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The Effect of Length on Modal Analysis of Cantilever Beam with and without Piezoelectric

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Abstract
The fundamental technique to determine the dynamic characteristic of engineering structures is the modal analysis. From the modal analysis can determine the natural frequencies and mode shapes. The natural frequencies and mode shapes are determined through finite element modeling (FEM) using ANSYS APDL 15.0 (ANSYS Parametric Design Language).
Keywords: Cantilever Beam, Finite Element Modeling (FEM), Modal Analysis.

1. Introduction

The finite element modeling is considered as very important tool for engineering components analysis because it’s a major contribution to our pairs to understand and control on the several types of vibration phenomena’s which are encountered in practice. To get best understanding the dynamic properties of structure used finite element modeling software ANSYS APDL. [1]

Beams are members of structure which have smaller dimension of cross-sections as compared to its length and subjected to loads vertical to its axis. Cantilever beam is fixed at one end and free at the other.

A cantilever beam is continuous system, and the mass and elasticity of the cantilever beam are distributed at all over volume. Cantilever beam has infinite degree of freedom and infinite natural frequencies. And for every natural frequency there is its shape of vibration called mode shape. Fundamental natural frequency is the lowest natural frequency, and its mode shape called fundamental mode or first mode.

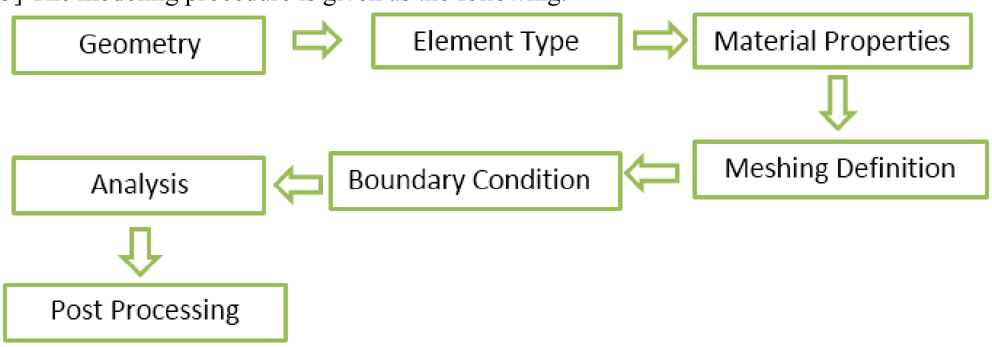
2. LITERATURE SURVEY

Ankit Gautam, Jai Kumar Sharma, Pooja Gupta, the theoretical and numerical modal analysis of beam are performed. The boundary conditions that used are fixed-free, free-free, and fixed-fixed. The theoretical modal analysis use Euler-Bernoulli and numerical modal analysis use ANSYS 14.5 [1]. DAVID V. HUTTON, modal analysis used to find natural frequency and mode shape of structure. The modes are the properties of structure and are determined by mass, stiffness, and damping (material properties) and boundary conditions of the structure [2]. Chandra deep Kumar, Anjani Kumar Singh, Nitesh Kumar, and Ajit Kumar, the measurement of vibration and analysis in engineering structure became very important; the behavior of a structure at resonance is a key of aspect of the dynamic analysis of structure. Modal analysis is one of a major alternative to understanding control of many vibration phenomena [3].

3. Modal Analysis

Modal analysis gives the sensibilities of resonant frequencies and is helping the user to choice the suitable design parameters of structures. The goal of studying modal analysis in structural mechanics is to determine the natural frequencies and mode shapes of cantilever beam during free vibration. It is general to use the finite element method (FEM) to do this analysis because, like other computations using the FEM, the object being analyzed can have spot shape and results of computations are agreeable.[2]

The vibration analysis of cantilever beam can be carried out on ANSYS by provision structural data and the condition of load on supports. Modal analysis is used to get natural frequencies and mode shapes of beam in ANSYS. [3] The modeling procedure is given as the following.



4. Natural Frequency

One of several Modal analyses is the study of the dynamic properties of the system in frequency domain.
Each system can be depicted in terms of a stiffness matrix that attached the displacement and the force. These frequencies are called natural frequencies of the system and the system can be given by eigenvalue of stiffness matrix.

5. The Finite Element Solution Using ANSYS

In this analysis, beams with and without piezoelectric are created in ANSYS by using BLOCK command. After assigning appropriate the element type and material properties of beam and piezo. The meshing is done, solid45 used to mesh beam and solid5 used to mesh piezo, the meshing is a process to divide the whole structure in to small-small parts, and the result became more accuracy. After meshing the boundary condition of fixed end is done, where the degree of freedom is made equal to zero. At the solution, the six frequencies and mode shapes of beam are obtained after performing analysis. [4]

6. Problem Statement

The studying modal is cantilever beam made from aluminum. A series of FE modal are generated for the beam with length from 200mm to 400mm with and without piezoelectric (piezo). The three-dimensional FEM of beam is performed in ANSYS 15.0 and calculate the modal analysis to get natural frequencies and mode shapes. The geometric and material properties of cantilever beam and piezoelectric is taken from the Table 1. The results of modal analysis of beam with and without piezo are given below.

Table 1: Geometric Parameter and Material Property

Geometric parameter of beam	Material property of beam	Material property of piezo
$L = from\ 200\ to\ 400\ mm$	$E = 70x10^9 N/M^2$	$E = 26X10^9 N/M^2$
$B = 40\ mm$	$\rho = 2780\ kg/M^3$	$\rho = 7350\ kg/M^3$
$H = 1.4\ mm$	$v = 0.3$	

6.1. Beam with Length 200mm

The natural frequencies of the cantilever beam are given in table 2, and mode shapes are given in figure below.

Table 2: Natural Frequency of Cantilever Beam with and without Piezoelectric

Mode	Natural Frequency without Piezo	Natural Frequency with Piezo
1	28.962	112.77
2	183.18	812.95
3	287.17	825.60
4	525.17	1749.4
5	794.71	2587.3
6	885.12	4426.3

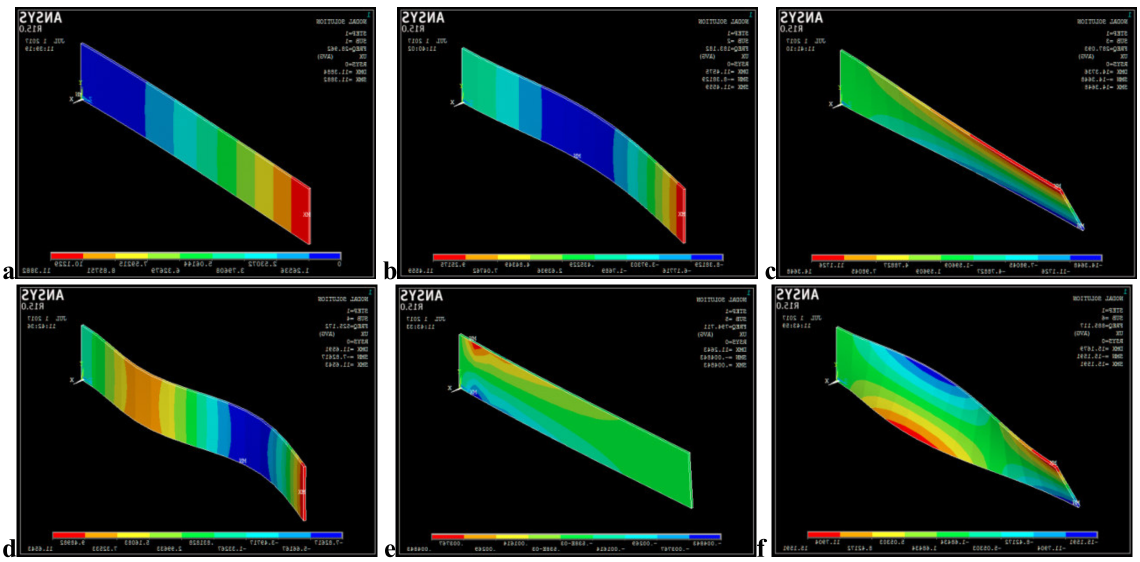


Figure 1: Model Shape of Cantilever Beam a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

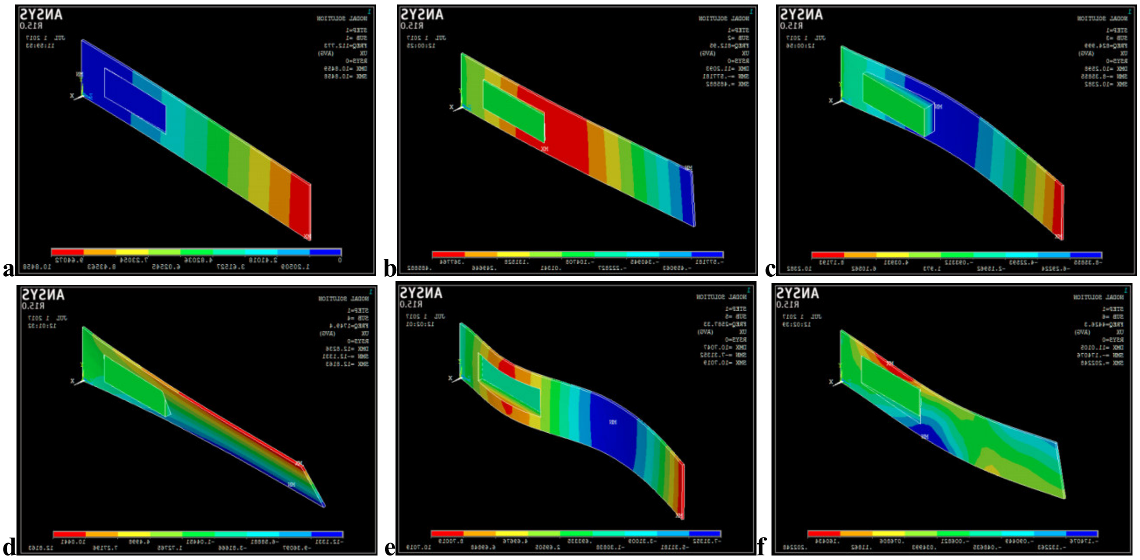


Figure 2: Model Shape of Cantilever Beam with piezo a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

6.2. Beam with length 250mm

The natural frequency of the cantilever beam is given in table 3, and mode shapes are given in figure below.

Table 3: Natural Frequency of Cantilever Beam with and without Piezoelectric

Mode	Natural Frequency without Piezo	Natural Frequency with Piezo
1	18.500	83.321
2	117.07	542.00
3	227.28	630.13
4	335.52	1685.0
5	513.99	1726.6
6	682.51	3101.6

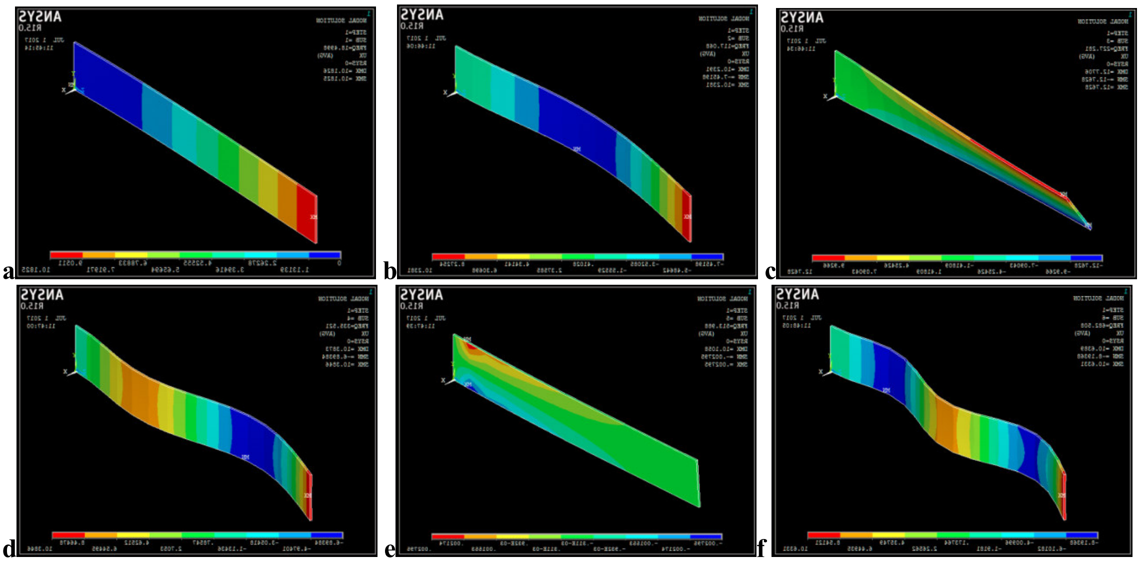


Figure 3: Model Shape of Cantilever Beam a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

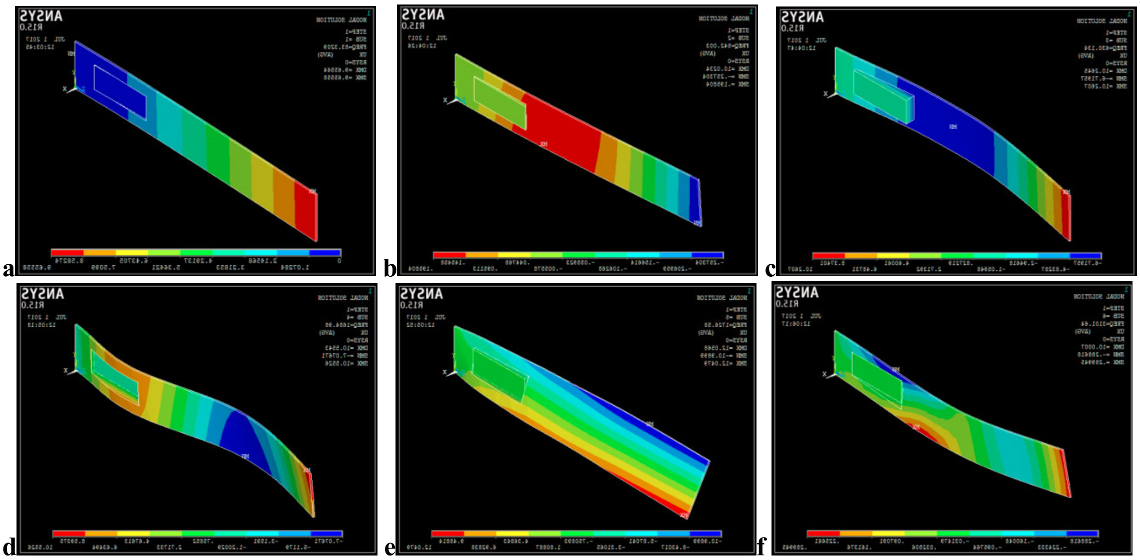


Figure 4: Model Shape of Cantilever Beam with piezo a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

6.3. Beam with length 350mm

The natural frequency of the cantilever beam is given in table 4, and mode shapes are given in figure below.

Table 4: Natural Frequency of Cantilever Beam with and without Piezoelectric

Mode	Natural Frequency without Piezo	Natural Frequency with Piezo
1	9.4172	60.765
2	59.619	292.67
3	160.53	443.77
4	170.80	1284.3
5	264.71	1457.2
6	347.25	1688.2

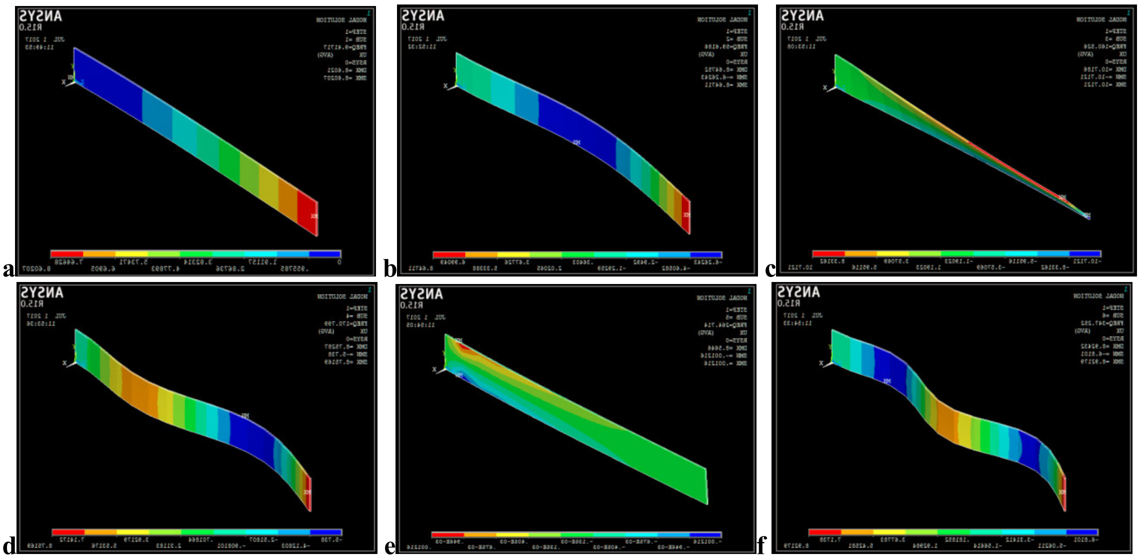


Figure 5: Model Shape of Cantilever Beam a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

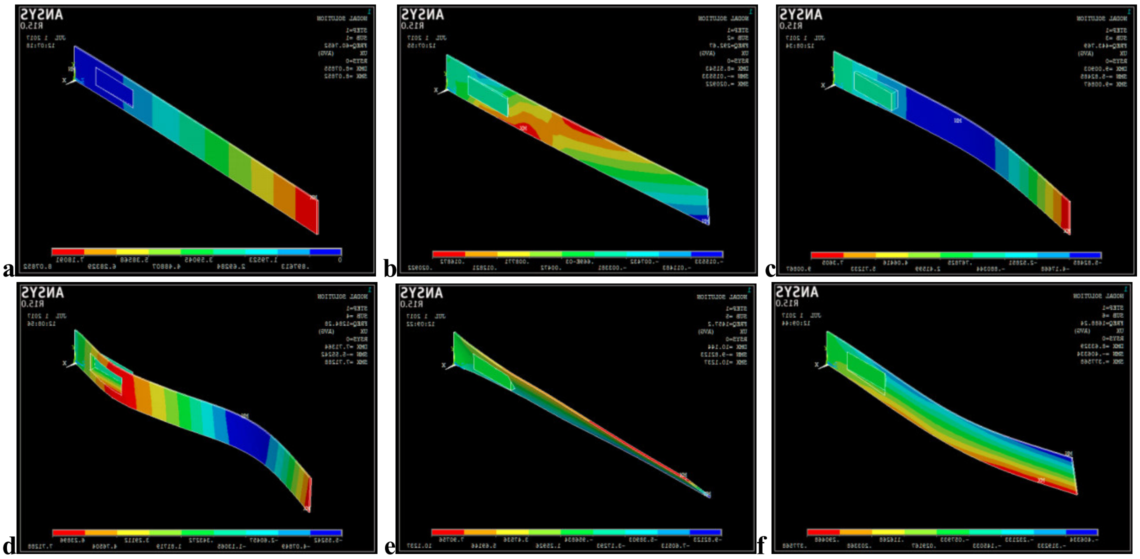


Figure 6: Model Shape of Cantilever Beam with piezo a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

6.4 Beam with length 400mm

The natural frequency of the cantilever beam is given in table 5, and mode shapes are given in figure below.

Table 5: Natural Frequency of Cantilever Beam with and without Piezoelectric

Mode	Natural Frequency without Piezo	Natural Frequency with Piezo
1	7.2049	57.685
2	45.618	226.09
3	130.67	391.23
4	140.00	1167.7
5	203.14	1329.7
6	265.61	1374.1

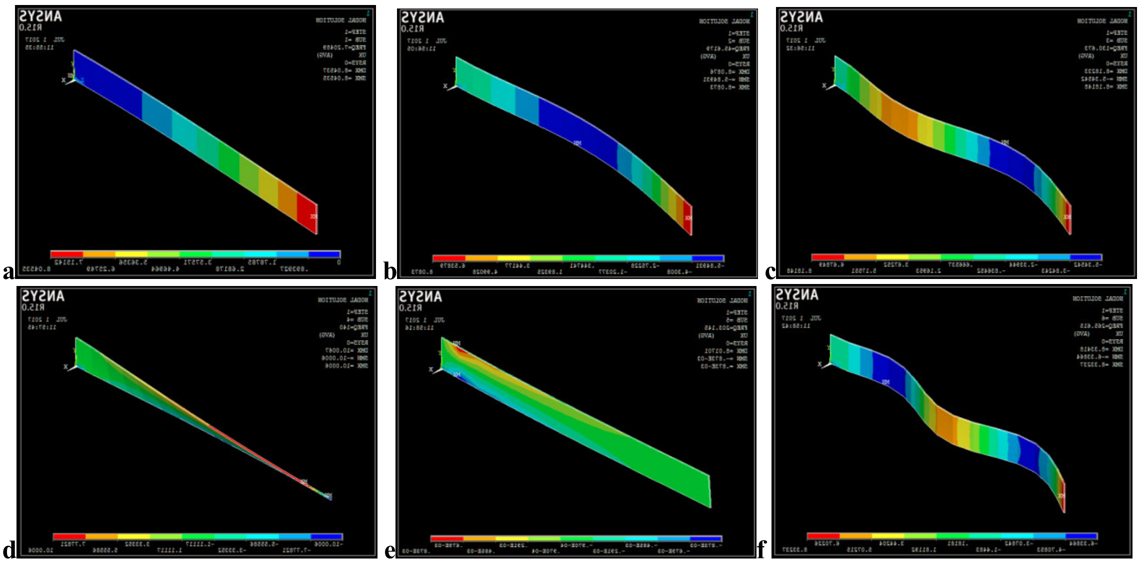


Figure 7: Model Shape of Cantilever Beam a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

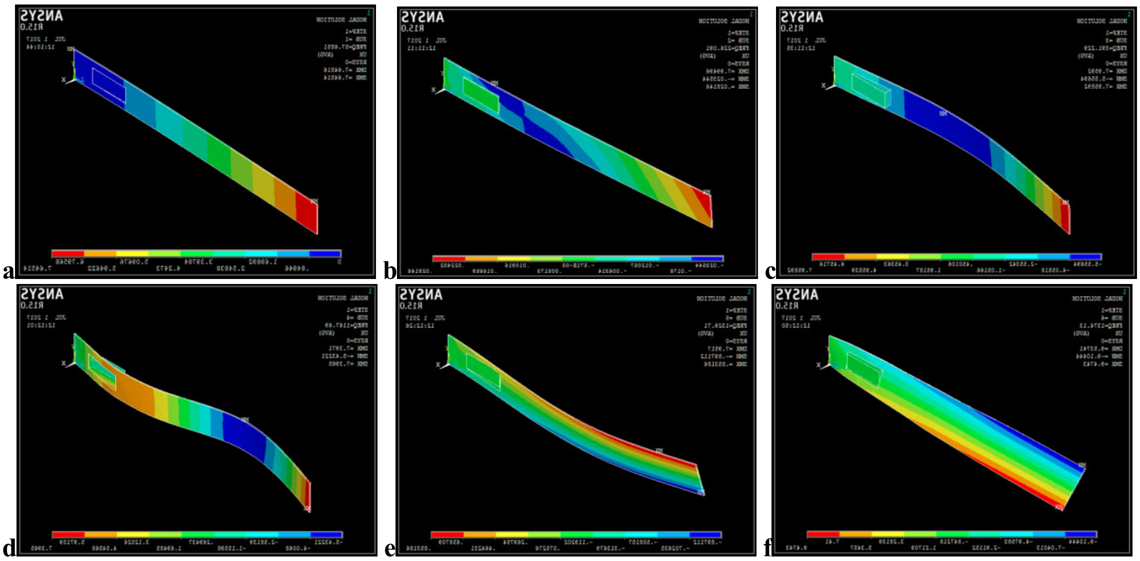


Figure 8: Model Shape of Cantilever Beam with piezo a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

7. Comparison

The results of Finite Element Method obtained natural frequencies of mild steel are taken from paper[1], beam are calculated using the material properties and dimensions of beam given in Table (6). The finite element natural frequencies are determined using ANSYS 14.5 and the results are tabulated in Table (7).

Table (6): Material and Geometry parameters

Material Property	Geometry Parameter
$E = 20.5 * 10^{10} N/M^2$	$L = 2m$
$\rho = 7830\ Kg/m^3$	$B = 0.3m$
$v = 0.33$	$H = 0.1\ m$

Table (7): Natural frequency of Beam

Mode	Natural Frequency of paper	Natural Frequency
1	20.818	20.53
2	129.25	128.48
3	357.05	361.34

When compare the result of paper with the result that I get from ANSYS 15.0, found the results are very close.

8. Conclusions

The natural frequency of cantilever beam was decreasing when the length increase, that leading led to there is a retrograde connection between length and natural frequency of cantilever beam. In case by letting a piezo on beam near the fixed end, the natural frequency of beam with same length is increasing, because the mass and stiffness of piezo was add to the beam and led to increase natural frequency. But increasing the length of beam with piezo is leading to make the natural frequency to decrease. From this work, the main conclusion is when the length of cantilever beam with and without piezo is increased the natural frequencies are decreased, and the mode shape of cantilever beam was different between the lengths of the beam, because the natural frequency was changed when the lengths changed.

9. Reference

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