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Vibrational Analysis of Cracked Beam: A Review

Bhagyashri Darkunde[1], A.B.Gaikwad[2]

[1]*Department of Mechanical Engineering, D.Y.Patil S.O.E. Pune, Pragatid04@gmail.com*
[2] *Department of Mechanical Engineering, D.Y.Patil S.O.E. Pune, Amol24gaikwad@gmail.com*

Abstract— In this paper we discuss the issues and challenges of research work that was important to structure, machine life and human safety. For the last number of years, a considerable amount of research work has been undertaken to investigate the failure in structures. Crack is the most important parameter for structure failure or machine damage. A cantilever when subjected to harmonic loading, if there is any crack in it, then the crack will open and closes alternatively in every cycle of loading. This phenomenon is known as 'crack breathing' and such type of crack is known as 'breathing crack'. Our present work is to analyze their models using a finite element package. To simulate the breathing cracks a small displacement frictionless contact problem between the two crack faces. The crack opens when the normal forces at the crack face are tensile. A displacement based finite element method in conjunction with the proposed crack model permit modeling of cracks of arbitrary size and at arbitrary locations. Cracks are present in the structure due to various reasons like loading condition, type of loading, material Properties etc. and it has been observed that most of the structural Members fail due to the presence of cracks. The cracks are developed mainly due to fatigue loading and Cracks initiate catastrophic failures. The presences of cracks change the physical characteristics of a structure which is directly affecting the Dynamic behavior of the system.
Keywords- Cracks, Structure, Catastrophic

I. INTRODUCTION

In this paper we discuss the issues and challenges of research work that was important to structure, machine life and human safety. For the last number of years, a considerable amount of research work has been undertaken to investigate the failure in structures. Crack is the most important parameter for structure failure or machine damage. A cantilever when subjected to harmonic loading, if there is any crack in it, then the crack will open and closes alternatively in every cycle of loading. This phenomenon is known as 'crack breathing' and such type of crack is known as 'breathing crack'. Our present work is to analyze their models using a finite element package. To simulate the breathing cracks a small displacement frictionless contact problem between the two crack faces. The crack opens when the normal forces at the crack face are tensile. 9Cracks are present in the structure due to various reasons like loading condition, type of loading, material Properties etc. and it has been observed that most of the structural Members fail due to the presence of cracks. The cracks are developed mainly due to fatigue loading and Cracks initiate catastrophic failures. The presences of cracks change the physical characteristics of a structure which is directly affecting the Dynamic behavior of the system. Therefore the detection of cracks is an important aspect of structure, machine and mechanical components.

II. METHODOLOGY

In this work [3], the vibrational characteristics of a cracked Timoshenko beam are analyzed. The study integrates the Finite element method and component mode synthesis. M. Kisa et al [3] first developed theoretical model. They used cantilever beam with transverse edge crack of depth 'a' with different damping coefficient.

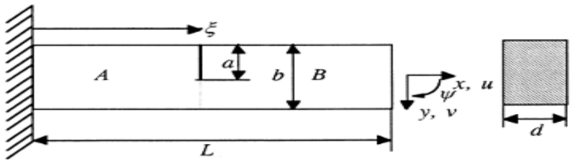

Fig. 1: Geometry of the Cracked Cantilever Beam

They considered beam is divided into two components related by a Flexibility matrix which incorporates the interaction forces. Each component is divided into finite element with two nodes and 3-DOF at each node is shown in fig.2.

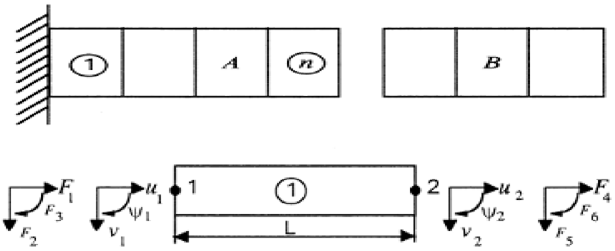

Fig 2: Cantilever Beam Divided Into Finite Number of Elements

The stiffness matrix of the cracked nodal element is written as

$$\mathbf{K}_{cr} = \begin{bmatrix} [\mathbf{C}]^{-1} & -[\mathbf{C}]^{-1} \\ -[\mathbf{C}]^{-1} & [\mathbf{C}]^{-1} \end{bmatrix}_{(6\times 6)}.$$

Finally they compare finite element solutions with proprietary software in order to check the accuracy of the model for various crack position and crack ratio. The interaction forces are found out with the help of fracture mechanics theory. They used stress intensity factors and strain energy release rate expressions for effectiveness of this approach results have been compared with previous studies in the literature leading for the validity of this approach. In this way they analyzed the cracked Timoshenko beam [3].

D.P.Patil et al [4] used (transfer matrix method) TMM Technique. Cantilever beams with two and three cracks are examined. They worked on the representation of an open edge crack oriented normally to the axis by a rotational spring has been proposed to solve the problem of detection of multiple cracks in beams with varying end conditions and intermediate support conditions. In this research work D.Y.Patil et al used fixed, simply supports and pin support elastic foundation beam. However the method suffers from one important limitation. That is, the maximum number of cracks that can be detected is less than equal to the number of segments into which the beam is virtually divided. The other shortcomings initiate from the assumptions the method cannot be applied to beams where rotational inertia, shear deformation and damping effects are significant.

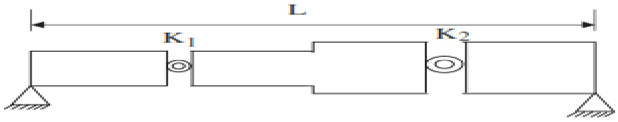

Fig. 3: Representation of Crack by Rotational Spring

A.S. J. Swamidas et al [5] has been used energy approach to estimate the influence of crack size and location on the natural frequencies of cracked beams. They also used Fracture mechanics approach for the purpose of to find out the effect of cracking on the dynamic response of the beam. They used Galerkin's approach for numerically solution.

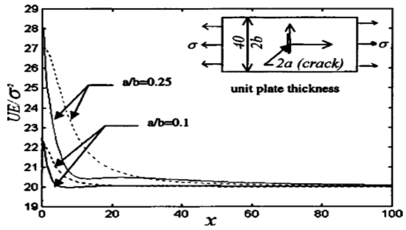

Fig 4: Energy Distribution in X-Direction for a Finite Crack Plate

Energy distributions (a/b=0.25 and a/b=0.1) for unit plate thickness are plotted in Fig.4, both curve are close to one another except near the crack zone. It is shown in fig.4. that, outside the crack influence zone, the energy distribution is nearly constant, and the change of strain energy was zero (outside the crack influence zone).

From Fig. 4, the correctness of energy distribution results around the crack tip and total increase of energy are also assured by Eq.

$$EN_c = \int_0^l \frac{Q(a,c)}{1+\left(\frac{x-c}{k(a)a}\right)^2}dx$$

Where, c is the distance to the crack location from one end of the beam. Therefore the crack energy function is represented in above equation and is considered to be valid for the problems investigated by swamidas and et al.

Sadettin Orhan[6] has performed a free and forced vibration analysis of a cracked cantilever beam. In this study orhan considered single and two-edge crack for work. It gives idea about identification of single and double crack in cantilever beam with the help of free and forced vibration. The results suggest that free vibration analysis provides appropriate information about detection of single and two cracks, but forced vibration can detect only the single crack condition.

G.Y.Xu et al [7] used a robust iterative algorithm for identifying the locations and extent of damage in cantilever beams using only the changes in their first several natural frequencies. The algorithm, which combines a first-order, multiple-parameter perturbation method and the generalized inverse method, and which is tested extensively through experimentally and numerically with different damage conditions.

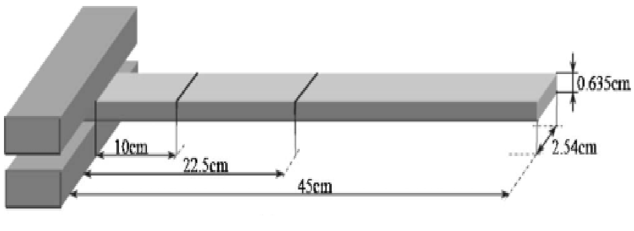

Fig 5: Cantilever Aluminium Beam Specimen with Two Cuts

In this work, a new method is developed to enrich the measurement information by modifying the structure in a controlled manner and using the first several measured natural frequencies of the modified structure and a new method using singular value decomposition is also developed to handle the ill-conditioned system equations that occur in the experimental investigation By using the measured natural frequencies of the modified structure [7].

[8]. Isham Panigrahi et al. evaluate dynamic behaviours of beam structure with transverse crack subjected to external force. In this work theoretical expression was developed for finding out the mode shapes and natural frequencies for beam with transverse crack using flexibility influence coefficient and local stiffness matrix.The flexibility influence co-efficient Cij is

$$C_{ij} = \frac{\partial U_i}{\partial P_j} = \frac{\partial^2}{\partial P_i \partial P_j} \int_0^{a_1} J(a)da$$

The local stiffness matrix can be obtained by taking the inversion of compliance matrix i.e.

$$K = \begin{pmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{pmatrix} = \begin{pmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{pmatrix}^{-1}$$

Isham Panigrahi et al. used the following experimental set up for experimentation work and finally they compared with FEA Result. They considered crack depth and crack position are two main parameters. Crack depth and relative crack position have got major effects on dynamic behaviours of cantilever beam. They got the natural frequency of a cantilever beam with transverse crack decreases with increase of crack depth [8].

K. Mazanoglu et al [9] gives the vibration analysis of single crack as well as double cracked cantilever beam. They give algorithm for detection of cracks on the beams and a statistical process for minimising the measurement errors in experiments.

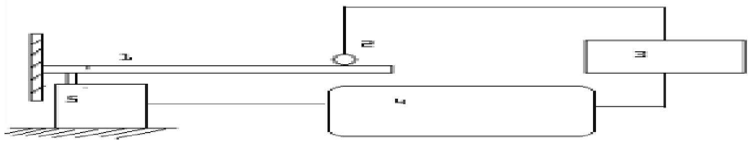

Fig 6: Experimental set up

1. Cracked Cantilever beam   2.Vibration pick-up   3. Vibration meter

4. Amplifier & Signal Generator   5. Electro Dynamic Exciter

They develop algorithm by using experimental ratios of natural frequencies as inputs and a map of theoretical natural Frequency ratios as base data. With the help of algorithm they developed the method for detection of single and double crack in beam. That means it gives statistical approach called 'recursively scaled zoomed Frequencies (RSZF)' for minimizing the deviations caused by sensitivity and resolution lack in measured natural frequencies.

D.K.Agarwalla et al. [10] gives the effect of an open crack on the modal parameters of the cantilever beam subjected to free vibration. The results obtained from the numerical method i.e. finite element method (FEM) which is compared with experimental data and identify the changes in cantilever beam. They found changes in Mode shapes and natural frequencies of the vibrating structures or cantilever beam. They concluded that crack is directly affecting the dynamic behaviour of the structure.

Orhan Studied the Single and double cracks in cantilever beam under the effect of free and forced vibration [6]. Orhan concluded that, the depth of crack increased and the natural frequency decreased when the beam is in both cases (single and double cracks). The reduction in the natural frequency is less when the crack location moves to the free end. In case of several cracks in various directions, this will reduce the impact on the dynamic properties and the decline is less. Therefore, when location of crack at the top it will be affected more than when the beam has two cracks in different sides [6].

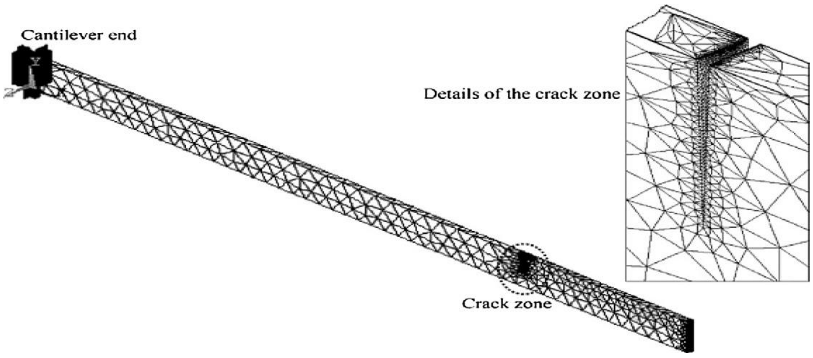

Fig 7: Finite Element Modelling Of the Cracked Beam

III. CONCLUSION

Crack is the most important parameter for structure failure or machine damage. Beam is the most important element in the research of vibration analysis for real engineering applications. It is the more flexible in various construction and machines that's why the crack detection is the important thing before use in practical application. In this paper different technique is adopted for crack detection and its analysis. This paper reviewed the vibration analyses for cantilever beam with crack

REFERENCES

[1] Zhang Xiaoqing, Han Qiang and Li Feng, "Analytical Approach for Detection of Multiple Cracks in a Beam", Journal of Engineering Mechanics. (ASCE March 2010):pp.345-357.

[2] E. Viola,L. Nobile and L. Federici "Formulation of Cracked beam element for structural analysis" journal of engineering mechanics / february 2002.pp 220-230.

[3] M Kisa, J Brandon, M Topcu, "Free vibration analysis of cracked beams by a combination of finite elements and component mode synthesis methods", Pergamon Journal of Computers and Structures 67 (1998) pp. 215-223.

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

[5] A. S. J. Swamidas, X.Yang and R. Seshadri "Identification of Cracking in Beam Structures Using Timoshenko and Euler Formulations", Journal of Engineering Mechanics (ASCE / November 2004): pp.1297-1308.

[6] Sadettin Orhan, "Analysis of free and forced vibration of a cracked cantilever beam", International Journal of NDT&E 40 (2007): pp. 443–450.

[7] G. Y. Xu, W. D. Zhu, and B. H. Emory, "Experimental and Numerical Investigation of Structural Damage De tection Using Changes in Natural Frequencies", Journal of Vibration and Acoustic. Volume 129 (December 2007): pp. 686-700.

[8] Isham Panigrahi and Dayal Ramakrushna Parhi " Dynamic analysis of Cantilever beam with transverse crack," 14th National Conference on Machines and Mechanisms (NaCoMM09).

[9] K. Mazanoglu, M. Sabuncu, "A frequency based algorithm for identification of single and double cracked beams via a statistical approach used in experiment", Mechanical Systems and Signal Processing 30 (2012) 168–185.

[10] D.K. Agarwalla, D.R. Parhi, "Effect of Crack on Modal Parameters of a Cantilever Beam Subjected to Vibration", Elsevier (NUiCONE 2012) Procedia Engineering 51 (2013) PP.665 – 669.