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A Review on Vibration analysis and Identification of Crack in Cantilever Beam

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Abstract—*Crack is known to be the physical discontinuity that exists in the structure. The analysis of damage in the form of crack in structures like beam along with health monitoring is important for leading safe operation without obstructing systems optimum performance. The scope of this review is to cad cam.*

Determine the location of crack and the amount of damage magnitude present. It has been found that cracks affect the stiffness flexibility along with the static and the dynamic performance of the beam. The present study focuses mainly on the variation in dynamic characteristics of a cantilever beam structure which is influenced by crack depth and position of the crack for various cross sections taken. The reported study briefly discuss various analytical and experimental investigations which describes the dynamic behavior of beam in terms of natural frequencies and modal shapes for various materials, cross-section, depth of crack and crack position of the cantilever beam. This study will provide a better insight towards the dynamic characteristics of the cantilever beam with the respect to these parameters and will help in predicting the location and nature of crack by using reverse engineering.

Keywords*: vibration analysis; cantilever beam; FEA; crack depth and location*

1. INTRODUCTION

Fascination for persuading is the ability to monitor a structure and hence to detect damage at the earliest possible stage is noticeable in mechanical, civil and aerospace engineering communities. In context to this study damage can be defined as "an alteration inducted into a system, either deliberately or accidentally, which unfavorably affect the present or upcoming accomplishment of that system". Some of the methods predefined for damage detection are manual or experimental methods mainly acoustic or ultrasonic methods, vibration-based damage detection techniques for the prediction of structural health, magnetic fields, radiography, eddy-currents or thermal fields. This study emphasis on the vibration based damage detection techniques where variation in dynamic properties such as natural frequency and mode shape of the system is analyzed with respect to nature as well as position of the crack.

In reference to literature it has been noted that numerous studies are developed for structural safety of beams, especially, crack detection by structural health monitoring. These presented researches explains structural health monitoring for crack detection with change in natural frequencies and mode shapes of the beam as well as dynamic responsiveness of the cantilever beam element due to application of harmonic forces. When a structure is affected by damages, its dynamical properties is changed, especially, the crack damage causing a stiffness reduction, along with an inherent decrement in the natural frequencies with an intended enhancement in modal damping, and a change of the mode shapes. Consequently, there would also be a great change in the dynamical response of the structure. From these changes in the position of crack and its magnitude can be identified. In view of the fact that the decrease in natural frequencies can easily be observed, most of the authors use this parameter. In addition to that, some studies focuses on the dynamic response of the beam for the applied harmonic forces and variation in response is analyzed. Since, vibrations has become a topic of modern studies, a brief review in this regard for the vibration analysis and identification of crack in cantilever beam is presented in current study.

2. LITERATURE REVIEW

Chasalevris et al. [1] studied the identification and characterization of transverse crack on the beam and obtain the depth and position of the crack. Further the paper discusses the dynamic behaviors of cracked beam influenced by two transverse surface cracks and each crack is characterized by its position of depth and its relative angle. In his research, two cracks are considered at an arbitrary angular position with respect to two longitudinal axes of the beam and at some predefined distance from the extreme left hand side. Bending in horizontal and vertical plane are used to modal the rotating transverse crack in the shaft by considering the local compliance matrix of two degree of freedom. These calculations are based on expression of the stress intercity factor and the associated expression for the strain energy release rate. First of all, the compliance matrix is calculated at an angle of rotation thus the compliance matrix has given as a function of both the crack depth and angular rotation. B- Spine curve is used to interpolate to known points and a function in analytical from is given for every crack depth and angle. When a crack is found in the beam structure then natural frequencies decreases. This reduction discussed here consists six independent parameters like the depth, location, and the rotation angle of each crack. If these six parameters are constant then the flexural Eigen modes were computed and plotted. The displacement changes the theory of wavelets due to sensitivity and is used to verify the crack location. The transformation of the wavelet shows a vibration mode or vibration response of the beam structure used to identify the crack, if the crack position is known, then the crack depth and its angular position can easily be determined.

A crack on a circular cross section beam affects its dynamic behavior. This method is also applied for two cracks or more than two cracks, the identification method not only gives the angular position of crack around the axis of shaft during the rotation of crack it also gives critical angle depending on its depth. The bending vibration of the shaft in simulation by the forth order Euler- Bernoulli differential equation, the boundary condition is used to construct the characteristic equation of the system at the beam ends as well as at the crack location. The root of homogeneous equation is the Eigen frequencies of the system that are varied with the input parameters. This verification is described in paper as a function of input parameter.

Orphan Sadettin et al. [2] discussed both the forced and free vibration of a crack intended cantilever beam. In order to determine the single crack, two edges of cantilever beam are evaluated. The dynamical response of the forced vibration described the changes in the depth of crack and its location than the free vibration analysis. When the location of crack in the beam is constant but the depth of crack increases then the natural frequency of beam was found to be decreasing for single crack and double crack on the upper and the bottom end surface of the beam. The natural frequency for the double crack on the bottom surface of the beam is less than the two cracks on the top surface. The natural frequency is obtain approximately same as the simulated value of the crack. The harmonic response at 96 Hz is different for the single crack on the top end and bottom end surface but this feature was not obtained for the two cracks on the top and bottom end surfaces of the beam. This paper result indicated that the harmonic response analysis is more appropriate than the free vibration analysis in the case of single crack on the top and the bottom surface. Otherwise free vibration analysis appears to be an effective analysis in the case of two cracks on the top and bottom surface of the beam to identify the crack.

Jabari et al. [3] studied the analytical and experimental approach for detection of crack in cantilever beam by vibration analysis. An experimental method was performed in which crack in cantilever beam is excited by hammering action and response is calculated by using an accelerometer attached to the cantilever beam. To identify the crack contour of normalized frequency with respect to the normalized depth of crack and its location were plotted for cracked cantilever beam. A minimization approach is used to detect the crack element within the cantilever beam. This experimental approach based on major frequencies and mode shape of the beam. Identification of crack in cantilever beam is to perform in two steps, in first step the first element modal of cantilever beam is established to know the behavior of crack element. In second step, the crack location and crack position is identifying the each element modal analysis for each position and depth of cantilever beam in funded the natural frequency of beam.

A method is developed for identify the crack location and depth of uniform cantilever beam, by using the linear function mechanics theory. The natural frequency and the modal shape were determined using FE technique for the cracked beam. It was also found that the crack location as well as crack size can be measured by theoretical analysis and experimental measurement in the cantilever beam. Natural frequency was decreased significantly as the crack location was moved towards fixed end of beam and crack near the fixed end was modified by using boundary conditions of beam.

S.P Mogal et at.[4] studied on vibration analysis for two open transverse cracks in cantilever beam and studied the response characteristics. In first case local compliance matrix of the different degree of freedom (D.O.F) was used on transverse crack on beam by its available expression of stress intensity factor and the associated expression for the strain energy. The numerical result was complied against the theoretical result obtained by the simulation using suitable boundary conditions to determine the natural frequency and mode of shape. This simulation was done with the help of the ansys software. It is identified by both computational and simulation analysis that the presence of crack decrease the natural frequency of the vibration. The modal shapes were also changed due to crack in the beam. Analytical computational method were used for solving the frequency of the elastic beam with crack and it is found that the natural frequency changes because of the presence of cracks, and these changes mainly depends upon the cracks location and size. The position of crack was obtained from the deviation of the fundamental modes between the crack and uncrack beam. The frequency is decrease with the increase in crack depth for all modes of vibration in the crack cantilever beam. For moderate cracks ($A_1/W=A_2/W=0.1667$) changes were obtained. For deep crack ($A_1/W=A_2/W=0.5$) changes were obtained for which the shape is quite substantial.

Cam et al.[5] Obtained the evidence about the depth and location of crack in the crack beam and also analyzed the vibration as a function impact shocks. The signals obtain in cracked and un-cracked beam are compared in frequency domain. Location and depth of the crack were analyzed by vibration signals. Experimental result and the simulated results are found in good agreement and ansys software was used for simulation purpose. It can be concluded that when the location of the crack increases starting from the clamped end of the beam, natural frequency of beam and amplitude of high frequency vibration is also increases, whereas the amplitude for low frequency vibration decreases. Also it can be concluded that it is more sensitive result obtain by the optimizing the impact point as the depth of crack increase at a high frequency, but the natural frequency will decrease. This is the fact that the stiffness reduction is inversely proportional to the depth of the crack in beam.

Chati et al.[6] discusses the vibration of the cracked beam. According to his findings, the beam's motion was complex and as such a tribute to presence of non-linearity provided to the opening and closing of the cracks in beam. This paper mainly describes the modal analysis of cantilever beam with transversal edge cracking. Here the ideas of bilinear frequencies are utilized for defining the effective natural frequency system. The bilinear frequency was computed and associated with the frequency of each and every linear pieces of the piece-wise linear system. The F.E.M is used for obtaining the value of natural frequencies in each linear region. Additionally, the understanding of the essential non-linear dynamics of the cracked beam as a piecewise linear, 2 DOF models are studied and non-linear normal modes of the vibration is attained by perturbation method calculating piecewise more shape by linear frequencies are most useful for understanding the dynamic of the infinity degree of freedom in a cracked beam. The main feature of the paper is to understand the crack beam dynamics. Due to the non-linear boundary condition, an Eigen value problem cannot be formulated for the crack beam. A definition for effective frequency called the bilinear frequency is developed. By modelling with crack beam as two linear configuration (crack open, crack closed). It is seem that the bilinear formula is indeed is good approximation for the effective natural frequency, especially when the difference between the linear region is small. Simulation of 2-D of freedom system shows that the more completed motion are possible including chaos. Chondros et al. [7] continued his research on continuous crack bar model where, lateral vibration induced in edge cracked Euler-Bernoulli cantilever beam was estimated. The Hu-Washizu-Barr formulation was utilized to develop the DEs and BCs is set for one dimensional continuum cracked beam. The crack in the cantilever beam was then modeled as a continuous flexible piece around the crack as a displacement function.

The experimental result are in close approximation with the predicted results obtained by continuous crack formation, considering the results for single edge cracked aluminum beam. Continuous crack beam theory better agrees with the results than the lumped flexibility theory.

The continuous crack beam theory for cantilever beam having a single crack agreed well for dynamic responses upon lateral excitation. Experimental results from aluminum testing and that by Wentdland closely approximates with the continuous crack formation

Continuous beam theory can be used as an alternative tool for the vibration analysis of the crack beam. The continuous crack beam formation can be implemented to flexural vibration with single and double edge cracked in the beam.

Chondros et al. [8] further extended the study for the analysis of open surface cracks, keeping remaining assumptions as above.

Qwalabi et al. [9] studied the crack deflection in the beam using the change in frequency and amplitude and determining the location and size.

It is based on experimental model analysis and result obtained from measurement of dynamic response of the crack beam. The change in natural frequency and response amplitude defined as a defined function of depth of crack and location. The author performed the experiment where the author considered a couple of sets of beam, each set contained 7 beams; one set of beams had fixed support and the other had simply supported ends. Cracks were located uniformly using the crack depth ratio from 0.1d to 0.7d.

The basic L.D.E. of motion was fitted for this multi DOF phenomenon. Defects existing in structure caused a change in the stiffness and affected mass distribution and damping properties and also change in dynamic response of the structure

Fang et al. [10] explored the detection of structural damage using frequency response functions as an input response to the back-propagation neural network (BPNN). The stated approach was based on computational technique and hence it had distinct advantages in many practical applications. The training and a recognition phase were key considerations in neural network based damage detection.

The gradient method was propounded to train the neural network in Error back-propagation algorithm which heavily depend on learning rate efficiency.

Suh et al. [11] relates that a crack has a significant effect on the dynamical behavior of the structure which depends mainly on the location and depth of the crack.

A hybrid neuro-genetic technique identified the location and depth of crack of a structure. The input-output relations were recorded using the feed-forward multi-layer neural networks. Lastly, genetic algorithm having trained neural network was effectively used to determine the crack and its depth by minimizing the difference from the measured frequencies.

Dharmaraju et al. [12] studied the Euler Bernoulli beam in finite element model considering Consider the transverse surface crack in the beam structure. The crack beam was has modeled by a local compliance matrix of the four degree of freedom. This compliance matrix contained diagonal and off-diagonal terms.

The known harmonic force amplitude and vibration frequency was used to dynamically excite the crack beam. The author presented an algorithm and was validated with analytical method.

Patil and Maiti et al. [13, 14] performed a study where they introduced an approach to predict the size and location of multiple cracks in the beam. In the stated approach, the authors used energy method and a rotational spring was used to represent the crack in the beams. Furthermore, the crack was segmented into a number of parts, each segment considered to be associated with damage index for the theoretical prediction of the beam. The damage index obtained was an indication of the strain energy (U) stored in the spring. The crack size was evaluated by using a standard rotation between the stiffness and crack size. The magnitude of measured frequency was equal to twice the number of cracks. These results were corroborated with the experiment performed on 2 and 3 normal edged cracked cantilever beams.

Khan and Parhi [15] studied the effect on double cracked cantilever beam by means of finite element analysis and further validated the responses via the experimental results.

The presented wok emphasis on quantifying the effect of crack depth on natural frequency and shape of the beam. Cantilever/fixed beam was engaged for analysis. The author considered two transverse cracks at a distance of 200 and 600 mm from fixed end and crack depth was varied from 0.5 to 3 mm in the interval of 0.5 mm. Here, the software package, ANSYS, was used for modeling as well as for numerical simulation (FEA)

Element type SOLID 187 having 10 nodes and 3 degrees of freedom in 3D-space was used for the analysis. The author concluded on behalf of his experimental validation that the oblique cracks are a harsh risk on the performance of the structures. The mode shapes and natural frequencies were affected due to the stiffness of the structure.

This analysis ensures to estimate the effects of crack depth on vibration signatures. A finite element examination and experimental expression have been done. It is seen that the natural frequencies increases with mode shapes decreasing as the depth of crack increases.

Kisa et al. [16, 17] presented a study where a numerical technique was introduced to analyze the free vibrations in a stepped as well as uniform cracked beam having circular cross section.

In the stated technique, component mode synthesis and finite element methods were used together, where the beam was segmented into parts from the crack section. These segmented structures were coupled by flexibility matrices by considering the interacting forces extracted from the fracture mechanics theory which is obtained as the inverse of the compliance matrix with stress intensity factors and strain energy. The accuracy and success of the proposed method were illustrated through many examples in their work. The results obtained in the study were validated with various available literatures.

Rizos, et al. [18] has estimated the crack depth and location in a cantilever beam having rectangular cross section using the vibration modes. A relation between the location and depth of the crack with the vibration modes was established. It has been found that the obtained results from the above relations are capable for the prediction of depth of crack and its location based on the amplitudes measured at two points of the structure in vibration, the respective frequency and an analytical solution of the dynamic response with satisfactory results was obtained.

Binici [19] propounded a new approach to determine the Eigen frequencies and modal shapes for beams subjected to axial forces with multiple cracks. In his study he used a similar approach by modeling cracks as a rotational spring and assuming boundary conditions as initial parameters for determining the modal shape functions. The above boundary conditions satisfy the mode shapes of the remaining parts and a second-order determinants and they were plotted.

Sekhar et al. [20, 21] extended the study of vibration analysis of cantilever beams in a rotor system with two cracks. The equivalent loads were replaced and the change of the rotor system due to the induced crack in the mathematical model was analyzed. The analysis determines the monitoring and detection capability of the slant crack in the rotor system using mechanical impedance.

The paper also emphasis several works of the authors on cracked rotors to compare the two types of shaft cracks while studying flexural vibration characteristics. Eigen value analysis; steady state and transient response; crack detection based on changes in mechanical impedance and wavelet techniques have been discussed in order to compare slant crack with transverse crack.

3. CONCLUSION

The important part in the research of vibration analysis for real engineering applications, is a cantilever beam. The cantilevers in machineries and construction should be flexible enough to withstand high levels of stress and strain. An essential factor in the estimation of the safety of the structure is to detect faults and defects in a structure at the early stages. The present investigation explores various theoretical and experimental approaches along with the advantages of Finite Element Analysis (FEA) over the other methods in order to detect the location and nature of the crack in cantilever beam. FEA is widely used in SHM in order to acquire analytical solutions of natural frequencies and dynamic responses. It has been found that changes in dynamic properties of the structure could lead to change in mode shapes, increase in damping, frequency reduction and hence crack detection.

REFRENCES

[1] A. C. Chasalevris and C. A. Papadopoulos, “Identification of multiple cracks in beams under bending,” *Mech. Syst. Signal Process.*, 20,2006, pp. 1631–1673.

[2] S. Orhan, “Analysis of free and forced vibration of a cracked cantilever beam,” *NDT E Int.*, 40,2007, pp. 443–450.

[3] H. Nahvi and M. Jabbari, “Crack detection in beams using experimental modal data and finite element model,” *Int. J. Mech. Sci.*, 47,2005, pp. 1477–1497.

[4] S. . Mogal, S.P, Behera , Dr.R.K, Pawar, “84 IJAET IIIpdf.”

[5] E. Çam, S. Orhan, and M. Lüy, “An analysis of cracked beam structure using impact echo method,” *NDT E Int.*, 38,2005, pp. 368–373, 2005.

[7] T.G.Chondros, and A.D.Dimarogonas,” Vibration of a cracked cantilever beam,” J Vib Acoust 120,1998.

[8] T. G. Chondros, A. D. Dimarogonas, and J. Yao, “A continuous cracked beam vibration theory,” Journal of Sound and Vibration, 215,1998, pp. 17–34.

[9] Qwolabi, Swamidas and Seshadri “Crack detection in beams using changes in frequencies and amplitude of frequency response functions” Journal of Sound and Vibration, 265, 2003, pp. 1–22.

[10] Fang X., Luo H. and Tang J., “Structural damage detection using neural network with learning rate improvement”, Computers and Structures, 83, 2005, pp. 2150–2161.

[11] Suh M.W., Shim M. B. and Kim M. Y., “Crack Identification using hybrid neuro – genetic technique, Journal of Sound and vibration”, 238, 2000, pp.617-635.

[12] Dharmaraju N., Tiwari R. and Talukdar S., “Identification of an open crack model in a beam based on force–response measurements”, Computers and Structures 82, 2004, pp.167–179.

[13] Patil D.P., Maiti S.K., “Experimental verification of a method of detection of multiple cracks in beams based on frequency measurements”, Journal of Sound and Vibration , 281,2005,pp.439–451.

[14] Patil D.P., Maiti S.K, “Detection of multiple cracks using frequency measurements, Engineering Fracture Mechanics” 70, 2003, pp.1553–1572.

[15] Irshad A Khan, Dayal R Parhi “Finite Element Analysis of Double Cracked Beam and its Experimental Validation” Procedia Engineering 51, 2013, pp. 703 – 708.

[16] Kisa Murat and Gurel M. Arif, “Free vibration analysis of uniform and stepped cracked beams with circular cross sections”, International Journal of Engineering Science 45, 2007, pp.364–380.

[17] Kisa M. and Brandon J., “The Effects of closure of cracks on the dynamics of a cracked cantilever beam”, Journal of Sound and Vibration, 238, 2000, pp.1-18.

[18] Rizos P.F., Aspragathos N., and Dimarogonas A.D., “Identification of cracked location and magnitude in a cantilever beam from the vibrational modes”, Journal of Sound and Vibration, 138, 1989, pp.381 – 388.

[19] Baris Binici, “Vibration of beams with multiple open cracks subjected to axial force”, Journal of Sound and Vibration 287, 2005, pp.277–295.

[20] Sekhar A.S., Mohanty A.R. and Prabhakar S., “Vibrations of cracked rotor system: transverse crack versus slant crack”, Journal of Sound and Vibration 279, 2005, pp.1203–1217.

[21] Sekhar A.S., “Model based identification of two cracks in a rotor system”, Mechanical Systems and Signal Processing, 18, 2004, pp.977–983.