Design and Fabrication of Free-Free Beam

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***Abstract-* This project involves the fabrication of a FREE-FREE BEAM. This setup is used transmit energy in the form of vibration to the free-free beam for vibration analysis. It is one of the low cost experimental setup which is used in laboratories for analysis the mode shape and the natural frequency of vibration. The transverse vibration can be defined as the vibrations in which the element moves to and fro in a direction perpendicular to the direction of the advance of the wave. Its primary function is to be used for studying of vibrations on free-free beam and also the properties of a material used in the beam. The mode shape which varies with excitation frequency can be demonstrated.**

Index Terms- free-free beam, frequency of vibration, vibration analysis.

1. INTRODUCTION

The motion repeats itself with an interval of time is called vibration. The theory of vibration deals with the study of motions and the forces. The vibration of a system involves the transfer of its potential energy to kinetic energy and of kinetic energy to potential energy, alternately. If the system is damped, some energy is dissipated and must be replaced by an external source. The Number of degree of freedom required to determine complete positions of all parts of a system.

A large number of practical systems can be described using a finite number of degrees of freedom but some systems, especially those involving continuous elastic members, have an infinite number of degrees of freedom. The infinite number of coordinates defines its elastic deflection curve. Thus the cantilever beam has an infinite number of degrees of freedom. Most structural and machine systems have deformable (elastic) members and therefore have an infinite number of degrees of freedom. Systems with a finite number of degrees of freedom are called discrete or lumped parameter systems, and those with an infinite number of degrees of freedom are called continuous or distributed systems.

2. IMPORTANCE OF THE STUDY OF VIBRATION

Most human activities involve vibration in one form or other. For example, we hear because our eardrums vibrate and see because light waves undergo vibration. Breathing also a vibration of lungs and Human speech also requires the vibration. In recent times, many investigations have been motivated by the engineering applications of vibration, such as the design of machines, foundations, structures, engines, turbines, and control systems. Most prime movers have vibration problems due to the inherent unbalance in the engines. The unbalance may be due to faulty design or poor manufacture. Imbalance in diesel engines, for example, can cause ground waves sufficiently powerful to create a nuisance in urban areas. The wheels of some locomotives can rise more than a centimetre off the track at high speeds due to imbalance. In turbines, vibrations cause spectacular mechanical failures. Engineers have not yet been able to prevent the failures that result from blade and disk vibrations in turbines. Naturally, the structures designed to support heavy centrifugal machines, like motors and turbines, or reciprocating machines, like steam and gas engines and reciprocating pumps, are also subjected to vibration. In all these situations, the structure or machine component subjected to vibration can fail because of material fatigue resulting from the cyclic variation of the induced stress. Furthermore, the vibration causes more rapid wear of machine parts such as bearings and gears and also creates excessive noise. In machines, vibration can loosen fasteners such as nuts etc.

3. MODE SHAPE

A mode shape is a specific pattern of vibration executed by a mechanical system at specific frequency. Modes are inherent properties of a structure and are determined by material properties and the boundary condition of the structure. A normal mode of an oscillating system is as pattern of motion in which all parts of system move sinusoidally with the same frequency and with a fixed phase relation. On the mode shape the node represents the point where the amplitude of vibration is zero and the anti-node represents the point where the amplitude of vibration is maximum.

4. VIBRATION ANALYSIS PROCEDURE

Vibratory system is a dynamic one for which the variables such as the excitations and responses are time dependent. The response of a vibrating system generally depends on the initial conditions as well as the external excitations. Most practical vibrating systems are very complex, and it is impossible to consider all the details for a mathematical analysis.
A basic steel frame was designed to hang the free-free beam. The 12V D.C. Motor is selected as the components to transmit vibration on the beam. The method to control the speed of the motor was proposed. The steel square pipes are bought and welded to build the steel frame as per designed dimension. Holes are drilled to insert nut with hole to hang the beam with a help of nylon strings. The D.C.Motor along with a regulator is purchased and assembled near the beam to produce vibrations on the beam. A tachometer sensor along with displayed unit is assembled near the setup help adjust the speed of the motor. Then the displacement and speed of the motor are recorded. Finally the natural frequency of the beam can be calculated and the mode shapes can also be demonstrated by spreading sand on top of the beam.

5. LITERATURE SURVEY

The value of young's modulus was determined by theoretical, analytical and practical methods and compared.the free-free model of a transversely vibrating beam which is euler-bernoulli model was examined. The results of practical method had variations with theoretical and analytical methods due to non-linearity which are not considered in theoretical and numerical analysis.
Dynamic characteristic of system changes if there is any damage in structure. In structure and machinery, one undesirable phenomenon is crack initiation which gradually leads failure of system. In order to estimate crack location and depth in the beam, we can compare the natural frequency of cracked and intact system.
Solid edge and PRO-E was used for CAD designing of transmission gearbox casing and FEA based ANSYS was used for modal analysis. Similar boundary conditions were used for different materials like gray cast iron, structural steel etc. It was concluded that the mechanical properties are directly related with natural frequency an vibration mode shapes. FEM model of the beam was created and simulation work was carried out on ANSYS software to compare with experimental model and computational model. Error was observed between mathematical, experimental value and ANSYS value is because a real beam material is not perfectly homogeneous,elastic and isotropic as is considered by ANSYS.
Free-free configuration is selected as it is easier to replicate these boundary conditions in both experiment and analytical model. Natural frequencies obtained using accelerometer and FFT analyze are lower than obtained analytically or numerically using software based modal analysis. The difference could be attributed to the change in the boundary conditions, variation in geometric model simulating the real system, change in material properties and effect of accelerometer mass with its location on the beam. The ANSYS software simulates the additional mass effect and gives the effect of drop in natural frequencies in congruence with the trend observed experimentally. The mass loading correction factor can be obtained from numerical modal analysis with ANSYS.
It was concluded that natural frequency increases in mode number. The effect of the type of the boundary conditions with increasing mode number. Natural frequencies increase with increasing cross sectional area but decrease with increasing length
All real physical structures, when subjected to loads or displacements, behave dynamically. Many developments have been carried out in order to try to quantify the effects produced by dynamic loading. One of the major problems in these machineries is the fatigue and the cracks initiated by the fatigue. To

predict the Failure, vibration monitoring can be used to detect changes in the dynamic responses and/or dynamic characteristics of the structure. The verification of the analytical approach with a considerable amount of experimental data and with the results of calculations showed that the analytical approach enables one to obtain well-founded relationships between different dynamic characteristics and crack parameters and to solve the inverse problem of damage diagnostics with sufficient accuracy for practical purposes.

It is important, then, to know the natural frequencies of the coupled beam-mass system, in order to obtain a proper design of the structural elements. The model allows to analyse the influence of the shear effect and spring-mass systems on the dynamic behaviour of the beams by using Timoshenko Beam Theory (TBT).The natural frequencies of Timoshenko multi-span beam calculated by using secant method for non-trivial solution are compared with the natural frequencies of multi-span beam calculated by using Bernoulli–Euler Beam Theory (EBT).study, frequency values and mode shapes for free vibration of the multi-span Timoshenko beam with multiple spring-mass systems are obtained for different number of spans and spring-masses with different locations.This result indicates that shear effects lead to reduction in natural frequency values.

6. DESIGNED MODEL

The design has done using AutoCAD inventor software, the main components are cover frame, and spring used to hang the beam and vibration beam. The simplest view is shown clearly below.

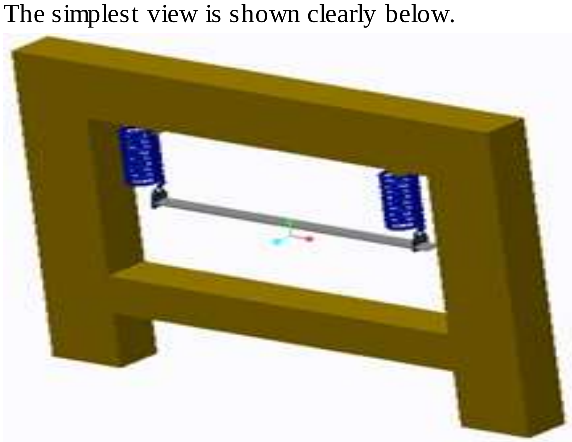

Fig: 6.1 view of free –free beam designed by AutoCAD inventor.

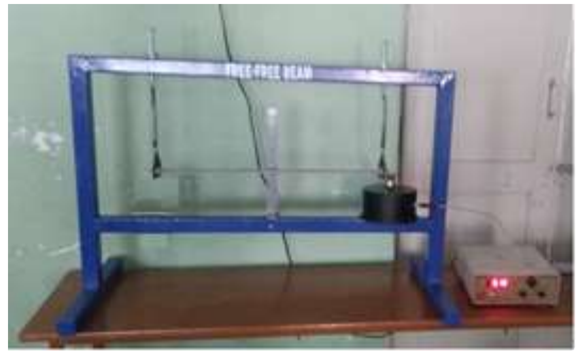

Fig: 6.2 view of free –free beam model

7. DESIGN CALCULATION

Dimension of frame:

The size of steel frame should be small enough to be placed table.

length x width x thickness = 900mm x 750mm x 30mm

Angular velocity:

$$\omega = \frac{2\pi N}{60} = \frac{2\pi}{60} x3000 = 314.15 \text{ rad/s}$$

Mass of the Beam :

M = Density x Volume = 0.0077 x (500 x 32 x5) = 616 g

Stiffness of spring:

$$s = \frac{\omega^2}{m} = \frac{314.5^2}{616}$$

= 160.5 kg/mm

Frequency of Vibration:

At 3000 rpm we can obtain the following frequency

$$f = \frac{1}{2\pi} x \sqrt{\frac{s}{m}}$$

$$= \frac{1}{2\pi} x \sqrt{\frac{133.8x1000}{160.5}} = 4.59 \text{ Hz}$$

8. CONCLUSION

The vibrations induced on free-free beam by the DC motor produces deflection which is measured using steel rule and the natural frequency can be calculated and the mode shape can be demonstrated. This setup can be used laboratories for the studying the vibrations of a beam. It fulfills its main objective to be used as experimental setup in laboratory.

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