NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 6 JUNE-2015

A Review of Vibration of a cantilever Beam

Prof. Vyankatesh S. Kulkarni
Department of Mechanical Engineering, Solapur University /BIT/Barshi/India

Abstract
Estimating damping in structure made of different materials (steel, brass, aluminum) and processes still remains as one of the biggest challengers. All materials posses certain amount of internal damping, which manifested as dissipation of energy from the system. This energy in a vibratory system is either dissipated into heat or radiated away from the system. Material damping or internal damping contributes to about 10-15% of total system damping. Cantilever beams of required size & shape are prepared for experimental purpose & damping ratio is investigated. Damping ratio is determined by half-power bandwidth method. It is observed that damping ratio is higher for steel than brass than aluminum.

Introduction
A wealth of literature exists in the area of vibrations of beams but while going through the literature regarding material damping of cantilever beams it has been figured out that still a lot of work has to be done regarding it. Usually whenever study of various materials has been done the focus of researchers has been damping, mode shapes, resonant frequency, etc. but material damping has not been paid much attention. Some important literatures are given below:

Literature Review

1. H H Yoo and S H Shin [4] Vibration analysis of a rotating cantilever beam is an important and peculiar subject of study in mechanical engineering. There are many engineering examples which can be idealized as rotating cantilever beams such as turbine blades or turbo engine blades and helicopter blades .For the proper design of the structures their vibration characteristics which are natural frequencies and mode shapes should be well identified. Compared to the vibration characteristics of non rotating structures those of rotating structures often vary significantly. The variation results from the stretching induced by the centrifugal inertia force due to the rotational motion. The stretching causes the increment of the bending stiffness of the structure which naturally results in the variation of natural frequencies and mode shapes. The equations of motion of a rotating cantilever beam are derived based on a new dynamic modeling method. With the coupling effect ignored the analysis results are consistent with the results obtained by the conventional modelling method. A modal formulation method is also introduced in this study to calculate the tuned angular speed of a rotating beam at which resonance occurs.

2. Mousa Rezaee and Reza Hassannejad [14] derived a new analytical method for vibration analysis of a cracked simply supported beam is investigated. By considering a non linear model for the fatigue crack, the governing equation of motion of the cracked beam is solved using perturbation method. The solution of the governing equation reveals the super harmonics of the fundamental frequency due to the nonlinear effects in the dynamic response of the cracked beam. Furthermore, considering such a solution, an explicit expression is also derived for the system damping changes due to the changes in the crack parameters, geometric dimensions and mechanical properties of the cracked beam. The results show that an increase in the crack severity and approaching the crack location to the middle of the beam increase the system damping.

In order to validate the results, changes in the fundamental frequency ratios against the fatigue crack severities are compared with those of experimental results available in the literature. Also, a comparison is made between the free response of the cracked beam with a given crack depth and location obtained by the proposed analytical solution and that of the numerical method. The results of the proposed method agree with the experimental and numerical results.

3. Chih Ling Huang,Wen Yi Lin,Kuo Mo Hsio[7]Rotating beams are often used as a simple model for propellers, turbine blades, and satellite booms. The free vibration frequencies of rotating beams have been extensively studied. Rotating beam differs from a non-rotating beam in having additional centrifugal force and Coriollis effects on its dynamics. The natural frequency of the flap wise bending vibration, and coupled lagwise bending and axial vibrations investigated for the rotating beam. A method based on the power series solution is proposed to solve the natural frequency of very slender rotating beam at high angular velocity. The rotating beam is subdivided into several equal segments. The governing equations of each segment are solved by a power series. Numerical examples are studied to demonstrate the accuracy and efficiency of the proposed method. The effect of Coriolis force, angular velocity, and slenderness ratio on the natural frequency of rotating beams is investigated. The Free vibration of the beam is measured from the position of the steady state axial deformation.

4. H.Ding,G.C. Zhang,LQ Chen[16]The axially moving beams has several applications, including robot arms, conveyor belts, high-speed magnetic tapes, and automobile engine belt. Understanding the vibrations of axially moving beams are important for the design of the devices. Recent developments in research on axially moving structures have been reviewed. Natural frequencies of nonlinear coupled planar vibration are investigated for axially moving beams in the supercritical transport speed ranges. The straight equilibrium configuration bifurcates in multiple equilibrium positions in the supercritical regime. The finite difference scheme is developed to calculate the non-trivial static equilibrium. The equations are cast in the standard form of continuous gyroscopic systems via introducing a coordinate transform for non-trivial equilibrium configuration. Under fixed boundary conditions, time series are calculated via the finite difference method. Based on the time series, the natural frequencies of nonlinear planar vibration, which are determined via discrete Fourier transform (DFT), are compared with the results of the Galerkin method for the corresponding governing equations without nonlinear parts. The effects of material parameters and vibration amplitude on the natural frequencies are investigated through parametric studies.

5. Liao-Liang Ke,Jie Yang, Sritawat Kitipornchai,Yang Xiang[13]Free vibration and elastic buckling of beams made of functionally graded materials (FGMs) containing open edge cracks are studied in this paper based on Timoshenko beam theory. The crack is modeled by a massless elastic rotational spring. It is assumed that the material properties follow exponential distributions along beam thickness direction. Analytical solutions of natural frequencies and critical buckling load are obtained for cracked FGM beams with clamped-free, hinged-hinged, and clamped-clamped end supports. A detailed parametric study is conducted to study the influences of crack depth, crack location, total number of cracks, material properties, beam slenderness ratio, and end supports on the free vibration and buckling characteristics of cracked FGM beams.

6. M.Shavezipur,S.M. Hashemi[10] A set of differential equations governing triply coupled vibrations of centrifugally stiffened beams, a refined dynamic finite element (RDFE) method is developed. The application of the proposed method is demonstrated to obtain numerical results for several examples. Some of these results are compared with those obtained from classical FEM and published results. As it was confirmed by numerical results, the RDFE method is a reliable solution method with drastically higher convergence rates compared to other numerical methods. The RDFE can be advantageously used when multiple natural frequencies and/or higher modes of the beam structures are of interest. It is important to note that the method is not limited to the equations introduced in this paper and can be extended to more advanced models whichmay include more geometric and material coupling terms. Many aerospace and terrestrial structures, such as aircraft wings, propeller blades, solar panels and satellite antenna, compressor, turbine and helicopter rotor blades, space structures, bridges, etc. can be modelled as a combination of beam elements with two or three coupled governing differential equations.

7.Michael I Frisswell,John E Mottershead[19] A Method is proposed for the replacement of unknown stiffness with rigid connections in two systems of equation from a finite element model and from measured response functions. The frequency response can be determined from standard modal tests and no special forcing arrangements or physical constraints are needed. The only use of constraints in mathematics where the physical behaviour of constrained system is inferred from the unconstrained measurements and predictions are obtained from constrained finite element equations since stiffness which are replaced by rigid connections can't experience any elastic strain they can have no effect on the inferred measurements from an elastic structure. The method can be used to determine erroneous connections in a finite element model or to locate discrete non-linearities. Simulated examples are used to illustrate the application of the technique.

8.Hamid Zabihi Ferezqi,Masoud Tahani,Hamid Ekhteraei Touss[15] This paper presents an analytical investigation of the free vibrations of a cracked Timoshenko beam made up of functionally graded materials (FGMs). It is assumed that the beam is constructed of FGM materials with a power law variation of metal-ceramic volume fraction. The perspective of wave method is adopted for the analysis. The method considers the nature of the propagation and reflection of the waves along the beam. Consequently, the propagation, transmission and reflection matrices for various discontinuities located on the beam are derived. Such discontinuities may include crack, boundaries or change in section. By combining these matrices a global frequency matrix is formed. In order to investigate the effect of the beam's structural synthesis, different natural frequencies are obtained and studied.

9.R. Lassoued, M. Guenfoud[8]An accurate procedure to determine free vibrations of beams and plates is presented. The natural frequencies are exact solutions of governing vibration equations witch load to a nonlinear homogeny system. The bilinear and linear structures considered simulate a bridge. The dynamic behavior of this one is analyzed by using the theory of the orthotropic plate simply supported on two sides and free on the two others. The plate can be excited by a convoy of constant or harmonic loads. The determination of the dynamic response of the structures considered requires knowledge of the free frequencies and the shape modes of vibrations. The formulation is based on the determination of the solution of the differential equations of vibrations. The boundary conditions corresponding to the shape modes permit to lead to a homogeneous system.

10.Metin O Kaya[9]There has been a growing interest in the analysis of the free vibration characteristics of elastic structures that rotate with constant angular velocity. Numerous structural configurations such as turbine, compressor and helicopter blades, spinning spacecraft and satellite booms fall into this category. A simple equation (known as the Southwell equation), which is based on the Rayleigh energy theorem to estimate the natural frequencies of rotating cantilever beams. Earlier studies mainly focused on Euler Bernoulli beams. However, due to the inclusion of shear deformation and rotary inertia effects, Timoshenko beam theory is more accurate than Euler Bernoulli beam theory. Therefore, considerable research has been carried out on the free vibrations of rotating Timoshenko beams, recently. Recently, the Dynamic Stiffness Method for a rotating cantilever Timoshenko beam that is based on Fresenius series expansion and claims its superiority of finding more correct results. On the other hand, the advantage of the DTM is its simplicity and high accuracy.

11.M.Shahidi,M.Bayat,I.Pakar,GR Abdollahzadeh[17]In this paper, the nonlinear governing equation of tapered beams, attempt has been made to analyze the nonlinear behavior of tapered beams analytically. The nonlinear governing equation is solved by employing the variational approach method (VAM) and Improved Amplitude-Formulation (IAFF). Despite the increasing expenses of building structures to maintain their linear behavior, nonlinearity has been inevitable and therefore, nonlinear analysis has been of great importance to the scientists in the field. The major concern is to assess excellent approximations to the exact solutions for the whole range of the oscillation amplitude, reducing the respective error of angular frequency in comparison with the VAM and IAFF. The effect of vibration amplitude on the nonlinear frequency is discussed. It is predicted that there can be wide application of VAM and IAFF in engineering problems, as indicated in this paper.

12.Sabah Mohammed Jamel Ali, Ziad Shakeeb Al-Sarraf[21] A numerical solution to the frequency equation for the transverse vibration of a beam (Simply Supported with symmetric overhang) is done. It is proposed two limiting cases of abeam with no overhang, and no span. This agrees with the cases in which the supports are at the nodal Points of a freely vibrating beam. Also the numerical results compared with the analytical solutions for this study are coincident. An approximation to the solution of the frequency equation for beams with small overhang is presented and compared with the numerical solution. This approximation is quite useful to determine a beam's flexural stiffness (EI), or modulus of elasticity (E), by free vibrating of a simply supported beam.

13.W.L. LI[22] A simple and unified approach is presented for the vibration analysis of a generally supported beam. The flexural displacement of the beam is sought as the linear combination of a Fourier series and an auxiliary polynomial function. The polynomial function is introduced to take all the relevant discontinuities with the original displacement and its derivatives at the boundaries and the Fourier series now simply represents a residual or conditioned displacement that has at least three continuous derivatives. As a result, not only is it always possible to expand the displacement in a Fourier series for beams with any boundary conditions, but also the solution converges at a much faster speed. The reliability and robustness of the proposed technique are demonstrated through numerical examples.

14.Gurgoze,H.Erol[5] The frequency response function is obtained through a formula, which was established for the reacceptance matrix of discrete systems subjected to linear constraint equations. The comparison of the numerical results obtained with those via a boundary value problem formulation justifies the approach used here. Frequency response is the quantitative measure of the output spectrum of a system or device in response to a stimulus, and is used to characterize the dynamics of the system. It is a measure ofmagnitude and phase of the output as a function of frequency, in comparison to the input. In simplest terms, if a sine wave is injected into a system at a given frequency, a linear system will respond at that same frequency with a certain magnitude and a certain phase angle relative to the input. Also for a linear system, doubling the amplitude of the input will double the amplitude of the output.

15.JinsuoNie,Xing Wei[18] This paper is aimed at determining how material dependent damping can be specified conveniently in ANSYS in a mode superposition transient dynamic analysis. A simple cantilever beam is analyzed using various damping options in ANSYS. The mode superposition method is often used for dynamic analysis of complex structures, such as the seismic Category I structures in nuclear power plants, in place of the less efficient full method, which uses the full system matrices for calculation of the transient responses. In such applications, specification of material-dependent damping is usually desirable because complex structures can consist of multiple types of materials that may have different energy dissipation capabilities. A recent review of the ANSYS manual for several releases found that the use of material-dependent damping is not clearly explained for performing a mode superposition transient dynamic analysis. This paper includes several mode superposition transient dynamic analyses using different ways to specify damping in ANSYS, in order to determine how material-dependent damping can be specified conveniently in a mode superposition transient dynamic analysis.

16.Shibabrat Naik, Wrik Mallik[20]Studied of substantial importance in complaint structures, now days ,are the dynamic parameters such as the modal frequencies and damping constant of their components. These parameters are the essential technical information required in engineering analysis and design. In addition this information is needed for numerical simulations and finite element modeling to predict the response of structures to a variety of dynamic loadings. In this work, experimental modal testing of a cantilever beam has been performed to obtain the mode shapes, modal frequencies and the damping parameters. A fast fourier transform analyzer, PULSE lab shop was used to obtain the frequency response functions and subsequent extraction of modal data was performed using ME's scope. These modal parameters were then checked using finite element analysis software, ANSYS which were found to comply with the experimental results. The range of applications for modal data is vast and includes checking modal frequencies, forming qualitative descriptions of the mode shapes as an aid to understanding dynamic structural behaviour for trouble shooting, verifying and improving analytical models. It is with this objective that the experimental method was standardized and thus the mathematical model can be updated further.The experimental methods include obtaining the FRF plots from a cantilever beam and then using the ME's scope to obtain the various parts of the FRF plots like the magnitude, phase, real, imaginary. Then the modal data was analyzed to obtain different parameters which were further compared with the model developed in ANSYS.

17. D.Ravi Prasad[11]Modal analysis is a process of describing a structure in terms of its natural characteristics which are the frequency, damping and mode shapes –its dynamic properties. The change of modal characteristics directly provides an indication of structural condition based on changes in frequencies and mode shapes of vibration. This paper presents results of an experimental modal analysis of beams with different materials such as steel, brass, copper and aluminum. The beams were excited using an impact hammer excitation technique over the frequency range of interest, 0-2000 Hz. Response functions were obtained using vibration analyzer. The FRFs were processed using NV solutions modal analysis package to identify natural frequencies, damping and the corresponding mode shapes of the beam.

CONCLUSION

The main objective of the present work is to study the vibration damping characteristics of three materials i.e. steel, brass and aluminum.

On the basis of present study following conclusions are drawn:

From the review it is evident that material damping is higher for steel in comparison with brass and aluminum.

The increase in material damping could be correlated to the stiffness of materials.

The damping ratio increases with decrease in thickness for each material.

The natural frequency decreases with decreases in thickness for each material. But it is vice-versa in case of length.

The damping of specimen made up of aluminum was found to be lowest than either steel or brass.

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