© 2015 IJSRST | Volume 1 | Issue 5 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

FEM Simulations of Z-axis MEMS Capacitive Energy Harvester using Various Beams

Hitesh Kumar Sharma*, Jit Dutta
Materials Research Centre, Malaviya National Institute of Technology, Jaipur, Rajasthan, India

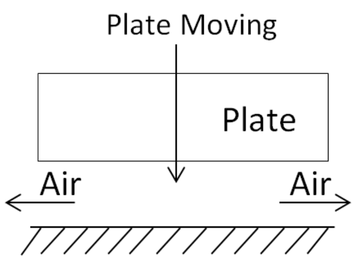
ABSTRACT

This paper represents the Finite element modeling of Z-axis MEMS capacitive energy harvester and analysis of spring constant of various type of springs, used in MEMS capacitive energy harvesting system and its effect at the resonance frequency. In this paper, FEM simulations of MEMS capacitive energy harvester along with three different types of springs are carried out using COMSOL Multiphysics tool. The theory of spring constant is discussed along with mathematical model. For simulations, three flexure springs (Linear, single serpentine, double serpentine) of width 12µm and thickness 8µm is used. The length of the spring for linear beam and single serpentine beam is used 264 um and for double serpentine beam is 330 µm. The dimension of the capacitive plate is used 2000 µm × 2000 µm with thickness of 8 µm. This plate is used with three different types of springs, 3-D model is meshed and appropriate boundary conditions are applied to calculate the spring constant.

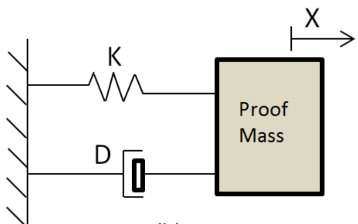
Keywords: Spring Constant, COMSOL Multiphysics Tool, MEMS Capacitive Energy Harvester.

I. INTRODUCTION

In our daily life, various types of undesired vibrations are present. These vibrations can effectively be converted into the electrical energy by some capacitive means. Of course; the generated power is of very small amount (µw) but still this is very effective in small power applications to drive some devices as Gyroscope, Accelerometer used in the field of Micro-Electro Mechanical System (MEMS) [4]. This paper represents the FEM simulation to calculate Eigen frequency for such type of "self-powered devices" which are necessary to operate at low frequency. One of the important key factors of this type of low frequency devices is spring constant. This spring constant creates a major effect during the calculation of the Resonance frequency.



(a)



(b)

Figure 1: (a) shows the schematic of MEMS capacitive energy harvester and (b) shows the 1-DOF resonator with spring constant K, Mass M, and a damper D.

II. METHODS AND MATERIAL

When a plate is placed parallel to a wall and moves towards the wall, then due to the mechanical movement of the plate, there is a change of capacitance between the plate and the wall and this capacitance is measured by some means and it is used to drive micro power devices as shown in fig. 1. The MEMS capacitive energy harvester is based on the same principal. This schematic shows the single air cavity MEMS capacitive energy harvester.

The spring used in the MEMS capacitive energy harvester has a significant effect at the Eigen frequency of the structure and can reduce to an appropriate value by proper choice of the springs as desired in MEMS inertial sensor.

Spring constant of linear rectangular spring is defined as [1]:

$$\boldsymbol{\omega_{eff}} = \sqrt{\frac{\mathbf{K}}{\mathbf{m_{eff}}}} \qquad (1)$$

Where, ω_{eff} = natural frequency of the linear rectangular spring

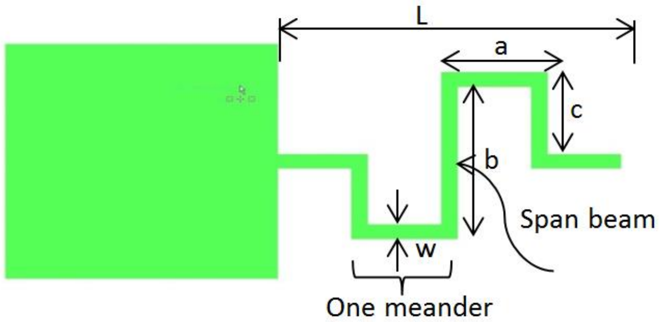
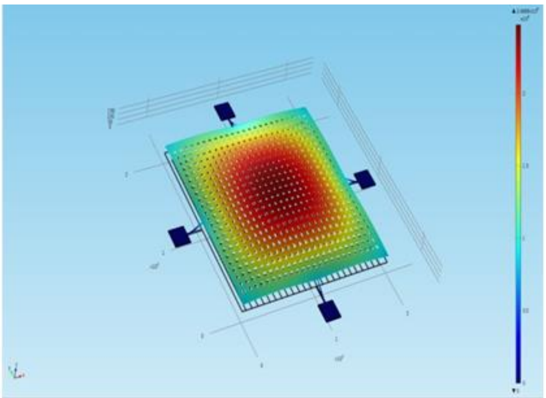
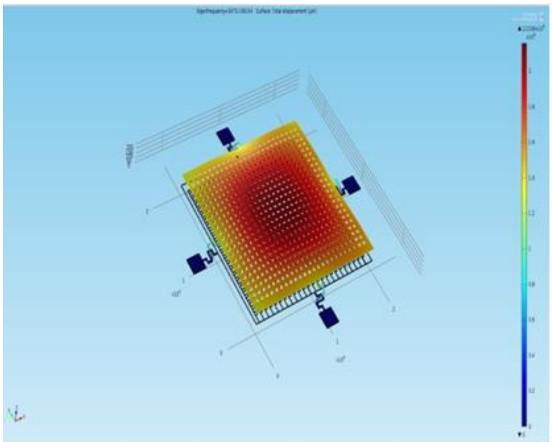


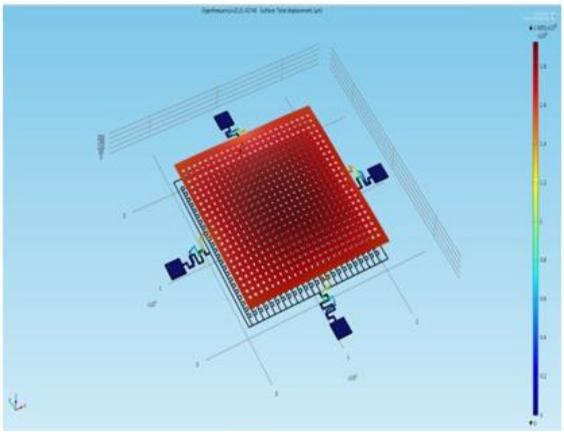
Figure 2 : Schematic layout of serpentine flexure snake spring



(a)

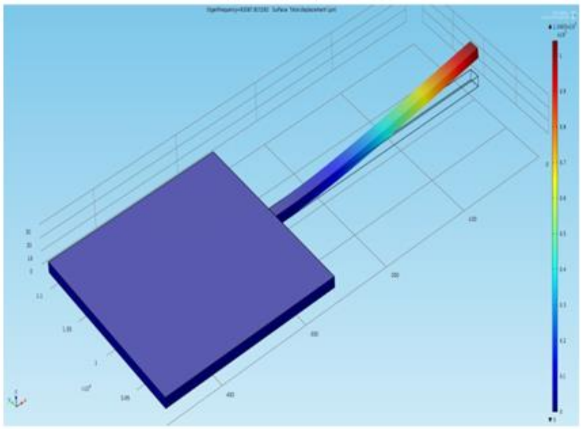


(b)

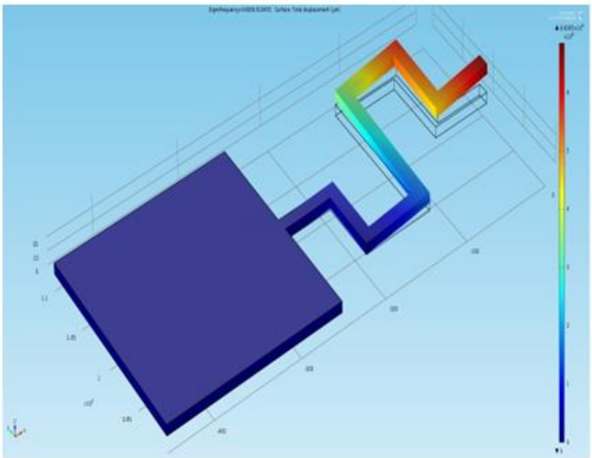


(c)

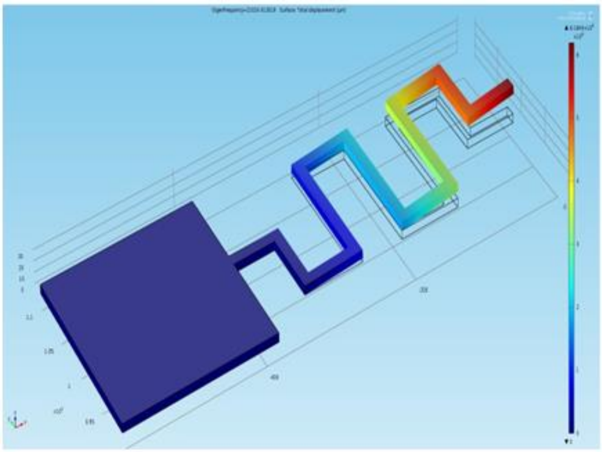
Figure 3: Z-axis MEMS capacitive energy harvester with (a) linear beam, (b) single serpentine spring, and (c) double serpentine spring.



(a)



(b)



(c)

Figure 4: Frequency analysis of various type of beams using FEM (a) linear beam, (b) single serpentine spring, and (c) double serpentine spring used in Z-axis MEMS capacitive energy harvester.

$$K_x = \frac{48EI_{z,b}}{a^2\,(\bar{a}+b)n^3} \quad (4)$$

$$K_y = \frac{48EI_{z,b}}{b^2\,(3\bar{a}+b)n} \quad (5)$$

$$K_y = \frac{48EI_{z,b}}{b^2\,(3\bar{a}+b)n} \quad (5)$$

$$K_z = \frac{48GJ_b}{a^2\left(\left(\frac{GJ_b}{EI_x}\right)a+b\right)n^3} \quad (6)$$

Where, $\bar{a} = \frac{I_{z,b}a}{I_{z,a}}$, E = young modulus of elasticity, I moment of inertia.

III. RESULT AND DISCUSSION

SIMULATIONS AND RESULT

For Eigen frequency measurement of MEMS capacitive energy harvester, we have taken a plate with a dimension of 2000µm × 2000µm and the resonance frequency is measured with three different types of springs.

TABLE I
FREQUENCY OF MEMS CAPACITIVE ENERGY HARVESTER USING DIFFERENT BEAMS

MEMS capacitive energy harvester using various spring	Material	Eigen Frequency (KHz)
Linear Spring	Nickel	4.97
Single Serpentine Spring	Nickel	3.47
Double Serpentine Spring	Nickel	2.13

TABLE II
FREQUENCY AND SPRING CONSTANT OF THE BEAMS

Spring	Length (µm)	Frequency (KHz)	Spring Constant (N/m)
Linear	264	92.08	76
Single Serpentine	264	54.80	26.55
Double Serpentine	330	21.02	5.17

Linear and single serpentine springs have the length of 264 µm and double serpentine has 330 µm of length with a width and thickness of 12 µm and 8 µm respectively.

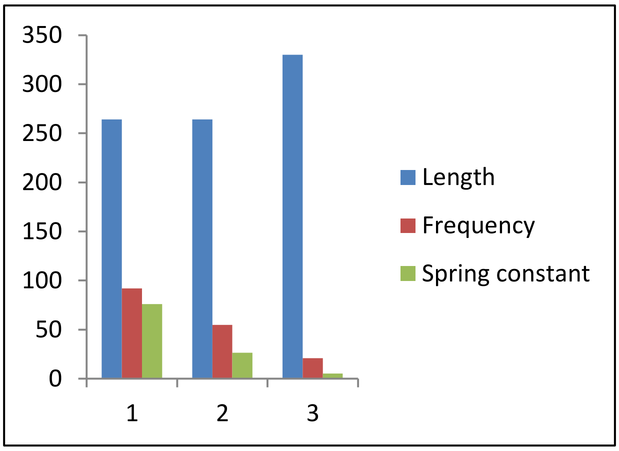


Figure 5: Bar graph of springs. 1 shows linear spring, 2 Single serpentine, and 3 double serpentine flexure spring

A lower resonance frequency can be achieved by using serpentine springs as compared to the linear spring. The double serpentine spring has lower value of spring constant which causes the resonance frequency of Z-axis MEMS capacitive energy harvester is reduced as shown in Table (1). These three springs are also analyzed individually to calculate the to evaluate the spring constants as shown in spring constant which values is closer to the analytical values, calculated by equation (2) and (6). Solid mechanics solver in COMSOL multiphysics is used table 2. The FEM simulations of frequency analysis of MEMS capacitive energy harvester with three different springs are shown in fig. (3) and (4) respectively. It is evident from fig.3 that resonance frequency indeed reduced in flexure serpentine spring.

IV. CONCLUSION

FEM simulations for estimating the effect of various springs used in Z-axis MEMS capacitive energy harvester as well the spring constant is carried using COMSOL multiphysics tool. The theory of spring constant is discussed along with mathematical model. For simulations one capacitive plate of 2000 µm × 2000µm and three different springs are taken. The 3-D model is then meshed and appropriate boundary conditions are applied to calculate the effect of spring constant. The simulations results are also compared with analytical results.

V. ACKNOWLEDGEMENT

The authors are thankful to department of Materials Research Centre, Malaviya National Institute of technology for providing facilities and support to carry out this research work.

VI. REFERENCES

[1] Mounika Reddy, G. V. Sunil Kumar (2013), "Design and Analysis of Microcantilevers with various shapes using COMSOL multiphysics software", IJETAE volume 3, issue 3

[2] Giuseppe Barillaro, AntonioMolfese, Andrea Nannini and Francesco Pieri (2005), "Analysis, Simulation and relative performances of two kinds of serpentine springs", J. Micromech. Microeng. 15:736-746

[3] D. V. Bambill, S.J.Escanes, C. A. Rossit (2003), "Forced vibrations of a clamped-free beam with a mass at the free end an external periodic distribution acting on the mass with applications in ships' structures, Ocean Engineering 30:1065-1077

[4] Jianxiong Zhu (2015), "Design, Analysis and Dynamic Phenomenon of MEMS Capacitive Power Harvester", University of Missouri-Columbia

[5] G. K. Fedder (1994), "Lumped parameter modeling" in Simulation of Microelectromechanical Systems, Department of Electrical Engineering and Computer Sciences, University of California at Berkeley

[6] COMSOL Multiphysics Tool