

# Analysis, Modeling and Simulation of Fixed Beam Cantilever Using Eigen Frequency

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**Abstract:** The modeling is performed by using the finite element analysis software, COMSOL Multiphysics, Structural Mechanics modules, version 4.3. The purpose of the study of static analysis is to find the magnitudes and locations of the maximum strain, stress, and electrical potential on the cantilever beam when an external static load is applied to the beam's free end. The eigen frequency analysis is then performed to find the first six modes of frequencies and the deformation pattern of the beam. The time-dependent analysis is used to solve for the transient solution when the applied external load is time dependent and has a frequency that is close to the beam's 1st natural frequency. Such a dynamic load should cause the beam to have maximum strain, stress, and electrical potential than a dynamic load with a frequency further away from the beam's natural frequency. In this paper analysis modeling and simulation of natural frequency of a fixed –end beam made of silicon, with a geometry and dimensions of beam having width  $40 \times 10^{-6}$  m, depth (thickness)  $6 \times 10^{-6}$  m, length  $600 \times 10^{-6}$  m. and subjected to a longitudinal stress at 187MPa.

## I. INTRODUCTION

Micro-Electro-Mechanical Systems (MEMS) are a latest technology in area of mechanical, electrical, electronics and chemical engineering[1]. Micro-Electro-Mechanical Systems, or MEMS, consists of mechanical, electrical systems whose order of size in microns. It is a technology used to miniaturize systems[2]. Electrical components such as inductors and tunable capacitors can be improved significantly compared to their integrated counterparts if they are made using MEMS and Nanotechnology[3].

Beam is a inclined or horizontal structural member casing a distance among one or additional supports, and carrying vertical loads across its longitudinal axis, as a purlin, girder or rafter. Three basic types of beams are:

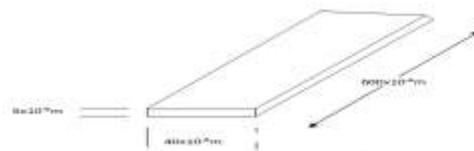
- (1) Simple span, supported at both ends
- (2) Continuous, supported at more than two
- (3) Cantilever, supported at one end with the other end overhanging and free.

The Physical systems such as mechanical vibrations, behave in characteristic patterns known as Modes[4]. Modes of vibration are the important considerations in the design of microcantilevers. It is important to understand the natural modes of vibration of cantilevers. Frequency based measurement is one of the most commonly used measurement for microcantilevers. Frequency based measurement is one of the most commonly used measurement for microcantilever sensing. Any oscillating object has a natural frequency and it is the frequency of the oscillating object that tends to settle into, if it is undisturbed.

The Phenomenon in which a relatively small, repeatedly applied force causes the amplitude of an oscillating system to become larger and that state is called resonance. Frequency measurements are sensitive to minute changes cantilever[5]. With absorbed masses in the mass of the micocantielver. With adsorbed masses in the range of nogram to pictogram on the beams of microcantilever may result in changes in the resonance frequency.

The different modes of vibrations of the microcantilever if it is trigged by appropriate stimulation[6]. The Amplitude of oscillation reaches to maximum peak while the driving frequency matches with one of the natural vibration frequencies of the beam[6]. In mode 1 all parts of the cantilever move except the fixed end[7]. In mode two there is a stationary point. Or node away from the end. In mode three there are two nodes and so on.

The amplitude of oscillation is exaggerated along the Y-axis. These mode shapes show the shape of the beam at the extreme of the oscillation when all points on the beam are insteaneously at rest[8,9]. One can say that all the points also go through zero displacement at the same time is Shown in figure 1.Model Geometry.



**Fig.1 Model Geometry**

## II. MATERIAL AND FIXED CONSTRAINT SELECTION:

In the geometry boundary selection manually 2 is selected as fixed constraint and its value is 95 KHZ. After the selection geometry one end of the beam is fixed is shown in fig.2.

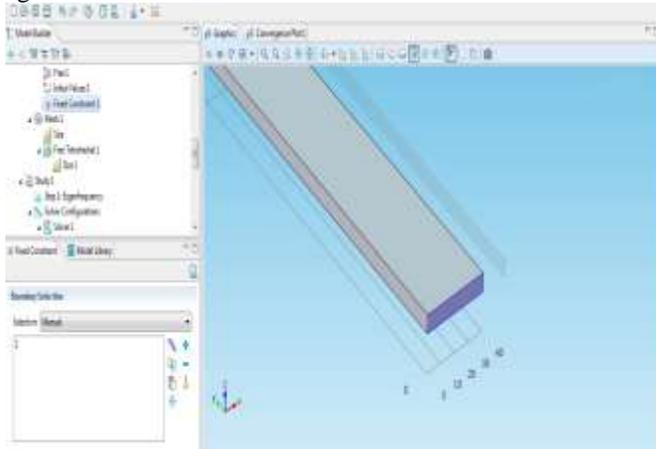


Fig.2 Fixed Constraint

## III. MODAL ANALYSIS USING COMSOL MULTIPHYSICS:-

### A.Problem Specification

For the determination of Shift of Natural Frequency of a fixed end beam made of silicon with geometry and dimensions. Preanalysis used to compute the amplitude of vibration with the following end and initial conditions is shown in below theory.

Length (L)	600x10 <sup>-6</sup> m
Width (b)	40x10 <sup>-6</sup> m
Height (h)	6x10 <sup>-6</sup> m
Longitudinal Stress	187 MPa
Mass per Unit Length of the Beam(Y)	5.52x10 <sup>-7</sup> kg/m
Weight per Unit Length of the beam(w)	5.4096x10 <sup>-6</sup> N/m
Area of Moment if Inertia (I)	7.2x10 <sup>-22</sup> m <sup>4</sup>

### B.Material Properties

Density	2300[kg m <sup>3</sup> ]
Youngs Modulus	190Pa
Poisson Ratio	0.28
Relative Permetivity	1
Electrical Conductivity	1e <sup>12</sup> [s/m]
Coefficient of Thermal Expansion	2.6e <sup>-6</sup> [1/k]
Heat Capacity at Constant Presessure	700[J/kg*k]
Relative Permutivity	11.7
Thermal Conductivity	130[W(m*k)]
Refractive Index	3.48

### C.Pre-Analysis :-

The following given equations have the of the modes frequencies and their shapes and have been deduced from Beam Theory.

#### Theory:

$$\frac{\partial y(x, t)}{\partial x} \Big|_{x=0} = 0 \text{ and } y(x, t) \Big|_{x=0} = 0$$

at the end x=0

$$\frac{\partial y(x, t)}{\partial x} \Big|_{x=L} = 0 \text{ and }$$

at the other end x=L

#### Initial Conditions:

$$\frac{\partial y(x, t)}{\partial x} \Big|_{t=0} = 0 \text{ for the initial velocity}$$

$$y(x, t) \Big|_{t=0} = f(x) = \frac{w}{24EI} (x-L)^2 x^2$$

$$y(x, t) \Big|_{t=0} = 0$$

For initial sag of the beam due to its own weight. The separation of variables technique used for the solution of the partial differential equation. The solution(x,t) then

$$y(x, t) = \sum_{n=1}^{\infty} k_n \left[ \cosh(\lambda_n x) - \cos(\lambda_n x) \right] \frac{\cosh(\lambda_n L) - \cos(\lambda_n L)}{\sinh(\lambda_n L) - \sin(\lambda_n L)} \left[ \sinh(\lambda_n x) - \sin(\lambda_n x) \right] \cos \left[ x (\lambda_n)^2 t \right]$$

Where the coefficient  $k_n$  is obtained from the following integrals:

$$k_n = \frac{\int_0^L f(x) X(x) dx}{\int_0^L [X(x)]^2 dx}$$

In which the function X(x) is part of the above general solution of y(x,t)

## IV. DISCUSSION AND RESULTS

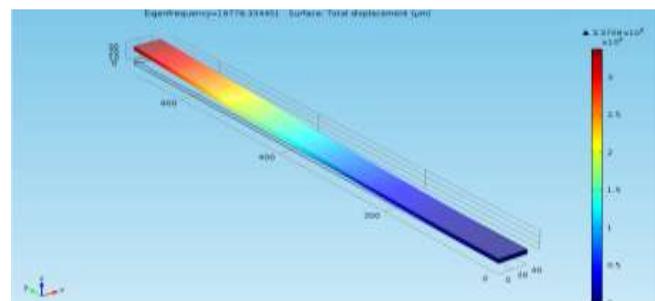
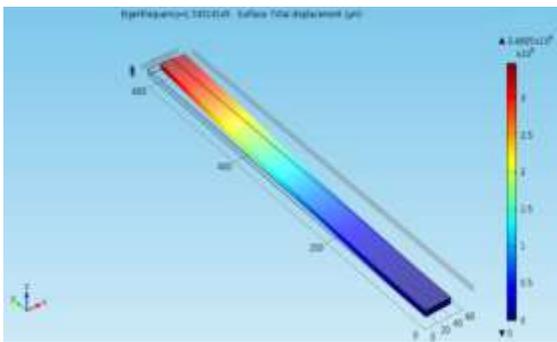
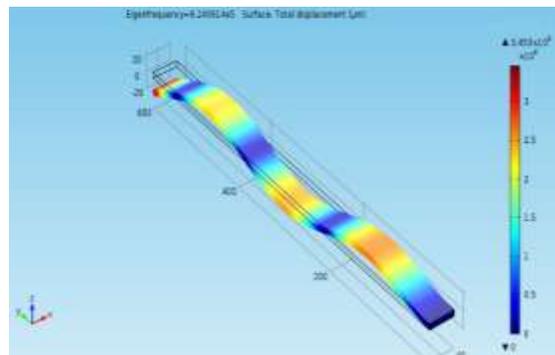


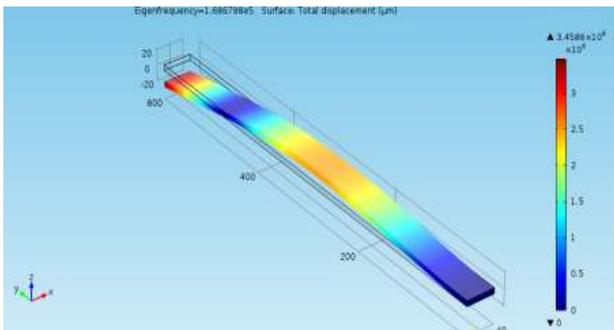
Fig.3 Modeshape one 19778.334451



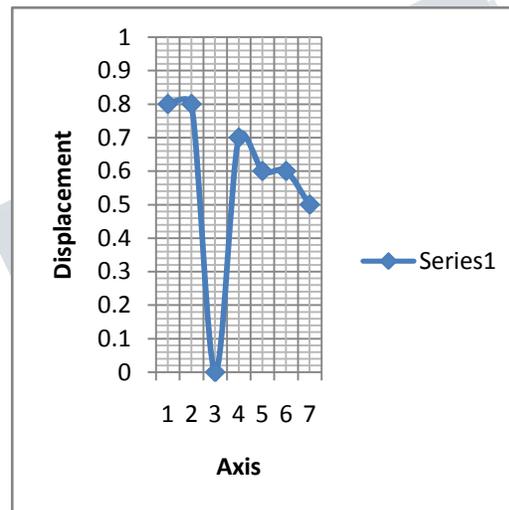
**Fig.4 Modeshape two  $1.530141e^5$**



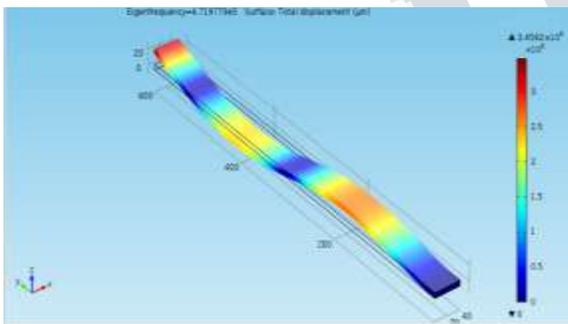
**Fig.8 Mode shape Six  $9.240914e$**



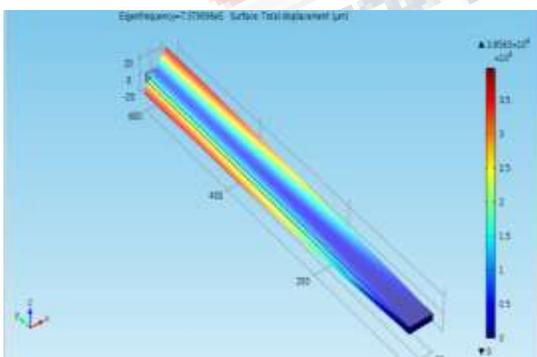
**Fig.5 Mode Shape Three  $1.686798e^5$**



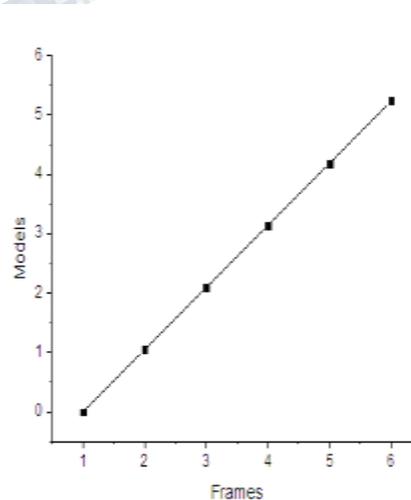
**Fig.9 XYZ Vs Total Displacement**



**Fig.6 Mode Shape Four  $4.79779e^4$**



**Fig.7 Mode Shape Five  $7.379096e^5$**



**Fig.10 No. Frames Vs Frequency Mode**

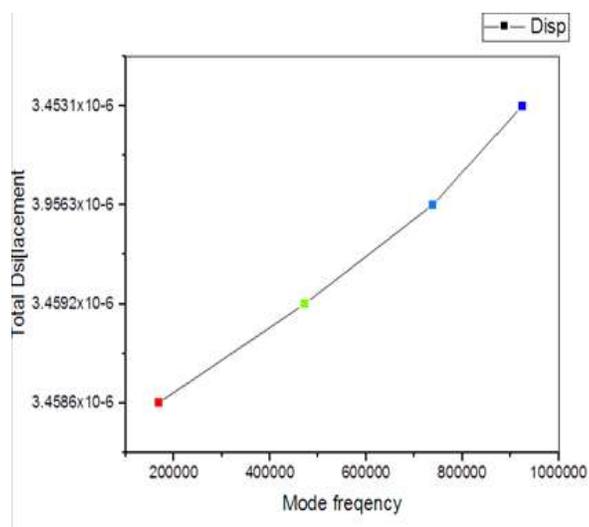


Fig.11 Total displacement Vs Mode Frequency

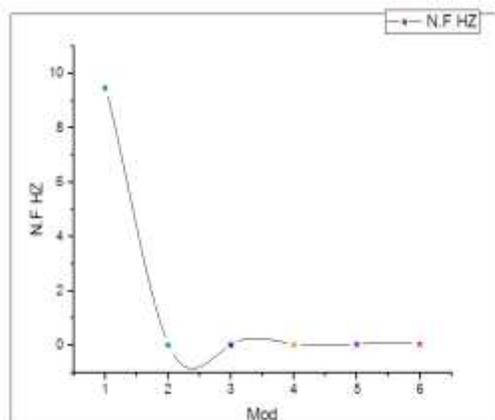


Fig.12 Mod Vs Natural Frequency

## V. CONCLUSION:

In simulation, we analyzed the Eigen frequencies of one end fixed cantilever beam. There are six modes of frequencies. 1st mode has fundamental frequency 19778.334451 Hz; also we get different modes with higher frequencies. This method is not limited to one end fixed beam MEMS applications this analysis can also be done in other models of MEMS Resonator. Silicon MEMS resonators have been demonstrated up to  $9.240914e^5$ . And also the natural frequency of the beam is calculated.

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