Experimental results indicate a maximum peak to peak voltage of 46.2V and power of 1.84μW. Based on the experimental results, when piezoelectric materials (PVDF) are arranged regularly and resonant frequencies of a diaphragm and piezoelectric materials correspond to driving energy source, it will be expected to improve the efficiency.

[16] Huicong Liu, Chengkuo Lee, Takeshi Kobayashi.et al.(2012) This paper investigated the design, micro fabrication, modeling and characterization of a piezoelectric energy harvester (PEH) system with a wide operating bandwidth introduced by mechanical stoppers. The wideband frequency responses of the PEH system with stoppers on one side and two sides are investigated thoroughly. The experimental results show that the operating bandwidth is broadened to 18 Hz (30–48 Hz) and the corresponding optimal power ranges from 34 to 100 nW at the base acceleration of 0:6g and under top- and bottom-stopper distances of 0.75 mm and 1.1 mm, respectively. By adjusting the mechanical stopper distance, the output power and frequency bandwidth can be optimized.

Conclusions

It is showed in various previous year papers that efficiency of harvesting power depend upon design of beam. Shape, material. The most important power generated by piezoelectric harvester is a function of resonance frequency of system and how frequently resonance frequency occours.it is found in literature that natural frequency of beam reduces as beam width ratio increases and a proof mass is attached at the tip of the beam. It is found that for heavier proof mass, the value of natural frequency decreases and the difference between its subsequent natural frequencies is smaller.

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