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# An Overview of Disarray in Vibration Analysis of Cracked Rectangular Cantilever Beam

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## 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 focus on previous study of the vibration analysis of cracked cantilever beam subjected to free and harmonic excitation at the base. The objective of the paper is to identify the effect of nonlinearities namely material, geometric, and damping on the natural frequency and mode shapes of cracked cantilever beam by theoretical, numerical and experimental methods and also to study method of experimentation.
**Keywords :** Cracked Cantilever Beam, Damping, Geometric and Natural frequency.

## I. INTRODUCTION

Moreover, structures like helicopter rotor blades, spacecraft antennae, flexible airplane wings, gun barrels, robot arms, high-rise buildings, long-span bridges, and subsystems of more complex structures can be modeled as a beam-like slender member. Therefore, studying the static and dynamic response, both theoretically and experimentally, of this simple structural component under various loading conditions would help in understanding and explaining the behavior of more complexes, real structures under similar loading. Interesting physical phenomena occur in structures in the presence of nonlinearities, which cannot be explained by linear models. These phenomena include jumps, saturation, sub-harmonic, super harmonic, and combination resonances, self-excited oscillations, modal interactions and chaos.

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.

In reality, no physical system is strictly linear and hence linear models of physical systems have limitations of their own. In general, linear models are applicable only in a very restrictive domain like when the vibration amplitude is very small. Thus, to accurately identify and understand the dynamic behavior of a structural system under general loading conditions, it is essential that nonlinearities present in the system also be modeled and studied.

The objective of this study is to analyze the vibration behavior of beams both experimentally and using FEM software ANSYS subjected to single and multiple cracks under free and forced vibration cases. Besides this, information about the location and depth of cracks in cracked steel beams can be obtained using this technique. Using vibration analysis for early detection of cracks has gained popularity over the years and in the last decade substantial progress has been made in that direction. Dynamic characteristics of damaged and undamaged materials are very different. For this reason, material faults can be detected, especially in steel beams, which are very important construction elements because of their wide spread usage construction and machinery. Crack formation due to cyclic loads leads to fatigue of the structure and to discontinuities in the interior configuration. Cracks in vibrating components can initiate catastrophic failures. Therefore, there is a need to understand the dynamics of cracked structures. When a structure suffers from damage, its dynamic properties can change. Specifically, crack damage can cause a stiffness reduction, with an inherent reduction in natural frequencies, an increase in modal damping, and a change in the mode shapes. From these changes the crack position and magnitude can be identified. Since the reduction in natural frequencies can be easily observed, most researchers use this feature. Natural frequency of the beam has also been determined and verified experimentally.

In recent decades with development in mathematics and computers very efficient FEM software's were developed (E.g. – ANSYS, Abaqus etc). These software's in combination with high computational powered work stations (computers) are working very efficiently. But for using FEA software, highly experienced people are required because a small mistake in assumption or applying boundary condition may be cause of larger error in results. Most important thing about FEA is that results which are inaccurate as well as correct, may be displayed in colored image.

The design of any product is an output of various considerations, right from the manufacturability, reliability, maintainability, cost, factor of safety, size, shape, weight, efficiency, etc. Thus selection of an appropriate design is a combination of various parameters. As the design result is a compromise of man parameters there will always be scope for optimization. Hence there is no exact answer to any design or related question. Codes are giving flexibility of using different design approaches and technology by stating that the code is not a handbook and cannot replace education, experience and use of engineering judgment, also it suggests for using of FEA software's in many situations. In this work FEM approach is used to numerical analysis of Cracked Cantilever Beam.

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 nonlinearities namely Material, Geometric, and Damping on the natural frequency and mode shapes of cracked cantilever beam by theoretical, numerical and experimental methods.

## II. LITERATURE REVIEW

Many of researchers have contributed in development of Cracked Cantilever Beam.

Irshad A Khan et.al carried out Finite Element Analysis of Double Cracked Beam and its Experimental Validation.

The objective of their study is to estimate the effects of crack depth on natural frequency and mode shape of beam; Cantilever and fixed- fixed beam are engaged for analysis. The presence of cracks a severe threat to the performance of structures and it affects the vibration signatures (Natural frequencies and mode shapes).Here two transverse cracks are deemed on the beam at 200 mm and 600mm from fixed end of the beam, the depth of cracks are varied from 0.5mm to 3mm at the interval of 0.5mm. Modeling and Numerical simulation is established using commercially available finite element analysis software package ANSYS. Based on convergence study a higher order 3- D, 10-node element having three degrees of freedom at each node, SOLID 187 element is used in analysis. Natural frequency increases and Mode shape decreases as the crack depth increases. Experiment are also conducted, results of experiment having good co-relation with results of finite element analysis.

Health monitoring and the analysis of damage in the form of crack in Beam like structures are important not only for leading safe operation but also retraining system performance. Since long efforts are on their way to find a realistic solution for crack detection in beam structures in this regard many approaches have so far being taken place. When a structure suffers from damages, its dynamic properties can change. Crack damage leads to reduction in stiffness also with an inherent reduction in natural frequency and increase in modal damping. The paper lends a viable relationship between the modal natural frequency and mode shape at the different crack depth. Since last few decade free vibration analysis has become a topic of many studies therefore attention is focused on it only [1].

D.K. Agarwall et.al studied Effect of Crack on Modal Parameters of a Cantilever Beam Subjected to Vibration. Crack hinders the optimum performance of a machine. Presently most of the failures encountered by machines are due to material fatigue. Therefore crack detection and localization is the main topic of discussion for various researchers across the globe. The dynamic behaviour of a whole structure is affected due to the presence of a crack as the stiffness of that structural element is altered. The cracks in the structure change the frequencies, amplitudes of free vibration and dynamic stability areas to an inevitable extent. So a diagnosis of the changes allows the experimenter to identify the cracks without aborting the system applications. The effect of an open crack on the modal parameters of the cantilever beam subjected to free vibration is analysed and the results obtained from the numerical method i.e. finite element method (FEM) and the experimental method are compared. It is concluded that results obtained from experiment have a very good agreement with the results obtained from FEM and the structure vibrates with more frequency in the presence of a crack away from the fixed end.

Vibration principles are the inherent properties of the physical science applicable to all structures subjected to static or dynamic loads. All structures again due to their rigid nature develop some irregularities in their life span which leads to the development of crack. The problem on crack is the basic problem of science of resistance of materials. Considering the crack as a significant form of such damage, its modelling is an important step in studying the behaviour of damaged structures. Knowing the effect of crack on stiffness, the beam or shaft can be modelled using either Euler-Bernoulli or Timoshenko beam theories. The beam boundary conditions are used along with the crack compatibility relations to derive the characteristic equation relating the natural frequency, the crack depth and location with the other beam properties. Researches based on structural health monitoring for crack detection deal with change in natural frequencies and mode shapes of the beam. [2]

UgoAndreaus et. Al. published paper Non-lineardynamicsofacrackedcantileverbeamunderharmonic excitation.

The presence of cracks in a structure is usually detected by adopting a linear approach through the monitoring of changes in its dynamic response features, such as natural frequencies and mode shapes. But these linear vibration procedures do not always come up to practical results because of their inherently low sensitivity to defects. Since a crack introduces non-linearities in the system, their use in damage detection merits to be investigated. With this aim the present paper is devoted to analyzing the peculiar features of the non-linear response of a cracked beam. The problem of a cantilever beam with an asymmetric edge crack subjected to a harmonic forcing at the tip is considered as a plane problem and is solved by using two-dimensional finite elements; the behaviour of the breathing crack is simulated as a frictionless contact problem. The modification of the response with respect to the linear one is outlined: in particular, excitation of sub- and super-harmonics, period doubling, and quasi-impulsive behaviour at crack interfaces are the main achievements. These response characteristics, strictly due to the presence of a crack, can be used in non-linear techniques of crack identification. [3]

Fabrizio Vestroni et. Al. carried out research on Crack Detection by Nonlinear Harmonic Identification in Beam Structures.

The dynamic behavior of structures with breathing cracks forced by harmonic excitation is characterized by the appearance of sub and super-harmonics in the response even in presence of cracks with small depth. Since the amplitude of these harmonics depends on the position and the depth of the crack, an identification technique is developed based on such a dependency. The main advantage of the proposed method relies on the use of different modes of the structure, each sensitive to the damage position in its peculiar way. In this paper the identification is tested considering structure of increasing complexity to evaluate the applicability of the method to engineering applications. In particular, a robustness analys is carried out for each test case to assess the influence of measuring noise on the damage identification.

The paper investigates specific aspects of a novel methodology for the identification of breathing cracks in beams structures that is able to detect simultaneously the location and the depth of the damage. The method exploits the nonlinear features in the response of the structure that are caused by the presence of even very small damage. In particular, sub- and super-harmonics of the forcing frequency appear in the response; these can be easily detected and measured through tests on the system by forcing it with a narrow-band excitation that causes one of the system mode tobe predominant. The proposed method uses a set of tests, each exciting one mode and, by combining the obtained information, a sharp identification is achieved through a minimization problem. It was previously shown how on a cantilever beam the nonlinear harmonic identification method, in contrast to other techniques that need a crack depth larger than 15%-20% of the beam's height to achieve a satisfactory identification, is able to detect the presence and the level of the damage just exceeding 5% depth, while at only 10% damage, the identification of the position is also correctly obtained. In this paper, the problem of symmetric structure is also addressed and it is shown how, even the small asymmetry caused by the presence of the damage can be exploited, by exciting the system with a non-symmetric load to correctly obtain the damage identification. Moreover, the use of more than one sensor on the structure is investigated, considering in the minimization process the information from each measured point. The results obtained, show that with 8 sensors distributed along the beam length, the method is able to locate the damage, unless it is close to a constraint, starting at just 5% severity finally, the case of a more complex structure with multiple constraints is addressed. The tests show that using three modes is not sufficient to identify the damage at any location. The use of another mode is necessary to identify the damage in any position. This aspect will be the subject of further investigation, increasing also the complexity of the system. [4] M. Rezaee et. Al. carried out theoretical and experimental investigation on free vibration behavior of a cantilever beam with a breathing crack.

In this paper the free nonlinear vibration behavior of a cracked cantilever beam is investigated both theoretically and experimentally. For simplicity, the dynamic behavior of a cracked beam vibrating at its first mode is simulated using a simple single degree of freedom lumped parameter system. The time varying stiffness is modeled using a harmonic function. The governing equation of motion is solved by a perturbation method – the method of Multiple Scales. Results show that the correction term that is added to the main part of the response reflects the effect of breathing crack on the vibration response. Moreover, this part of response consists of the super harmonic components of the spectrum which is due to the system's intrinsic nonlinearity. Using this method an analytical relation is established between the system characteristics and the crack parameters in one hand and the nonlinear characteristics of system response on the other hand. Results have been validated by the experimental tests and a numerical method.

The nonlinear vibration behavior of a cantilever beam with a breathing crack was investigated both theoretically and experimentally. For the sake of simplicity only free vibrations of the beam were considered. The primary aim was to highlight the nonlinear characteristics of the response of a cracked beam by using a perturbation analysis instead of the traditional numerical methods. For this purpose, first the lumped equation of motion of the cracked beam converted to the standard form which can be solved by the perturbation method. Then using the multiple scales method the response was obtained. It was found that the correction term of the calculated response exhibits a temporal behaviour oscillating between zero and a maximum value which decays by time due to the damping. Thus, the effect of the crack breathing behaviour on system response not only in frequency domain but also in time domain is captured and revealed. Moreover, this part of the response relates the crack parameters to the first and the most important super harmonic of response. As a result, this method not only can be used for investigating nonlinear vibration behavior of cracked beam but also due to its considerably low computational cost, it has the potential of being used in developing the crack detection indexes in the inverse problem. It was shown that the ratio of the super harmonic part to the main response increases with crack parameters following a three dimensional surface. Also, the presence of the super harmonic as an indicator of nonlinearity was confirmed by the experimental tests. The vibration tests have been performed on the beam with a real fatigue crack. [5]

## III. CONCLUSION

By the literature review one can 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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