Finite Element Analysis of Cantilever Beam to Reduce Ill Effect of Vibration

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Abstract **- In this paper cantilever beam model is design and studied. The smart cantilever beams is developed to calculate the beams dynamic characteristics. Comparative study of conventional cantilever beam and smart cantilever beam vibrations under identical condition are studied. To derive the governing differential equation of motion Euler-Bernoulli beam theory has been employed in the finite element form for the Magneto-Rheological (MR) fluid sandwich beam. The finite element is used for free vibration analysis of the cantilever beams, the natural frequencies, mode shapes and the static deflections of the cantilever beams are calculated. Vibration behavior of MR fluid filled beam is analyzed by using FEA (ANSYS14) and experimentally. Obtained results of smart beam are comparing with conventional beam result and validate through experiment. Change in frequencies and amplitude is observed every mode shape of cantilever beam with the aim of suppress or reduces the vibration.**

IndexTerms **- Cantilever beam, Magneto-Rheological (MR), Analytical analysis, Finite element analysis, Vibration analysis.**

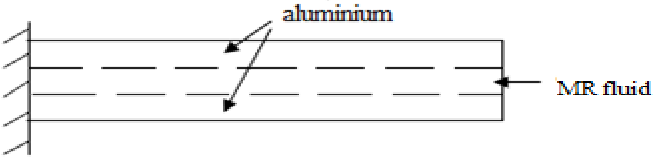
I. INTRODUCTION

The mechanical system or structure show vibrational response when exposed to external disturbances. In various engineering applications vibrations are undesirable and its may lead to poor performance and may have harmful effects. Therefore, vibration control is an important now days. It is desired to design lighter mechanical systems carrying out higher workloads at higher speeds.. In general, vibration suppression aims to avoiding the resonance frequency of the system gain at and around one or more of the modal frequencies. This is control by dissipating energy at the desired frequency. Vibration suppression can be achieved using two methods: passive damping and active damping. The passive damping method works by adding a viscoelastic material that is designed to dissipate energy in order to reduce vibration response. Passive vibration suppression is achieved using viscoelastic material which is added between lamina in a composite layer in order to improve energy dissipation.[4]

Smart materials and passive control method can be used to eliminate the undesired vibration. This combination of smart material and passive vibration control paid considerable attention in the last decade especially in the space structures application. The cantilever beams are commonly used in various types of mechanical instrument and applications. The study is to analyze the smart beam for vibration suppression. A simple sandwich cantilever beam system is selected to study the performance of Magneto- rheological (MR) fluids in adaptive structures. The efficient control is the one that allows limiting the displacement amplitude and provides shorter stabilization time than the passive treatment. [5] In this study we present the vibration analysis of cantilever beam using MR fluid as a smart material. The cantilever beam structure is analyzed by FEA (ANSYS14) with their natural frequency, mode shape, static deflection and vibration behavior of cantilever beam structure with smart material and conventional beam is observed.

II. MODELING OF SMART CANTILEVER BEAM

The smart structure is modeled based on the concept of Bernoulli - Euler beam theory, using Finite Element Method (FEM). Straight cantilever beam with rectangular cross section has one end is fixed and other end free is designed shown in Figure-1. Cantilever beam made of aluminium material and MR fluid is filled inside the beam.



Fg.1: Schematic representation of MR fluid cantilever beam

Table.1 Illustrate the properties of the mentioned material with which the beam is made.

Material	Density ρ [kg/m^3]	Young's Modulus E[GPa]	Poisson's ratio ϑ
Aluminium	2700	70	0.33
MR	3000	224	0.4

Magneto-rheological (MR) fluids use as smart fluids which are capable to changing their viscosity from liquid to semi-solid state in few seconds when magnetic field is applied and properties can be controlled with the help of metal particles and magnetic field. Therefore fluids have the ability to transmit force in a controlled manner with the help of magnetic field, thus improving their performance in areas where controlled fluid motion is required.

MR fluids can exhibit higher yield stresses. ER fluids require expensive high-voltage power, while MR fluids require small magnetic fields, which produced by low-voltage magnetic coils..MR fluids are operating effectively from -40 to +150 C. In the absence of magnetic field Magneto-Rheological (MR) fluid is in a free-flowing liquid state and when magnetic field is applied each magnetic particle forms a dipole.

III. ANALYSIS

Modal analysis is a worldwide used methodology that allows fast and reliable identification of system dynamics in complex structures. The Structures vibrate in special shapes called mode shapes when excited at their resonant frequencies. A mode shape defined by relative amplitudes of the extreme positions of vibration of a system at a single natural frequency is the characteristics deformation. The natural frequencies, modal masses associated with each of the mode shape and damping ratio are the modal parameters. The structure will vibrate in a complex combination of all the mode shapes under the normal operating conditions. Modal analysis is use to measuring and predicting the mode shapes and frequencies of a structure.

Through performing of Modal Analysis, the following Frequencies can be obtained with respect to mode shape. Frequencies can be obtained with respect to six mode shapes vibration of cantilever beam for simple and smart cantilever beam. The values of natural frequencies for a simple cantilever beam made of aluminium with rectangular cross section calculated analytically and by using ANSYS14 software are shown in table II. These values are shown in table for a simple cantilever beam with uniform and rectangular cross section, natural frequency can be obtained by the following formula:

$$\omega_n = \frac{1}{2\pi}(\beta l)^2 \sqrt{\frac{EI}{\rho A L^4}} \qquad (1)$$

Where,
A=Area of cross section,
L=Length of the beam,
(βl)= Constant relative to vibration bound condition,
(EI)=Equivalent bending stiffness

FEM model of smart cantilever beam which is used for modeling is done in ANSYS14.Then pre-processing of the only aluminium material and aluminium with MR fluid beam is done on the ANSYS 14 in which solid186 element type is used for geometry and it meshed by using tetra fine mesh.. The equivalent material properties are assigned to the smart model. The properties of the aluminium are Modulus of Elasticity is (E) is $54*10^9$ Pa, poisons ratio 0.18 and density 1421kg/m^3 .The boundary condition is and constraints applied to fixed end of beam. Modal analysis of both simple aluminium and smart cantilever beam is done by using ANSYS14

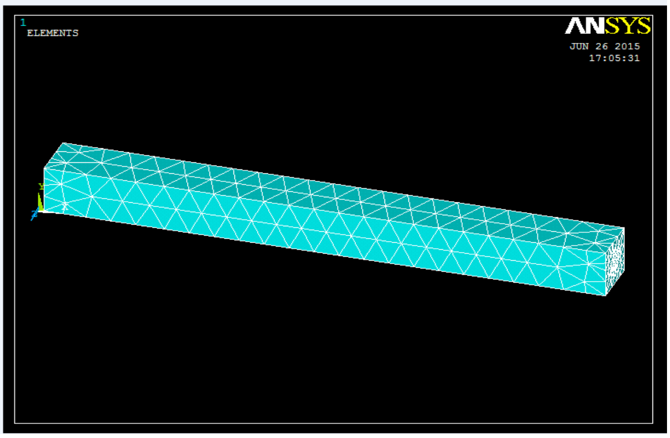


Fig.2 Finite element model after meshing

This work deals with free vibration analysis i.e. no external force is applied on structure or component at the time of analysis. All real life objects have infinite natural frequencies but finite element analysis can compute natural frequencies equal to degree of freedom of FE model only. The damping is usually neglected for free vibration analysis. ANSYS 14 software is used to calculate the natural frequencies and mode shapes of the structure. Applying the boundary conditions to the structure, modal analysis used it's one of the type of FE analysis to determine six modes of natural frequencies for the smart cantilever beam and comparing both result to each other.

The natural frequencies of aluminium beam are calculated analytically and by using ANSYS14 with respect to six modes of vibration of cantilever beam shown in table-2

Table.2 Natural Frequencies for Aluminium beam

Mode Shape	Analytical Frequency Hz	ANSYS Frequency Hz	% Deviation
1	329.00	329.00	0%
2	2061.76	1980.4	3%
3	5381.93	5234.5	2.5%
4	11313.13	9559.4	15%
5	18701.65	14654.7	21%
6	27937.62	20363.9	25%

Figure.3 shows the comparison frequencies of aluminium beam analytical and ANSYS14

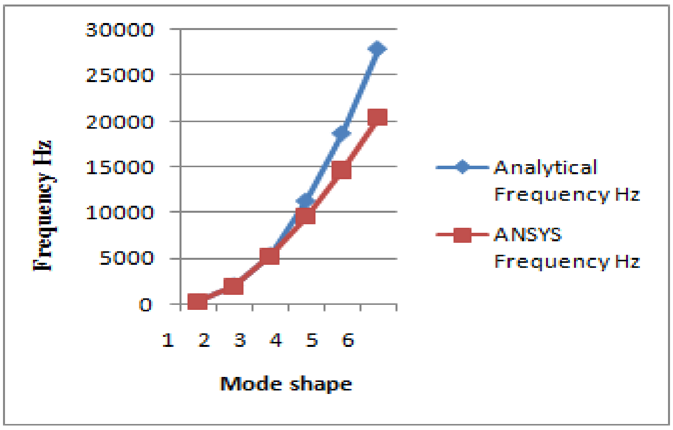


Fig.3 Natural frequency Vs mode shape for aluminium beam

FE model is used for finding the natural frequencies of smart Magneto-Rheological (MR) fluid filed cantilever beam.tne frequency obtained from ANSYS14 and analytically are shown in table III.

Table.3 Natural frequencies for Magneto-Rheological (MR) filled sandwich cantilever beam

Mode Shape	Analytical Frequency Hz	ANSYS Frequency Hz	%Deviation
1	395.84	393.69	7%
2	2774.19	2368.07	9%
3	6944.54	6238.3	10%
4	13611.40	11413.9	16%
5	22500.89	17465.5	20%
6	33613.21	24119.1	25%

Figure.4 shows the frequency comparison of smart Magneto-Rheological (MR) sandwich cantilever beam analytically and ANSYS14 with respect to six modes of vibrations.

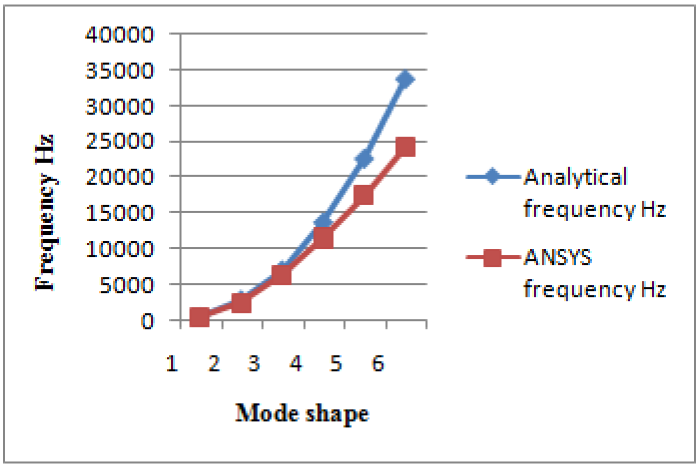


Fig.4 Natural frequency Vs mode shape for MR sandwich beam

IV. EXPERIMENTAL SET UP AND RESULTS

The validation of the present result is done through the experiment; an experiment has been conducted further validation of the present work in universal vibration lab. The FFT analyzer is used for performing experiment. The devices used for the experiments included- a rigid fixture for holding or mounting beam then because of which it acts like cantilever beam, accelerometer, an amplifier, data acquisition system i.e. Fast Fourier transform Analyzer (FFT) instrument .The experiment set up is as shown in fig-6 the testing object i.e. cantilever beam is arranged for obtaining necessary boundary conditions. Experimental setup as shown in Figure.5

Fig.5 Experimental setup

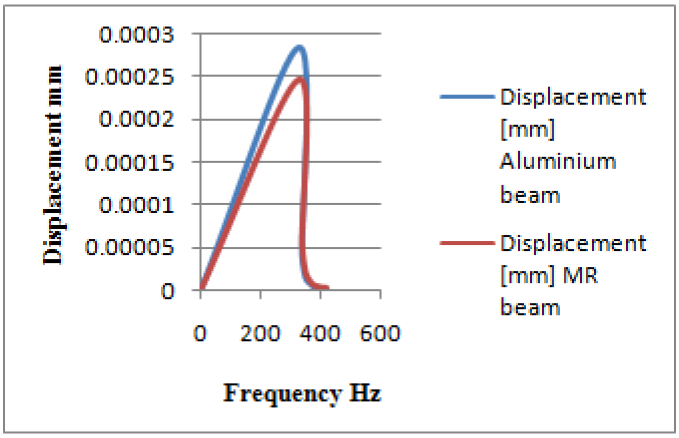


Fig.6 Comparison displacement of aluminium and MR cantilever beam for first mode

V. CONCLUSION

The finite element ANSYS 14 is used for free vibration analysis of the smart sandwich beams; the natural frequencies, mode shapes and the static deflection of the sandwich beams are calculated. The obtained results such as static deflections and natural frequencies are compared with that obtained from the ANSYS14 and experimentation. .According to the readings and plotted graph for aluminium and smart MR fluid filled sandwich beam, changes in natural frequencies and displacement is observed. It's observed that displacement of Magneto-Rheological (MR) filled cantilever beam, first mode of vibration of beam is decreased as compared to simple beam made of only aluminium material.

From Figure.6 its conclude that maximum amplitude for aluminium cantilever beam which is decreases when we can uses the smart material in beam structure .Therefore the structural vibration can be suppressed by using smart materials in cantilever beams and structures.

Proposed work will be done on design and analyze the composite cantilever beam or structure for reduce the unwanted vibration using smart material i.e. Magneto-Rheological (MR) fluid.

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