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Modeling and Analysis of a Cantilever Beam

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ABSTRACT: The aim of this project is to study the control fundamental frequency of the fixed free beam by using experimental approach, theoretical and numerical approach using the ANSYS programme. For control the natural frequency different masses are attached to cantilever beam with different cases. The concept of analysis plays important role in the design of practical mechanical system or any civil engineering structures. So it becomes important to study its effects on different frequency domain. The theoretical, numerical (FEA) calculated natural frequency and experimental are found good agreement. The finite-element method is the most powerful method of analysis for its flexibility and accuracy. Results were compared and found almost similar. In this project, main focused was on the passive dynamic vibration absorber and future scope of this project will be the development of an active dynamic vibration absorber

KEYWORDS: ANSYS, Finite Element Analysis

I. INTRODUCTION

Vibration is one of the major issues in the environment, which may cause some serious injuries to the human health. Vibration may occur due to mechanical oscillation from industrial machines, railway track nearby human reside and many more reasons. The term vibration represents the mechanical oscillation about an equilibrium point. The oscillation may be periodic or arbitrary for e.g., the motion of a pendulum, the movement of a wheel on a grave road. There are two types of vibration, namely free vibration and forced vibration. Free vibration occurs when a mechanical system start with an initial input and then allowed to quiver freely. The mechanical system will then quivers at one or more of its natural frequency and fall down to zero. Forced vibration occurs when an alternating force or action is applied to a mechanical system. Some of examples are quivering of washing machine due to an imbalance, transportation vibration.

Vibration analysis is one of the vital tasks in designing of structural and mechanical system. Vibration of any system is characterized by its fundamental natural frequency and effect of external excitation frequency on it. Excitation frequency is generated from the external sources like earthquake, other parts present in assembly, when the excitation frequency equals the natural frequency of the structural elements resulting in an infinite response. This is called resonance, could lead to severe problems like sudden damage, mechanical failure in structural elements. It is essential to keep the natural frequency of the system away from the excitation frequency to avoid resonance. In this project, free vibration of cantilever beam and control of fundamental frequency have been studied.

The objective of this work is to control the natural frequency of the cantilever beam by passive control system. Spring mass systems attachments have been used extensively to control the natural frequency of the cantilever beam. Furthermore, mathematical models of free vibration of a cantilever beam and with attached spring mass system have been developed. Spring mass systems attached in series and in parallel connection with cantilever beam have been investigated for its effect on the natural frequency of the cantilever beam. The developed mathematical models have been validated with numerical and experimental analysis. Further the optimum numbers of spring mass system and optimum mass have been concluded.

II. LITERATURE SURVEY

Thota Nithin Prabhakar et al.[1] have studied about the vibration behaviour of rectangular beams with different end conditions i.e. for simply supported and cantilever type was determined. This behaviour was estimated for two different materials namely aluminium (Al6063L) and mild steel (304L). Initially five natural frequencies for simply supported and cantilevered conditions were investigated using Rayleigh-Ritz method for both aluminium and mild steel. Vibration behaviour of rectangular beam under different end conditions and different material properties were carried out experimentally and results were validated. It was observed that the experimental results were in very close agreement with both theoretical and Ansys results.

R. B. Barjibhe et al. [2] has performed numerical and experimental analysis of cantilever beam with shape memory alloy springs connected in parallel. The results demonstrate the effectiveness of using SMA springs based DVA for controlling vibration both in experimentally and numerically. The numerical results were closely mapping with the experimental results and percentage of error was less than 7%. The results demonstrate that the SMA springs were more effective in vibration control.

Indrajeet J Shinde et al. [3] has performed experimental modal analysis. Experimental Modal Analysis (shortened as EMA) is a method to predict the behaviour of a system by effectively using the modal or vibration data. It helps in understanding and evaluating the dynamic behaviour of a system in actual scenario. In this paper, an attempt was made to study the free vibration analysis of the cantilevered beams of different materials and lengths using the EMA technique. EMA was implemented using the OROS FFT analyzer and NV Gate software to acquire the vibration data of the specimens. The results obtained by experimentation were cross checked using the ANSYS simulation package.

S. P. Chaphalkar et al.[4] has studied the free vibration of fixed free beam by using experimental approach and the numerical (FEA) approach. Firstly obtained results for mode shape frequency numerically (FEA) and analyzing this mode shape frequency by experimental on the fixed free beam. It is observed that the numerical (FEA) results values are in-tuned with the experimental values.

D.B. Jadhav et al. [5] have described classical beam theories to study the modal characteristics viz. mode shapes, frequency and damping. The change of modal characteristics provides an indication of structural condition based on changes in frequencies and mode shapes of vibration. In the present work, a setup for the beam vibrations with different configurations was developed economically. Further a case study was presented, whereby cantilever beam specimens with different materials were checked using FFT analyzer on the setup developed and the results were validated using ANSYS package.

Mohammad Vaziri et al. [6] have investigated lateral vibration. Static and dynamic analysis of the cantilever beam has been carried out. In the experimental analysis, Accelerometer was used along with a device called as Fast Fourier. Analytical and experimental analysis was carried out with respect to the mode shapes of Aluminum cantilever beam. Furthermore they introduced analytical and numerical analysis for frequencies of cantilever beams made of Isotropic Polymer, Mild Steel, and Aluminum beam.

A.P. Parameswaran et al.[7] have explained the active vibration control system. All mechanical systems suffer from undesirable vibrations during their operations. Their occurrence is uncontrollable as it depends on various factors. However, for efficient operation of the system, these vibrations have to be controlled within the specified limits. In this paper, direct output feedback based active vibration control has been implemented on a cantilever beam using Lead Zirconate-Titanate (PZT) sensors and actuators. The designed algorithm was implemented on Lab View. Finally it was concluded that though active vibration control of the smart system was achieved, it was non-deterministic as well as non-sustained. Hence, it was concluded that experimental control of the vibrating smart beam needed to be performed on a real time operating system (RTOS) platform wherein deterministic and reliable control could be achieved.

J.P Chopade et al. [8] have presented the analytical analysis of transverse vibration of fixed free beam and investigated the mode shape frequency. All the analytical values were validated with the numerical approach method (finite element analysis) by using ANSYS program package. It has been revealed from the results that analytical data is in good agreement with numerical results with negligible error.

Kshirsager PrashantR.et al.[9] have performed theoretical and numerical analysis of vibration of cantilever beam and validated the obtained results with the experimentation. In this work theoretical natural frequencies and mode shape of the cantilever beam type main vibrating system i.e. cutting tool idealized by a cantilever with free ends was determined. Dynamic vibration absorber was designed and developed at one of the resonant frequencies of the main vibrating system. Natural frequencies and mode shapes of main vibrating system was determined using FFT analyzer and ANSYS. Experimental set up was developed to test the performance of vibration absorber for the cantilever beam type main system.



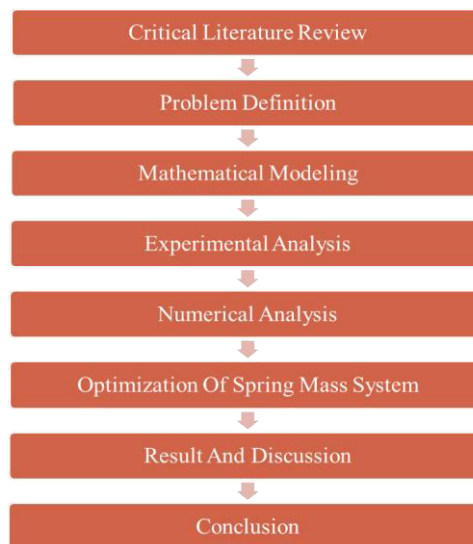
S.Mohammadi, et al.[10] has discussed free vibration analysis and vibration measuring system. Free vibration analysis is one of the fundamental points in vibration design. Most of the time, engineers are using cantilever beam as a simple model instead of complicated system. Therefore, in order to get familiar with this simplifying, they discussed the theoretical analysis of cantilever beam. Two vibration measuring systems, accelerometer and RFID systems have been introduced in study and concluded that RFID is easy to use and with respect to its price, RFID is more beneficial than using accelerometer.

TarsicioBelendez, et al. [11] have investigated the classical problem of deflection of a cantilever beam of linear elastic material, under the action of a uniformly distributed load along its length (its own weight) and an external vertical concentrated load at the free end was experimentally and numerically analyzed. They introduced differential equation governing the behavior of this system. It is observed that this differential equation, although straightforward in appearance, is in fact rather difficult to solve due to the presence of a nonlinear term. The ANSYS program was used to numerically evaluate the system and calculate Young's modulus of the beam material. Finally, numerical results were compared with the experimental ones obtained in the laboratory.

III. PROBLEM STATEMENT

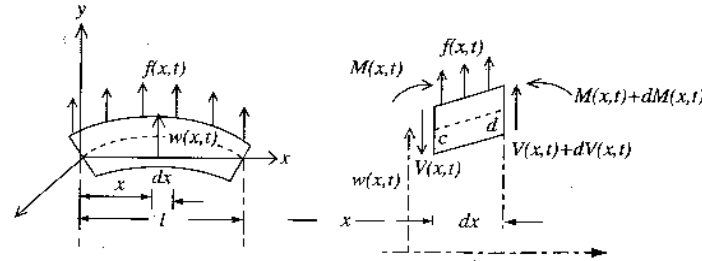
A cantilever beam can be used as a basic representative model for a number of advanced flexible engineering structures. There are two types of frequency which affect the behavior of the system, namely natural frequency and excitation frequency due to external forces. When excitation frequency equals the natural frequency of the structural elements it will result in an infinite response. This is called resonance, could lead to severe problems in vibrating systems. So damages the engineering or mechanical structures. When resonance created occur some serious injuries to human health. Destroy civil structures when equal the natural frequency and the excitation or external frequency. So should control the natural frequency of the structures in such situation, various types of vibration control systems can be used like active, passive, semi-active and hybrid.

IV. METHODOLOGY



V. TRANSVERSE VIBRATION OF CANTILEVER BEAM

Consider the free body diagram of an element of a beam shown in Fig. where $M(x, t)$ is the bending moment $V(x, t)$ is the shear force and $f(x, t)$ is the external force per unit length of the beam. Since the inertia force acting on the element of the beam.



We get the frequency of the cantilever beam is 1 st mode- 16.450 Hz, 2nd mode- 103.060 Hz, 3rd mode- 288.520 Hz, 4 th mode- 565.520 Hz, 5th mode- 934.850 Hz.

Parameters	Units
Material of Beam	AL
Length (l)	0.5 m
Width (b)	0.045 m
Height (h)	0.005m
Density	2700 Kg/m ³
Young's Modulus(E)	7 x 10 ⁹ N/m ²
Moment of inertia(I)	4.6875 x 10 ⁻¹⁰ m ⁴

VI. EXPERIMENTATION

Modal testing is a common method of characterizing the vibrations of a structure by imparting a known force and measuring the response of the structure. By measuring both the input to the structure and the response, the frequency response of the structure can be calculated. A typical impact test will use an impact modal hammer and a response accelerometer. It is important to consider the scale of the test structure when selecting these sensors.

The impact hammer imparts an impulse force into the system and is intended to excite a broad bandwidth. The Impact hammers range in size, sensitivity, and hardness depending on the scale of the system they need to excite and the bandwidth of interest. Similarly, the response accelerometer needs to be sensitive enough to detect the ringing of the structure without saturating. The output of the impact hammer and accelerometer are used to calculate the frequency response functions (FRFs) across the structure.

VI. (a) Procedure for Experimentation

- A cantilever beam of aluminium material is taken, dimensions length (l) 0.5 m, width (b) 0.045 m, height (h) 0.005 m.
- One end of the cantilever beam is fixed.
- The connections of the FFT analyzer, laptop, transducers, and modal hammer along with the requisite power connections were made.
- The accelerometer was fixed at the free end of the cantilever beam.
- The hammer was kept ready to strike the plate at the singular points.
- Then start the measure the frequency of cantilever beam without mass attached.
- Then modal hammer was struck once and the amplitude Vs frequency graph was obtained from graphical user interface.
- Then taken 50gm mass is attached at the end of the beam with the help of spring , spring material steel, wire diameter 0.00075 m, mean diameter 0.006 m, number of turns 20. Then hammer struck once and measure frequency.
- Then same 50gm two springs mass attached in series and measure the frequency.
- Then same 50gm three springs mass attached in series and measure the frequency.
- Then 50 gm single-single springs mass attached in parallel. One mass attached in end of beam and other mass attached middle of the beam and hammer was struck once then measure the frequency.
- Then 50gm two-two spring mass attached in parallel. One mass attached in end of beam and other mass attached middle of the beam and hammer was struck once then measure the frequency.

- Then 50gm three-three spring mass attached in parallel. One mass attached in end of beam and other mass attached middle of the beam and hammer was struck once then measure the frequency
- Above procedure was repeated for 100gm, 150gm, 200gm, 250gm, 300gm, 350gm and 73.64gm.
- The FFT analyzer and the accelerometer are the interface to convert the time domain response to frequency domain. Hence the frequency response spectrumH1 (response, force) was obtained.
- By moving the cursor to the peaks of the FFT graph, the cursor values and the resonant frequencies were recorded.
- At the time of the striking with modal hammer to the singular point precautions were taken whether the striking should have been perpendicular to the aluminum beam surface.
- The values (i.e., natural frequencies and resonant frequencies) obtained from the FRF spectrums were compared with respect to the FEM analysis.
- Two graph generated Time domain (time Vs amplitude) and frequency domain (amplitude Vs frequency).

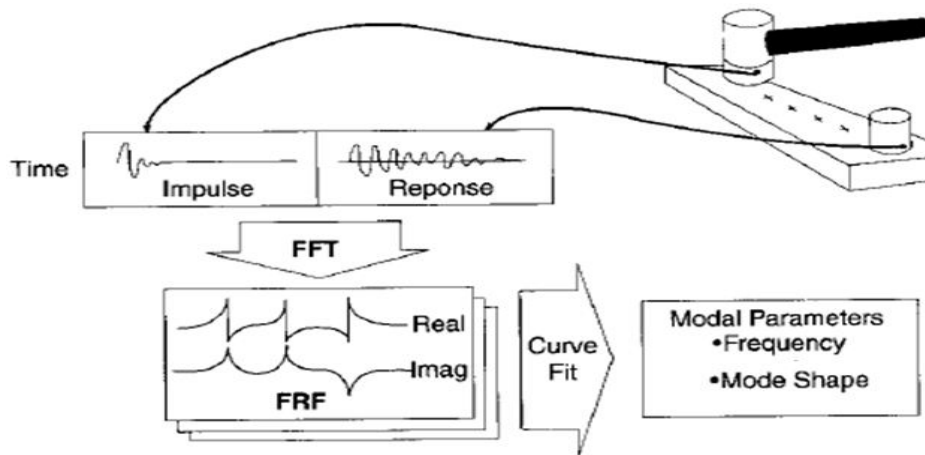


FIGURE 1: Experimental Set-Up Line Diagram

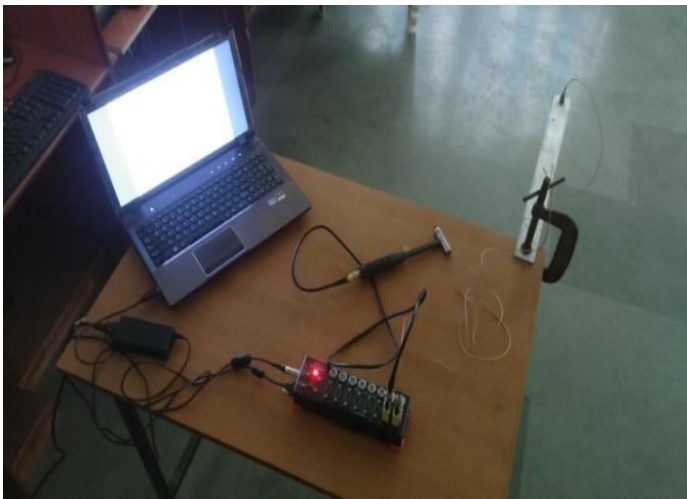


FIGURE 2: Experimental Set-Up



FIGURE 3: Experimental Set-Up

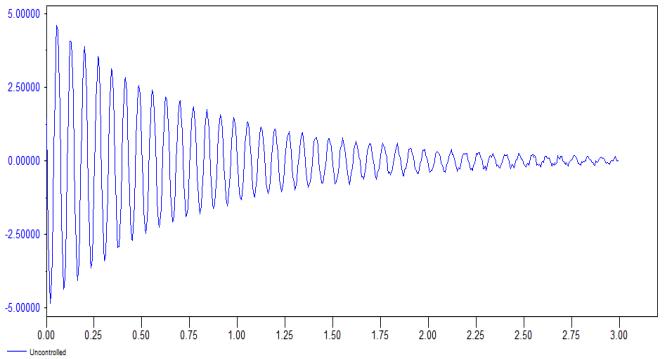


FIGURE 4: Settling Time graph of No Mass Attached at the Cantilever Beam

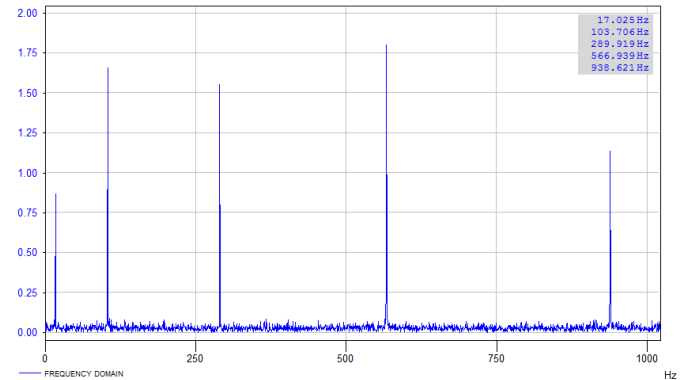


FIGURE 5: Frequency Response Graph of No Mass Attached at the Cantilever Beam

VII. FINITE ELEMENT ANALYSIS

It is not always possible to obtain the exact analytical solution at any location in the body, especially for those elements having complex shapes or geometries. Always what matters are the boundary conditions and material properties. In such cases, the analytical solution that satisfies the governing equation or gives extreme values for the governing functional is difficult to obtain.

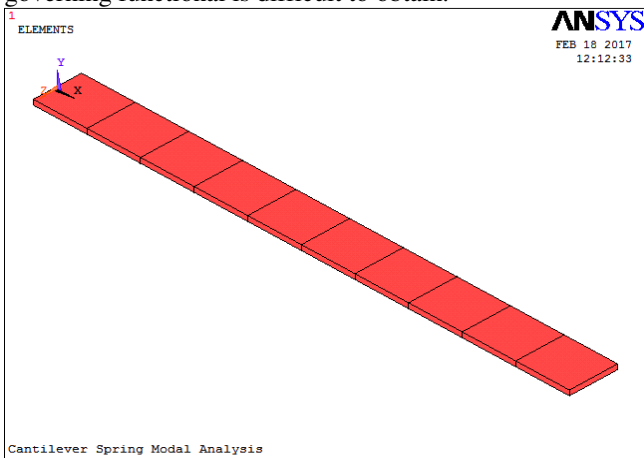


FIGURE 6: Frequency of The Cantilever Beam with No Mass Attached

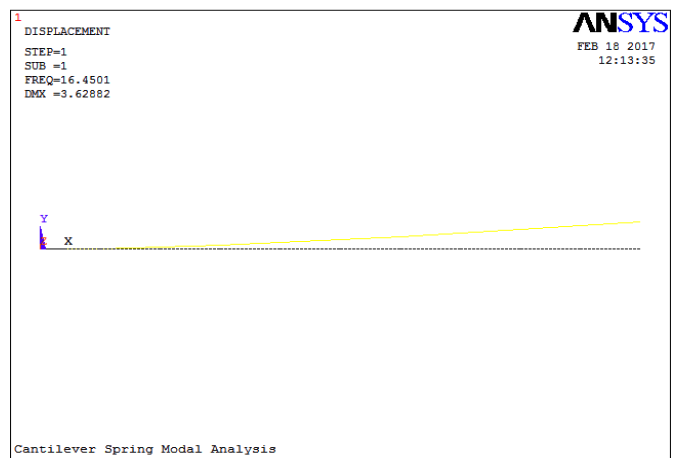


FIGURE 7: Frequency of Cantilever Beam

VIII. RESULT AND DISCUSSION

1. The theoretical, numerical (FEA) calculated natural frequency and experimental are found good agreement. For control the natural frequency different masses are attached to cantilever beam with different cases.
2. When the external forces and the natural frequency of the structure is same that time resonance created.
3. Firstly we found the frequency when attached the masses at the series and parallel. Masses increases simultaneously weight of structure also increases. So Optimized mass find the natural frequency by the experimentally and the ANSYS. Optimized frequency is less than the natural frequency of the no mass attached, so control natural frequency simultaneously resonance is not created.
4. Shows the graph of the no load and the optimized mass attached at the beam by the Theoretically, Ansys and the experimentally



	Mass (gm)	Theoretical Frequency (Hz)	ANSYS Frequency (Hz)	Experimental Frequency (Hz)
No. Mass	0	16.45	16.45	17.025
Single Mass	73.64	10.125	10.194	10.968
Two Mass	73.64	7.154	7.331	7.753
Three Mass	73.64	5.31	5.718	5.935

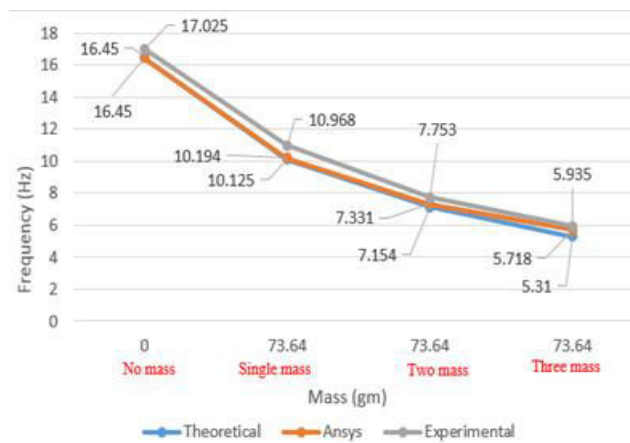


FIGURE 8: Mass is Attached in Series with Different Cases

	Mass (gm)	Theoretical Frequency (Hz)	ANSYS Frequency (Hz)	Experimental Frequency (Hz)
No. Mass	0	16.45	16.45	17.025
Single-Single Mass	73.64	9.399	9.964	10.625
Two-Two Mass	73.64	7.04	7.173	7.59
Three-Three Mass	73.64	5.412	5.611	6.17

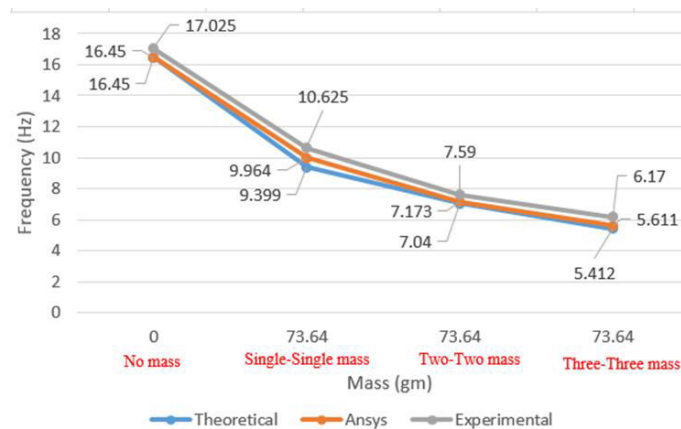


FIGURE 9: Mass is Attached in Parallel with Different Cases

IX. CONCLUSION

We have studied the control the fundamental frequency of the fixed free beam by using experimental approach, theoretical and numerical approach using the Ansys programme, it has been found the relative error between these very minute. Firstly we obtain the result from without mass attached cantilever beam and then various masses attached to cantilever beam, then using optimized weight finding the natural frequency. This optimized weight attached series and parallel result is the frequency is less than the fundamental frequency of the cantilever beam. So, we control the resonance. When optimized weight is attached to cantilever beam natural frequency is less than the fundamental frequency and also structure weight is in controlled.

The finite-element method is the most powerful method of analysis for its flexibility and accuracy. Results were compared and found almost similar.

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