An Overview of Vibration Analysis of Cracked Cantilever Beam with Non-Linear Parameters and Harmonic Excitations

R. S. Pawar, S. H. Sawant

Abstract-A beam is an elongated member, usually slender, intended to resist lateral loads by bending. These beam-like structures are typically subjected to dynamic loads. Therefore, the vibration of beams is of particular interest to the engineer. This paper tries to focuses in the study of the vibration analysis of cracked cantilever beam subjected to free and harmonic excitation at the base. The objective of the study is to identify the effect of non-linearities namely material, geometric, and damping on the natural frequency and mode shapes of cracked cantilever beam by theoretical, numerical and experimental methods.

Keywords - Cracked simply supported beam, Cracked Cantilever Beam with Non-linear Parameters and Harmonic Excitation, Free Vibration and Elastic Buckling beams, Modal Analysis of beams with different materials, Rotating Cantilever Beam, Non-linearities in Cracked cantilever beam, Vibrations of axially moving beam.

I. INTRODUCTION

A beam is an elongated member, usually slender, intended to resist lateral loads by bending [1]. Structures such as antennas, helicopter rotor blades, aircraft wings, towers and high rise buildings are examples of beams. These beam-like structures are typically subjected to dynamic loads. Therefore, the vibration of beams is of particular interest to the engineer.

For beams undergoing small displacements, linear beam theory can be used to calculate the natural frequencies, mode shapes, and the response for a given excitation. However, when the displacements are large, linear beam theory fails to accurately describe the dynamic characteristics of the system. Highly flexible beams, typically found in aerospace applications, may experience large displacements. These large displacements cause geometric and other nonlinearities to be significant. The nonlinearities couple the (linearly uncoupled) modes of vibration and can lead to modal interactions where energy is transferred between modes [2].

This investigation focuses in the study of the vibration analysis of cracked cantilever beam subjected to free and harmonic excitation at the base. The objective of the study is to identify the effect of non-linearity's namely Material, Geometric, and Damping on the natural frequency and mode shapes of cracked cantilever beam by theoretical, numerical and experimental methods.

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II. EXPERIMENTAL MODAL ANALYSIS OF BEAMS WITH DIFFERENT MATERIALS

Dr. Ravi Prasad et al. [3] proposed a work on a Modal analysis for 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.

III. NUMERICAL AND EXPERIMENTAL ANALYSIS OF A CANTILEVER BEAM

TarsicioBeleândez et al. [4] published a paper on Numerical and Experimental Analysis of a Cantilever Beam: a laboratory project to introduce geometric nonlinearity in mechanics of materials. 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, is experimentally and numerically analyzed. They present the differential equation governing the behavior of this system and shown that this equation, although straightforward in appearance, is in fact rather difficult to solve due to the presence of a nonlinear term. The experiment described in this paper is an easy way to introduce students to the concept of geometric nonlinearity in mechanics of materials. The ANSYS program is used to numerically evaluate the system and calculate Young's modulus of the beam material. Finally, they compared the numerical results with the experimental ones obtained in the laboratory.

IV. VIBRATION ANALYSIS OF A ROTATING CANTILEVER BEAM

H H Yoo and S H Shin [5] carried out a work on 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

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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 their 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 modeling 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.

V. NEW ANALYTICAL METHOD FOR VIBRATION ANALYSIS OF A CRACKED SIMPLY SUPPORTED BEAM

Mousa Rezaee and Reza Hassannejad [6] derived a New Analytical Method for Vibration Analysis of a Cracked Simply Supported Beam .By considering a nonlinear 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 shows 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.

VI. VIBRATION ANALYSIS OF ROTATING BEAMS

Chih Ling Huang et al. [7] proposed a work on Rotating beams 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 carioles effects on its dynamics. The natural frequency of the flap-wise bending vibration, and coupled lag-wise 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 Carioles 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.

VII. VIBRATIONS OF AXIALLY MOVING BEAMS

H. Ding et al. [8] proposed a work on Vibration of Axially moving Beams. 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.

VIII. FREE VIBRATION AND ELASTIC BUCKLING OF BEAMS

Liao-Liang et al. [9] presented a paper on free vibration and Elastic Buckling of Beams made of functionally graded materials (FGMs) containing open edge cracks which are studied in this paper based on Tarsicio Beleândez beam theory. The crack is modeled by a mass less 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.

IX. VIBRATION ANALYSIS OF CRACKED CANTILE- VER BEAM WITH NON-LINEAR PARAMETERS AND HARMONIC EXCITATION.

Mr.R.S.Pawar, Prof. Dr. S.H.Sawant [10] in this method Theoretical, Numerical and Experimental Analysis of a cracked cantilever beam subjected to free and harmonic excitation with nonlinear parameters. Theoretical study of vibration analysis of cantilever beam with cracks considering linear system and evaluation of natural frequency and mode shapes for both Free and Forced vibration. Numerical and Experimental Analysis of a cracked cantilever beam to identify the nonlinearities & their effects on load deflection characteristics of cantilever beam. Develop equation to describe the non-linear load-deflection characteristics of cantilever beam. Numerical verification of vibration analysis of cracked cantilever beam with non-linear parameters and evaluation natural frequency and mode shapes with MATLAB/ANSYS software for both Free and Forced vibration. Experimental validation of results obtained by theoretical and numerical method with the help of FFT Analyzer for both Free and Forced vibration of cracked cantilever beam with nonlinear parameters.

X. CONCLUSION

By the literature review it is seen that, compare with previous old systems of vibration analysis of cantilever beam this method identifies the nonlinearities & effects on load deflection characteristics of cantilever. In this method Numerical verification of vibration analysis of cracked cantilever beam with non-linear parameters and evaluation of natural frequency and mode shapes with MATLAB/ANSYS software for both Free and Forced vibration are done & the Experimental validation of results obtained by theoretical and numerical method with the help of FFT Analyzer for both Free and Forced vibration of cracked cantilever beam with nonlinear parameters gives better result than previous old systems.

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