American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-10, pp-178-185
www.ajer.org
Research Paper Open Access

Modal analysis of cantilever beam Structure Using Finite Element analysis and Experimental Analysis

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ABSTRACT: *The modal analysis is presented in this paper some basic concepts of modal analysis of transverse vibration of fixed free beam. It is described an experimental apparatus and the associated theory which allows to obtain the natural frequencies and modes of vibration of a cantilever beam. The concept of modal analysis plays an important role in the design of practical mechanical system. So it becomes important to study its effects on mechanical system for different frequency domain i.e. low, medium and high frequency. This paper focuses on the numerical analysis and experimental analysis of transverse vibration of fixed free beam and investigates the mode shape frequency. All the frequency values are analyzed with the numerical approach method by using ANSYS finite element package has been used. The numerical results are in good agreement with the experimental tests results.*

Keywords - *Finite Element analysis, Modal analysis, Fixed Free Beam, Experimental Analysis, Free vibration.*

I. INTRODUCTION

In the past two decades, modal analysis has become a major technology in the quest for determining, improving and optimizing dynamic characteristics of engineering structures. Not only has it been recognized in mechanical and aeronautical engineering, but modal analysis has also discovered profound applications for civil and building structures, biomechanical problems, space structures, acoustical instruments, transportation and nuclear plants. The Free vibration takes place when a system oscillates under the action of forces integral in the system itself due to initial deflection, and under the absence of externally applied forces. The system will vibrate at one or more of its natural frequencies, which are properties of the system dynamics, established by its stiffness and mass distribution. In case of continuous system the system properties are functions of spatial coordinates. The system possesses infinite number of degrees of freedom and infinite number of natural frequencies. Vibration analysis of fixed free Beam like components has been an active research subject and numerous technical papers have been published. For to calculating the natural frequencies and mode shapes of a structure modal analysis method is used. This method determined the dynamic response of complicated structural dynamic problems.

In general, applications of modal analysis today cover a broad range of objectives identification and evaluation of vibration phenomena, validation, structural integrity assessment, structural modification, and damage detection. In engineering design, it is important to calculate the response quantities such as the displacement, stress, vibration frequencies, and mode shapes of given set of design parameters. The study of mathematical models which involve physical and geometric parameters such as mass density ρ, elastic modulus E, Poisson's ratio v, lengths, and cross-section shape characteristics. In many practical engineering applications, these parameters frequently do not have well-defined values due to non-homogeneity of the mass distribution geometric properties or physical errors, as well as variation arising from the assembly and manufacturing processes.

II. MAIN OBJECTIVES:

All the Vehicles, aircraft and home appliances structures are made up of fixed beam with one end free or combination of fixed beams so it becomes necessary to study fixed beam vibration. The following are main objective of yoke design.

1. A detailed understanding of function and configuration of fixed beam with one end free
2. To Analysis of fixed beam with one end free using FEA Method.
3. To Analysis of fixed beam with one end free using Experimental method.

III. NUMERICAL ANALYSIS BY USING ANSYS:

3.1 Basic steps of finite element analysis:

There are three basic steps involved in this procedure,

1. Pre Processor (Building the model (or) Modeling)
2. Solution (Applying loads and solving)
3. Post Processor (Reviewing the results)

3.2. Numerical Approach for Transverse Vibration of Fixed Free Beam:

We shall now investigate the free vibration of fixed free beam using the ANSYS program, a comprehensive finite element package. We use the ANSYS structural package to analyse the vibration of fixed free beam. Finite element procedures at present very widely used in engineering analysis. The procedures are employed extensively in the analysis of solid and structures and of heat transfer and fluids and indeed, finite element methods are useful in virtually every field of engineering analysis.

3.3. Description of the finite element method:

The physical problem typically involves an actual structure or structural component subject to certain loads. The idealization of the physical problem to a mathematical model requires certain assumptions that together lead to differential equations governing the mathematical model. Since the finite element solution technique is a numerical procedure, it is necessary to access the solution accuracy. If the accuracy criteria are not met, the numerical solution has to be repeated with refined solution parameters until a sufficient accuracy is reached.

3.4. Important features of finite element method

The following are the basic features of the finite element method: Division of whole in to parts, which allows representation of geometrically complex domains as collection of simple domains that, enables a systematic derivation of the approximation functions. Derivation of approximation functions over each element the approximation functions are algebraic polynomials that are derived using interpolation theory.

3.5. Boundary Conditions:

The meshed model is then analyzed (static) and the boundary conditions are:

- One end is fixed (All DOF).

3.6. Numerical (FEA) Results:

The dimensions and the material constant for a uniform fixed free beam (cantilever beam) studied in this paper are: Material of beam = mild steel, Total length (L) = 0.8 m , width (B) = 0.050 m, height (H) = 0.006 m, Young's Modulus (E) = 210 x 10^9, mass density = 7856 kg/ m^3. Poisson Ratio= 0.3. The numerical results were found out by using the ANSYS program as shown in Table 3. The Numerical (FEA) values obtained are 7.67 Hz and 688.89 Hz for first and last modes respectively.

Table 1: Numerical frequency from ANSYS

Mode	Numerical frequency from ANSYS program in Hz
1	7.6769
2	48.1
3	63.585
4	134.69
5	229.16
6	264.01
7	391.46
8	436.63
9	652.62
10	688.89

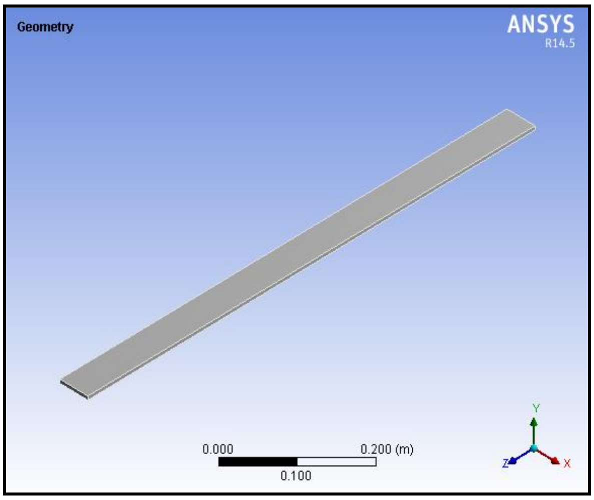


Fig. 1 : Geometry of fixed beam at one end

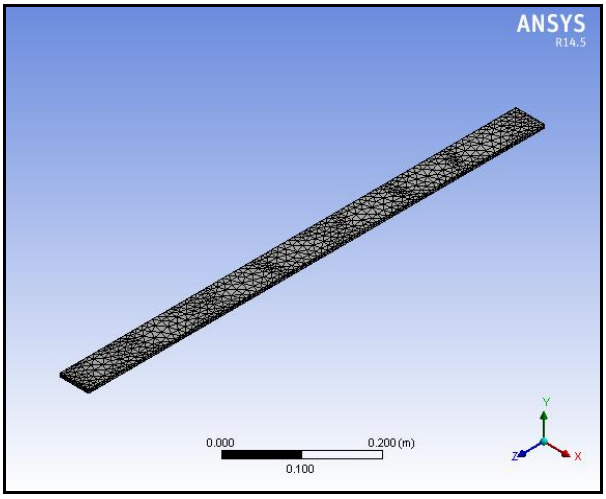


Fig. 2 : Meshing of fixed beam at one end

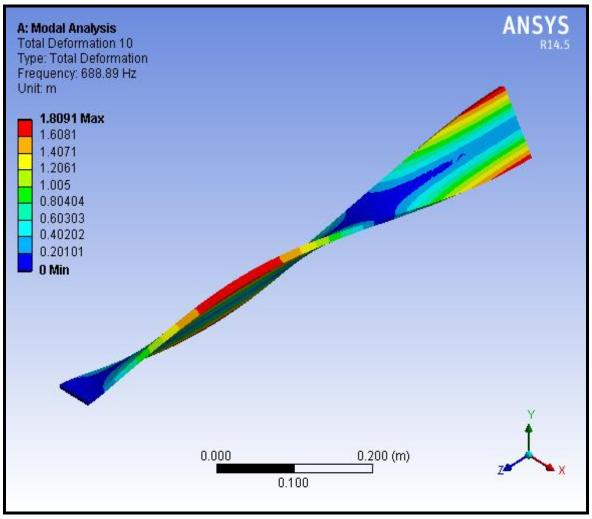


Fig. 3 : Total Deformation-10

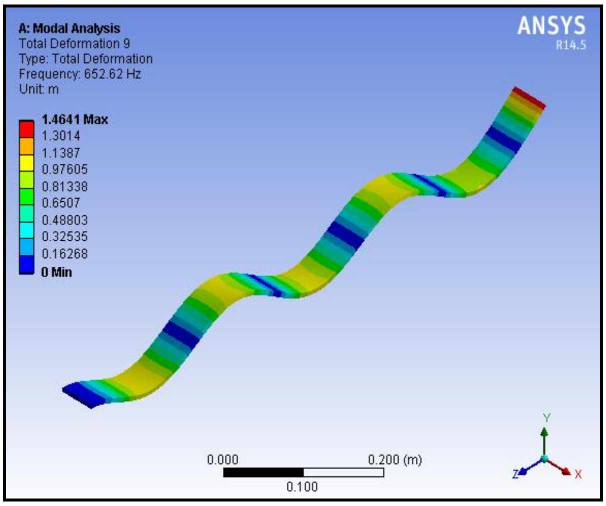


Fig. 4 : Total Deformation-9

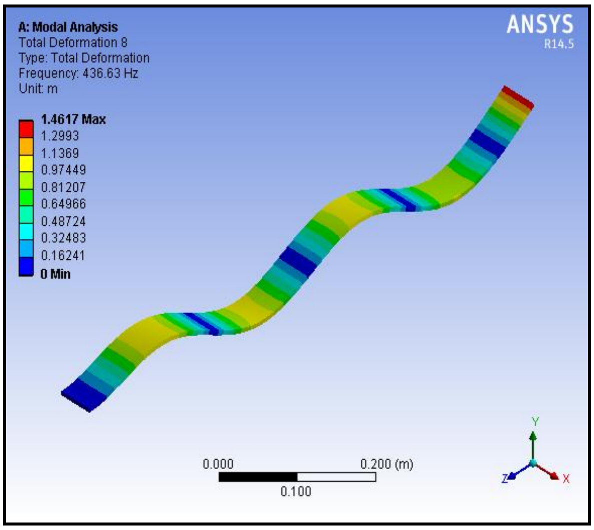


Fig. 5 : Total Deformation-8

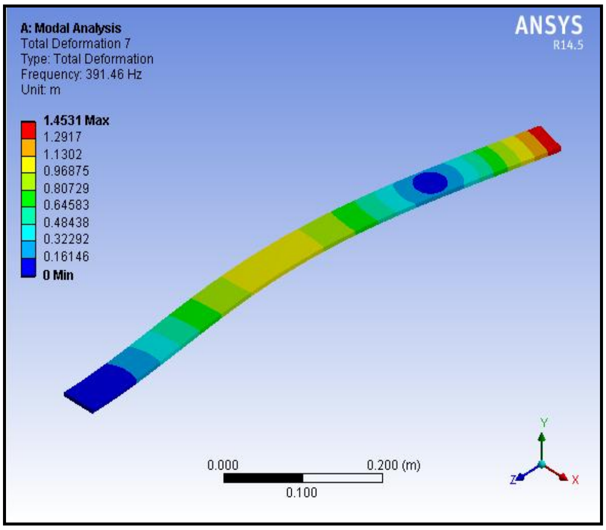


Fig. 6 : Total Deformation-7

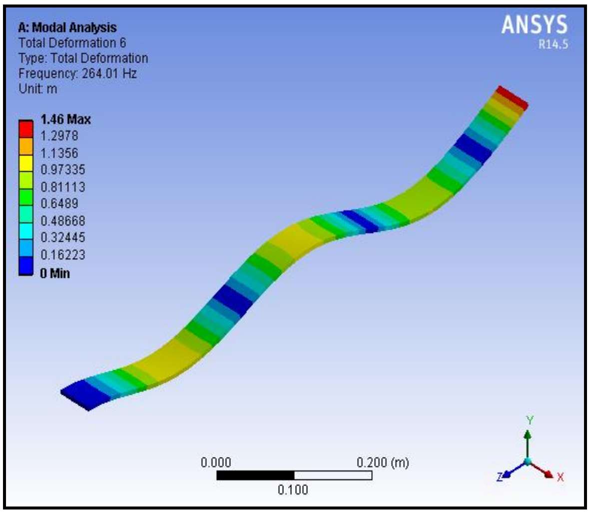


Fig. 7 : Total Deformation-6

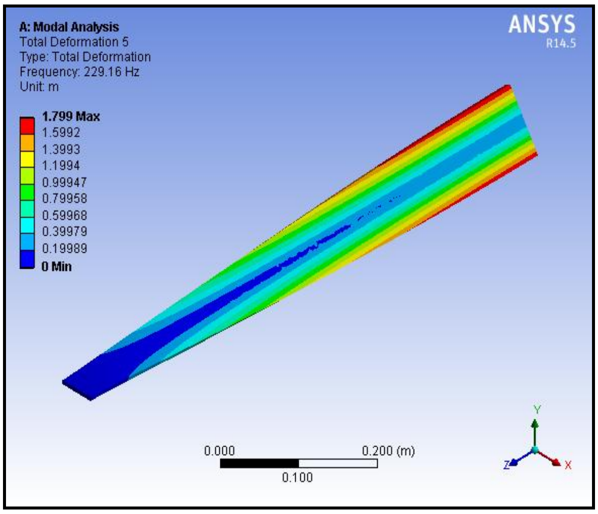


Fig. 8 : Total Deformation-5

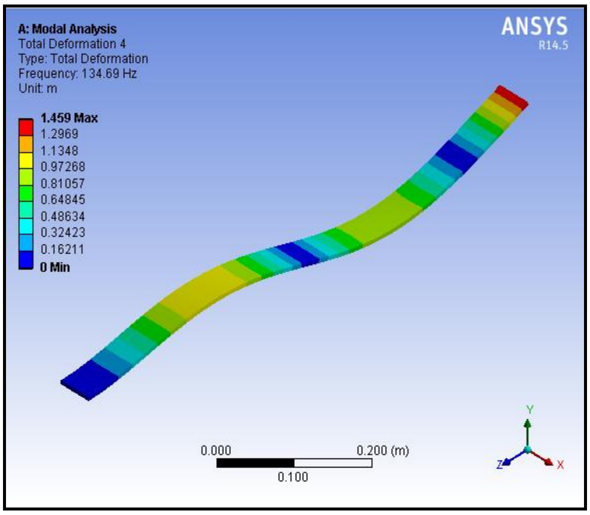


Fig. 9 : Total Deformation-4

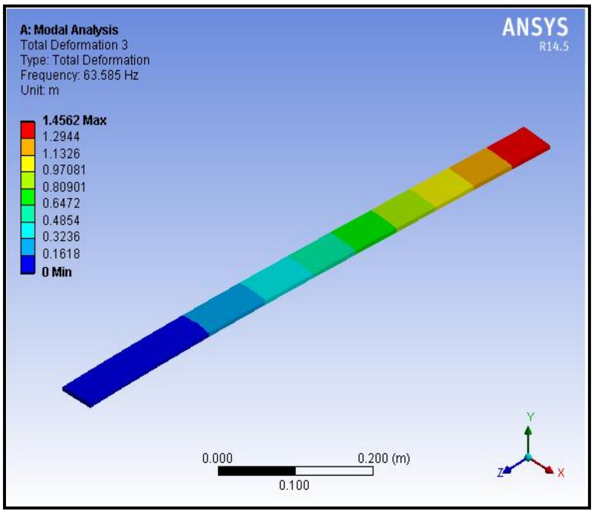


Fig. 10 : Total Deformation-3

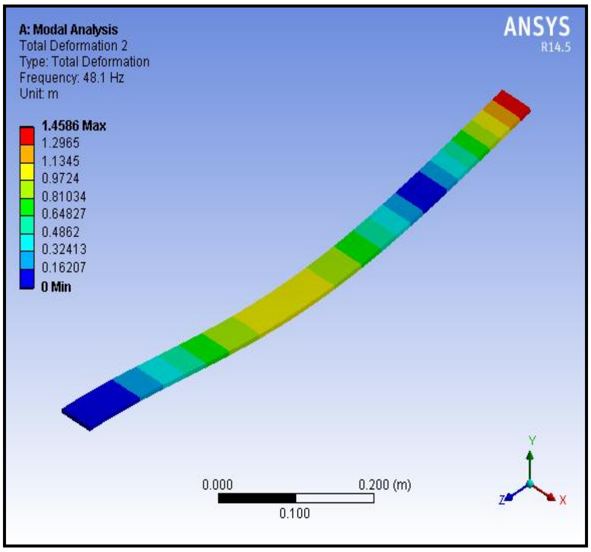


Fig. 11 : Total Deformation-2

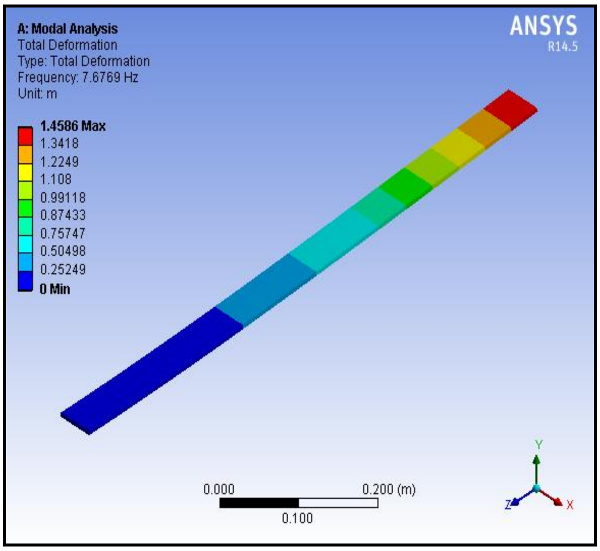
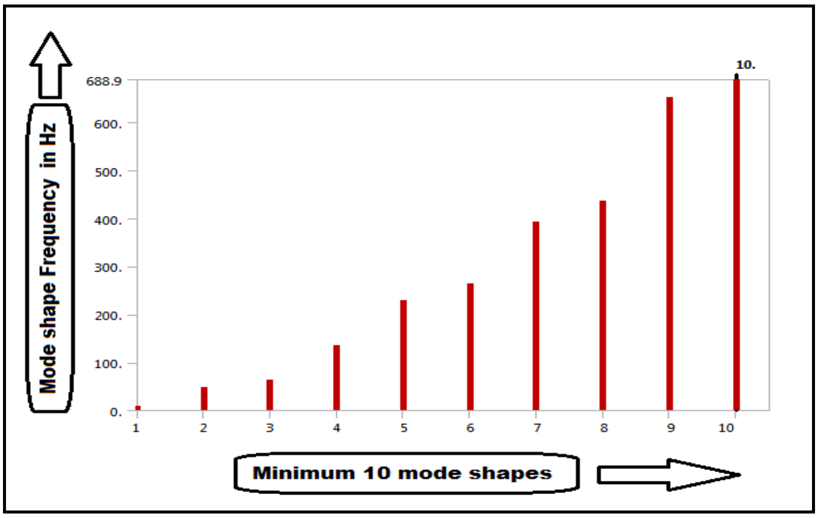


Fig. 12 : Total Deformation-1



Graph. 1 : Graphical representation of the modal frequencies

IV. EXPERIMENTAL ANALYSIS OF TRANSVERSE VIBRATION OF FIXED FREE BEAM:

4.1 Experimental Setup:

The dimensions and the material constant for a uniform fixed free beam (cantilever beam) studied in this paper are: Material of beam = mild steel, Total length (L) = 0.8 m , width (B) = 0.050 m, height (H) = 0.006 m, Young's Modulus (E) = 210 x 10^9, mass density = 7856 kg/ m^3. Poisson Ratio= 0.3

A beam which is fixed at one end and free at other end is known as cantilever beam. From elementary theory of bending of beams also known as Euler-Bernoulli. In experiment we will use digital phosphor oscilloscope (Model DPO 4035) for data acquisition.

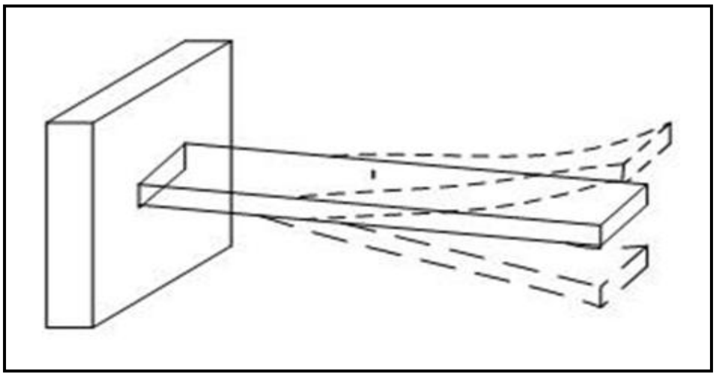


Fig. 13. Free vibration for cantilever

Accelerometer is a kind of transducer to measure the vibration response (i.e., acceleration, velocity and displacement). Data acquisition system acquires vibration signal from the accelerometer, and encrypts it in digital form. Oscilloscope acts as a data storage device and system analyzer. It takes encrypted data from the data acquisition system and after processing (e.g., FFT), it displays on the oscilloscope screen by using analysis software. Fig. shows an experimental setup of the cantilever beam.

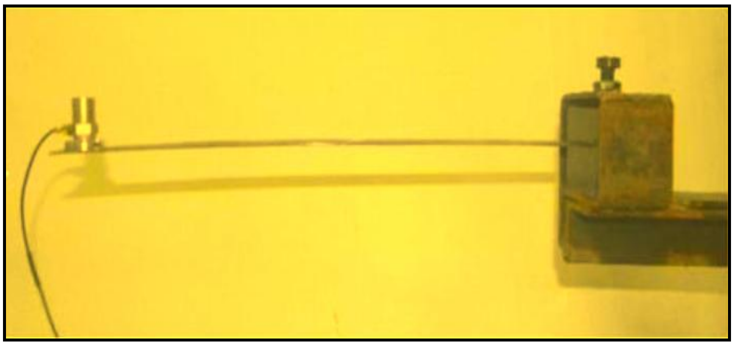


Fig. 14. Experimental setup

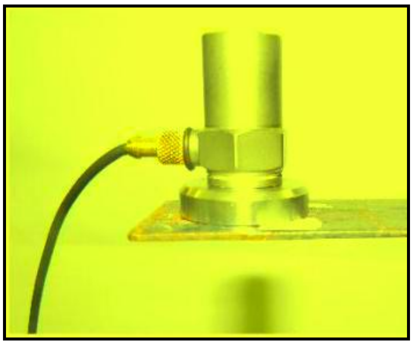


Fig. 15. Closed View of Accelerometer

It includes a beam specimen of particular dimensions with a fixed end and at the free end an accelerometer is clamped to measure the free vibration response. The fixed end of the beam is gripped with the help of clamp. For getting defined free vibration cantilever beam data, it is very important to confirm that clamp is tightened properly; otherwise it may not give fixed end conditions in the free vibration data.

4.2 Experimental Procedure:

[1] A beam of a particular material (steel, aluminum), dimensions (L, w, d) and transducer (i.e., measuring device, e.g. strain gauge, accelerometer, laser vibrato meter) was chosen.
[2] One end of the beam was clamped as the cantilever beam support.
[3] An accelerometer (with magnetic base) was placed at the free end of the cantilever beam, to observe the free vibration response (acceleration).
[4] An initial deflection was given to the cantilever beam and allowed to oscillate on its own. To get the higher frequency it is recommended to give initial displacement at an arbitrary position apart from the free end of the beam (e.g. at the mid span).
[5] This could be done by bending the beam from its fixed equilibrium position by application of a small static force at the free end of the beam and suddenly releasing it, so that the beam oscillates on its own without any external force applied during the oscillation.
[6] The free oscillation could also be started by giving a small initial tap at the free end of the beam.
[7] The data obtained from the chosen transducer was recorded in the form of graph (variation of the vibration response with time).
[8] The procedure was repeated for 5 to 10 times to check the repeatability of the experimentation.
[9] The whole experiment was repeated for same material, dimensions, and measuring devices.
[10] The whole set of data was recorded in a data base.

4.3 Experimental Results:

To observe the natural frequencies of the cantilever beam subjected to small initial disturbance experimentally up to third mode, the experiment was conducted with the specified cantilever beam specimen. The data of time history (Displacement-Time), and FFT plot was recorded. The natural frequencies of the system can be obtained directly by observing the FFT plot. The location of peak values relates to the natural frequencies of the system. Fig. below shows a typical FFT plot.

Table 2: Mode shape frequency by Using Experimental Method

Mode	Experimental frequency in Hz
1	7.6769
2	48.1001
3	63.5854
4	134.6906
5	229.1626
6	264.0133
7	391.4638
8	436.6341
9	652.6247
10	688.8954

The present experimental results are based on the assumption that one end of the cantilever beam is properly fixed. However, in actual practice it may not be always the case because of flexibility in support. The experimental values obtained are 7.6769 Hz and 688.8954Hz for first and last modes respectively.

V. SUMMARY OF RESULT

The numerical (FEA) calculated natural frequency and the experimental are found good agreement. The correction for the mass of the sensor will improve the correlation better. The present numerical (FEA) results and experimental results is based on the assumption that one end of the cantilever beam is properly fixed. However, in actual practice it may not be always the case because of flexibility in support. The summary of analysis of result summarized as show in table 3.

Table 3: Summary of result in Percentage error

Mode	Numerical (FEA) frequency in Hz	Experimental frequency in Hz	Percentage Error %
1	7.6769	7.6769	0
2	48.1	48.1001	0.0001
3	63.585	63.5854	0.0004
4	134.69	134.6906	0.0006
5	229.16	229.1626	0.0026
6	264.01	264.0133	0.0033
7	391.46	391.4638	0.0038
8	436.63	436.6341	0.0041
9	652.62	652.6247	0.0047
10	688.89	688.8954	0.0054

VI. CONCLUSION

We have studied the free vibration of fixed free beam by using experimental approach and the numerical (FEA) approach using the ANSYS program, it has been found that the relative error between these two approaches are very minute. The percentage error between the numerical (FEA) approach and the experimental approach are allowed up to 5% to 7%. Firstly we obtained the results for mode shape frequency numerically (FEA) and analyzing this mode shape frequency by experimental on the fixed free beam which we were used in this paper. The numerical study using the ANSYS program allows investigates the free vibration of fixed free beam to find out mode shape and their frequencies with high accuracy. The experimental mode shape frequency values are also compared with the numerical (FEA) results that are obtained from the ANSYS software. It is observed that the numerical (FEA) results values are in-tuned with the experimental values. The procedure and experimental models that are used in this paper are very useful to researchers who willing to work experimental analysis.

VII. ACKNOWLEDGEMENTS

We gratefully acknowledge department of mechanical engineering of **Rajarshri College of Engineering, Tathawade, Pune (India),** for technical support and providing the research facilities. Their help and dedication toward our work and related research, also their library staff and expert for their directly & indirectly help, support and excellent co-operation.

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