An Overview of Disarray of cantilever beam bonded with piezoelectric material for energy harvesting application Subjected to single degree of freedom system

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ABSTRACT

Abstrac this paper presents an overview of vibration based energy harvesters. The maximum harvesting can be obtained from the cantilever beam as many researchers done work on that in that I found one of research paper of Hong-yan WANG. He found out that we can obtain the maximum energy when cantilever beam subjected to additional SDOF system. The additional SDOF system is used to magnify the vibrations. The effects of the structural parameters of the SDOF elastic system on the electromechanical outputs of the energy harvester are analyzed numerically. The accuracy of the output performance in the numerical solution is identified from the finite element method (FEM). A good agreement is found between the numerical results and FEM results. The results show that the power output can be increased and the frequency bandwidth can be improved when the SDOF elastic system has a larger lumped mass and a smaller damping ratio. So by taking those parameters into considerations my study is going to carry out.
Keywords: piezoelectric material, SDOF, vibrational energy.

1. INTRODUCTION

The piezoelectric effect is a reversible process. In this the internal generation of electrical charge is resulting from an applied mechanical force and the reverse piezoelectric effect is that internal generation of a mechanical strain resulting from an applied electrical field. It not only fulfills the growing needs of renewable sources of energy but also propose several potentially inexpensive and highly effective solutions. Because of their electromechanical coupling characteristics, piezoelectric material can be used for vibration control, but the capability of transferring energy from the mechanical to the electrical domain can be exploited to store vibrational kinetic energy into circuitry elements or batteries. Piezoelectric material reduces the complexity of wiring. Today there is increasing popularity of wireless networking, piezoelectric material fulfill the demands of wireless networking and as it is charged without electricity. It is eco-friendly and it reduces the negative impact on environment. The research interest in converting ambient vibration energy to usable electrical energy has increased in the last years [1–5]. The concept of energy harvesting is particularly useful for wireless sensors powered by batteries and remotely operated systems with limited energy source. The goal of the research in vibration-based energy harvesting is to provide electrical energy for such systems by utilizing the vibrations available in their environment.

2. STUDY OF DIRECT PIEZOELECTRIC EFFECT WHEN AN EXTERNAL LOAD IS APPLIED AT THE FREE END OF A PIEZOELECTRIC COMPOSITE BEAM.

D. P. D'Souza used the COMSOL Multiphysics finite element package to study the direct piezoelectric effect when an external load is applied at the free end of a piezoelectric composite beam. He studied the primary output parameters such as electric potential and electric field as a function of the input strain and stress. He done the modeling for the relatively new single crystal lead magnesium niobate-lead titanate (PMN32) and three different lead zirconate titanate ceramics (PZT-5A, PZT-5H, and PZT-4). Material performance was assessed by using a common geometry and identical excitation conditions for the different piezoelectric materials. He carried out three analyses namely, static, Eigen frequency, and transient/time-dependent analysis for each material [1].

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3. VIBRATION ENERGY HARVESTER COMBINING A PIEZOELECTRIC CANTILEVER AND A SINGLE DEGREE OF FREEDOM (SDOF) ELASTIC SYSTEM.

Hong-yan WANG, Xiao-biao SHAN and Tao XIE in year 2012 studied a piezoelectric material combined with cantilever beam subjected to SDOF. The main function of the additional SDOF elastic system is to magnify vibration displacement of the piezoelectric cantilever to improve the power output. He developed a mathematical model of the energy harvester based on Hamilton's principle and Rayleigh-Ritz method. Furthermore, the effects of the structural parameters of the SDOF elastic system on the electromechanical outputs of the energy harvester are analyzed numerically. The accuracy of the output performance in the Numerical solution is identified from the finite element method (FEM). The following conclusions are drawn. The additional SDOF elastic system increase the power output of the piezoelectric cantilever and improve the frequency bandwidth when the mass ratio of the piezoelectric cantilever to the lumped mass of SDOF elastic system is below 0.105. A larger damping ratio seriously weakens the function of the SDOF elastic system as a displacement magnifier and decreases the power output. Hence, a proper damping ratio for the additional SDOF elastic system should be determined to improve the power output of the piezoelectric cantilever [2].

4. AN ELECTROMECHANICAL FINITE ELEMENT MODEL FOR PIEZOELECTRIC ENERGY HARVESTER PLATES

Carlos De Marquis verified the predictions of the FE model against the analytical solution for a unimorph cantilever and then against the experimental and analytical results of bimorph cantilever with a tip mass reported in the literature. Finally, an optimization problem is solved where the aluminum wing span of an unmanned air vehicle (UAV) is modified to obtain a generator spar by embedding piezo ceramics for the maximum electrical power without exceeding a prescribed mass addition limit [3].

5. IV MODELING DYNAMIC OF COMPOSITE PLATE WITH PZT PATCHES EMBEDDED BY USING FEMLAB3.1

Jiyuan Wang considers composite thin plate excited by PZT actuators in this work. To describe the dynamic response of the quadrate plate clamped at its boundaries, commercial package FEMLAB3.1 is used to build and simulate a mathematical model. The model is a set of nonlinear partial differential equations (PDEs) with spatial discontinuous coefficients, which is developed on the basis of the Kirchhoff–Love plate theory, Von-Karman nonlinear strain-displacement relationship, and the macroscopic and quasi-static piezoelectric polarization. The result comparisons between the numerical simulation of FEMLAB model and one existing tested model are carried out. The comparisons demonstrate that the model made by FEMLAB3.1 is right and can flexibly be used in the dynamic simulation of such MEMS structure; the composite plate with PZT patches embedded [4].

6. VIBRATION ENERGY HARVESTING USING MACRO-FIBER COMPOSITES

Yaowen Yang developed a finite element model for the system and verified with the experimental results, showing its capability for accurate evaluation of the voltage output from the MFC harvesters. Subsequently, the procedure of energy extraction and storing to the capacitor in the EH300A is simulated by using the electronic design automation (EDA) software. By combining the FEM and EDA simulations, parametric analysis is conducted to optimize the energy harvesting performance of the system. It is found that, with the MFC stack configuration with two layers and the beam dimensions of 250 mm × 62 mm × 1.5 mm, energy extraction from the MFC harvesters can be optimized. The optimized power of 151.6 µW is achieved when the beam vibrates at the first natural frequency. It is demonstrated that the combined FEM and EDA simulations are useful tools for evaluating and optimizing the efficiency of MFC-based energy harvesting systems, which are also applicable to other piezoelectric material-based systems [5].

7. A CONTRIBUTION ON THE OPTIMAL DESIGN OF A VIBRATING CANTILEVER IN A POWER HARVESTING APPLICATION – OPTIMIZATION OF PIEZOELECTRIC LAYER DISTRIBUTIONS IN COMBINATION WITH ADVANCED HARVESTING CIRCUITS

Juergen Schoeftnera contribution was to point out the influence of several spatial distributions of piezoelectric patches and three different kinds of interface circuits, a standard interface circuit with full-wave rectifier bridge and filter capacitor, a SSHI-circuit and a ''synchronous charge extraction''-technique circuit, for a vibrating cantilever used for power harvesting. After giving a brief summary for the derivation of the differential equation of a laminated, passive, piezoelectric beam within the framework of an extended Bernoulli–Euler theory, the working principles and the equations of three different types of interface circuits are presented. In the case study, where a laminated cantilever is investigated, the governing equations of motion are validated by means of three-dimensional coupled finite element

results with ANSYS, where Eigen frequencies and frequency responses for the tip displacement and the voltage drop across the piezoelectric transducer are compared. Finally, the transient responses of an oscillating cantilever with various, spatially piecewise constant distributions for the piezoelectric transducers, whose electrodes are attached to non-linear electric circuits, have been calculated. It is found out that the beam configuration with the piezoelectric elements distributed according to a quadratic function and with the SCE-interface circuit is most efficient (i.e. the dissipated energy is maximal) and approximately 10 times higher than the energy consumed by the beam with a constant layer distribution and a standard interface circuit [6].

8. A ROTATION ENERGY HARVESTER EMPLOYING CANTILEVER BEAM AND MAGNETOSTRICTIVE/PIEZOELECTRIC LAMINATE TRANSDUCER

Ming Li presents an energy harvester employing a cantilever beam and a magnetostrictive/piezoelectric (ME) laminate transducer to transform rotation energy into electrical energy. The harvester has a magnetic circuit attached to the free end of the beam, and the ME transducer is placed in the air gap of the magnetic circuit. He summarized as The harvester should be designed to achieve the second-order super-harmonic resonance at the target rotation frequency if possible. However, in some application environments, the rotation speed is variable. In these cases, broadband energy harvesting can be realized by employing magnetic coupling. Since the power output of the harvester is proportional to the square of the ME voltage coefficient, higher power output can be obtained by employing transducers with higher ME voltage coefficient, such as Terfenol-D/Pb(Mg1/3Nb2/3)O3–PbTiO3/Terfenol-D laminate composite. The power output is also proportional to the square of the induced magnetic flux density of the ME transducer. The enhancement of the induced magnetic field can be realized by incorporating additional high-permeability _-metal layers into the ME transducer].In the future, we will investigate the influences of the radial location of the harvester on the electrical output performances and develop a MEMS-scale generator [7].

9. PIEZOELECTRIC CANTILEVER PROTOTYPE FOR ENERGY HARVESTING IN COMPUTING APPLICATIONS

Levant Beker presents a piezoelectric energy harvester (PEH) to convert vibrations to electrical power. A unimorph cantilever beam is used to generate voltage on piezoelectric material bonded close to the anchor of the cantilever beam [8].

10. CONCLUSION

From extensive literature review, it is found that the COMSOL Multi physics finite element package was used to study the direct piezoelectric effect when an external load is applied at the free end of a piezoelectric composite beam. The primary output parameters such as electric potential and electric field were studied as a function of the input strain and stress. Vibration energy harvester combining a piezoelectric cantilever and a single degree of freedom (SDOF) elastic system the main function of the additional SDOF elastic system is to magnify vibration displacement of the piezoelectric cantilever to improve the power output.

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