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# Parameter Optimization In Piezoelectric Energy Harvester Using Mems

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**Abstract**: In flexible structures the piezoelectric elements can be used as sensor and actuators. The basic concepts of piezoelectric micro-power generators, with all implementations for getting desired output have been discussed for different positions on the cantilever beam. The model of 3D finite element has been designed and simulated. This can be done by introducing the deposition of the piezoelectric PZT thin films. The optimization of parameters (Length, Breadth, and Thickness) has been done in corresponding Cantilever beam and PZT block in CREO Parametric Software. The designed model has been imported to the virtual prototype ANSYS. The modelling and simulation of generalized piezoelectric block with proper specifications and properties are done using FEA (Finite Element Analysis), CAD(Computer Aided Design) tool, ANSYS. By applying few voltages over PZT, the given source is harvested into an electrical energy for the applicable purposes.

**Keywords**: ANSYS software, CREO Parametric Software, Cantilever beam, PZT.

## I. INTRODUCTION

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. Energy harvesting from ambient sources, such as mechanical vibrations, is a very promising alternative. One of the most efficient ways of harvesting vibration energy is piezoelectric harvesters. The piezoelectric materials are extensively used in electromechanical and micro electro mechanical actuators and sensors. Piezoelectric materials have found widespread application as transducers that are able to change electrical energy into mechanical motion or force. Finite element analysis is extensively used for the modeling of such materials. ANSYS is a useful tool to simulate the structure of piezoelectric devices successfully and accurately.

Harvesting energy from vibrations are piezoelectric, electromagnetic and electrostatic. Piezoelectric energy harvesting received greatest attention due to high power density and ease of application [1]. MEMS fabrication techniques allow implementation of micro scale piezoelectric energy harvesters (PEH). Most of the MEMS PEH's are in cantilever beam form with fixed-free [2]. Piezoelectric materials exhibit anisotropic material behavior, it is important to model the system adequately to evaluate the stress or strain on piezoelectric material[3]. Improved modeling of piezo-ceramics and silicon is required to maximize the voltage output of MEMS PEH. Models based on isotropic treatment lead to miscorrelations with experimental results [4]. MEMS fabrication techniques allow implementation of micro scale piezoelectric energy harvesters (PEH) are in a cantilever beam form with fixed-free or fixed-fixed boundary conditions, in which piezoelectric materials exhibit anisotropic material behavior, to model the system adequately the evaluation of stress or strain on piezoelectric material is represented in [5].Voltage output of the piezoelectric material related with the stress on the material in [6].

The modeling of piezo-ceramics and silicon is required to maximize the voltage output of MEMS PEH has been improved in [7]. This paper reports an improved method for modelling and optimization of a

 

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MEMS piezoelectric energy harvester (PEH) within desired frequency range with maximum voltage output using finite element method(FEM). PZT and silicon materials are usedin which silicon act as a cantilever beam. PZT material block is placed both sides of the silicon beam. One block of the PZT material act as a actuator and other actas a sensor. The 3D finite element modelling and simulation for energy harvesting is done using FEA CAD tool, ANSYS platform.

## II. ENERGY HARVESTING

The piezoelectric generator transforms mechanical vibrations, strain or stress into electrical voltage/current. As the energy generating source injects energy into the detector electronics, these electrical impulses are collected and used for various application.Fig.1 shows the structure of PZT material over a cantilever beam for energy harvesting.

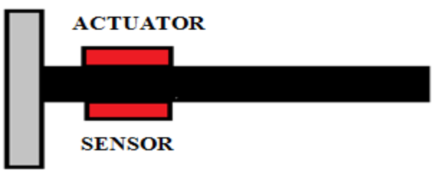


Fig:1 Structure of PZT material over a cantilever beam

Table 1
Materials Properties

| SL.NO | PROPERTIES | SILICON BEAM | PZT |
|---|---|---|---|
| 1 | Length | 6.5mm | 2.0mm |
| 2 | Breadth | 2.5mm | 5.0mm |
| 3 | Thickness | 10 | 60 |
| 4 | Young's Modulus | 410 GPa | 9.2e10 Pa |
| 5 | Density | 3.1 g/m^3 | 7700 kg/m^3 |
| 6 | Poison's Ratio | 0.14 | 0.33 |

Optimization of Mems Peh-ANSYS has built-in optimization tool consisting of several methods Parametric design code developed is embedded to optimization tool to maximize the objective function which is obtaining highest voltage from the piezoelectric material. It includes modal analysis to observe the voltage output from a given constant excitation. Time required for the optimization process is heavily dependent on the meshing of the structure. Initially free mesh pattern is used during optimization, which requires shorter time segments. It is observed that as the dimensions vary during the optimization process, patterns of the free mesh also changes.

## III. DESIGN AND SIMULATION OF PZT ENERGY HARVESTING FEA CAD TOOL, ANSYS

Ansys is an easy-to-use virtual prototyping and modular simulation. It is software environment for performing structural, thermal and electromagnetic analyses. ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products.

Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment. ANSYS software with its modular structure as seen in the table below gives an opportunity for taking only needed features. ANSYS can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules.

The Steps followed are:
1.Modeling
2.Material Properties
3.Boundary Conditions
4.Meshing

*A. Modeling:*

 

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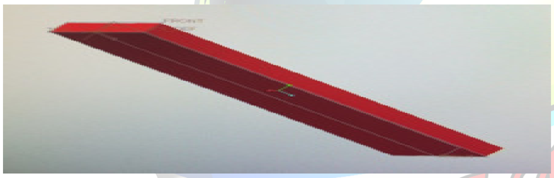
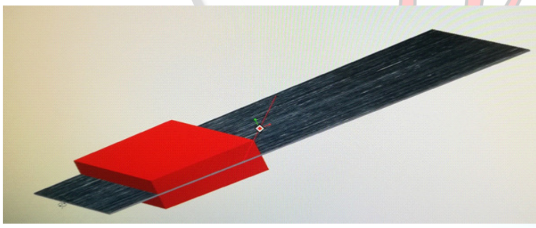
In ANSYS terminology, the term model generation usually takes on the narrower meaning of generating the nodes and elements that represent the spatial volume and connectivity of the actual system. Thus, model generation in this discussion will mean the process of defining the geometric configuration of the model's nodes and elements. The ANSYS program offers you the following approaches to model generation: Creating a solid model in CREO parametric software and importing that model to ANSYS software.Fig.2 shows the silicon part, PZT part and assembly of PZT over silicon beam.

Fig(2.a): Silicon part



Fig(2.b): PZT part



Fig(2.c): Assembly of PZT over a silicon beam

*B. Boundary Conditions*

The way the beam is supported translates into conditions on the function $w(x)$ and its derivatives. These conditions are collectively referred to as *boundary conditions*. One end of the beam is fixed and the other end is let free i.e(X=Y=Z=0). The PZT is placed above and below the fixed end of the beam.

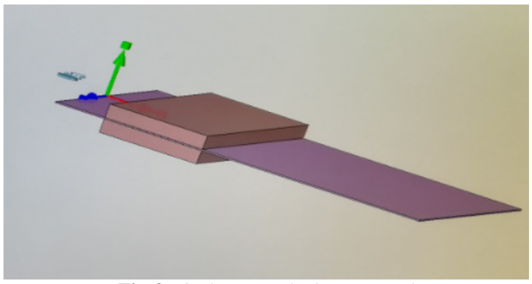


**Fig:3** Displacement lock at one end

*C. Meshing*

Meshing is defined as the process of dividing the whole component into number of elements so that whenever the load is applied on the component it distributes the load uniformly called as meshing. Auto meshing is a meshing method depending on the type of 2D or 3D meshing in which the model will be fairly small, even using a spreadsheet to compute node coordinates and set the element connectivity has been done in useful approach. A component is analyzed in two ways. One is with Meshing and the other is without meshing. Figure 4(a) and 4(b) shows the energy harvester with and without meshing.

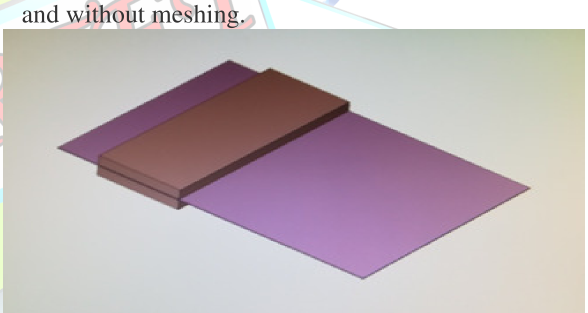


*Fig:4(a) Without meshing*

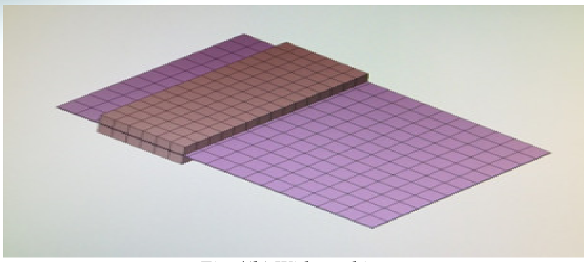


*Fig:4(b) With meshing*

**IV. OUTPUT**

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Voltage is given as a input over the PZT actuator. The given voltage is 10V. After applying the voltage, PZT sensor sense the given voltage and generate vibration in the silicon beam. From that generated vibration the Piezoelectric energy is harvested. Figure (5) shows that PZT is placed at the bottom of the Energy Harvesters where PZT sensor pickup the vibration and generate output voltage.

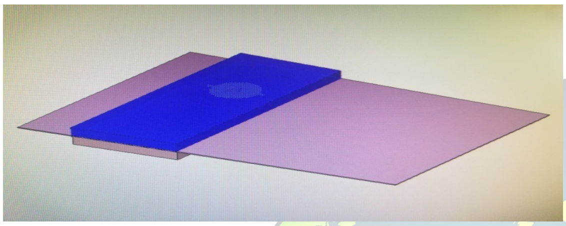

Fig:5 Voltage is given as input over PZT actuator

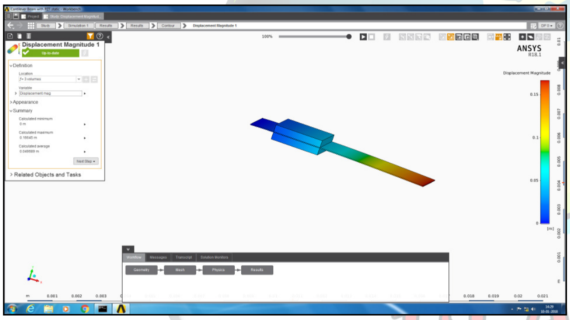


Fig:6 Simulation in the ANSYS platform

## V. WAVEFORM

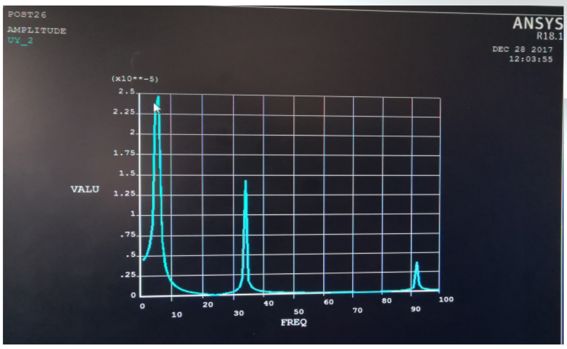


Fig:6 The stress and strain variations for the input voltage of 10V

## VI. CONCLUSION

MEMS PEH is modelled and optimized using ANSYS tool. Dimension and voltage are applied for optimization procedure where objective is maximization of voltage output of the piezoelectric material has been obtained. The simulation of output voltage in PZT material and the energy harvesting is done using FEA CAD tool, ANSYS.

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