A Review on Vibration Analysis of a Cantilever Cracked Beam Using Various Techniques

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ABSTRACT

This paper discusses the crack detection of cantilever beam using the various vibration based Crack/damage diagnosis techniques presented by various researchers for cracked structures. These methods use "Mathematical analysis, finite element analysis techniques, together with experimental results, to detect damage in a cantilever beam for its vibration analysis. Damage in structure alters its dynamic characteristics. It results in reduction of natural frequencies and changes in mode shapes, stiffness of the beam. An analysis of these changes makes it possible to determine the location and depth of cracks.

Keyword: - Beam, Crack Detection, Vibration analysis

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1. INTRODUCTION

Beams are widely used as structural element in civil, mechanical, naval, and aeronautical engineering. Damage is one of the important aspects in structural analysis and engineering. Damage analysis is done to promise the safety as well as economic growth of the industries. During operation, all structures are subjected to degenerative effects that may cause initiation of structural defects such as cracks which, as time progresses, lead to the catastrophic failure or breakdown of the structure. To avoid the unexpected or sudden failure, earlier crack detection is essential. Taking this ideology into consideration crack detection is one of the most important domains for many researchers. Many researchers to develop various techniques for early detection of crack location, depth, size and pattern of damage in a structure. Many nondestructive methodologies for crack detection have been in use worldwide. However the vibration based method is fast and inexpensive for crack/damage identification.

In this paper efforts have been made to present various cost effective reliable analytical numerical and experimental techniques developed by various researchers for vibration analysis of cracked beams.

In this paper the effect of various parameters like crack size, crack location, of beam on modal parameters subjected to vibration of a damaged beam also have been reviewed.

2. LITERATURE REVIEW

Ranjan K. Behera [1] has presented to model an inclined open edge crack in a cantilever beam and analyse the model using a finite element package, as well as experimental approach. The experiments are carried out using specimens having inclined edge cracks of different depths, positions and crack inclinations to validate the FEA results achieved. Aniket S. Kamble [2] has presented crack is modeled as a rotational spring and equation for non-dimensional spring stiffness is developed. By evaluating first three natural frequencies using vibration measurements, curves of crack equivalent stiffness are plotted and the intersection of the three curves indicates the crack location and size. The time amplitude data obtained is further used in the wavelet analysis to obtain time-frequency data. Marco A. Perez [3] has presented to investigate the feasibility of using vibration-based methods to identify damages sustained by composite laminates due to low-velocity impacts. Four damage indicators based on modal parameters were assessed by comparing pristine and damaged states. It's precision in determining the location of damage, its sensitivity regarding damage extent and pertinent correlations with residual bearing capacity.

P. K. Jena [4] has presented the fault detection of Multi cracked slender Euler Bernoulli beams through the knowledge of changes in the natural frequencies and their measurements. The spring model of crack is applied to establish the frequency equation based on the dynamic stiffness of multiple cracked beams. Theoretical expressions for beams by natural frequencies have been formulated to find out the effect of crack depths on natural frequencies and mode shapes. Cantilever beam with two cracks analysis show an efficient state of the research on multiple cracks effects and their identification. Kaushar H. Barad [5] has presented detection of the crack presence on the surface of beam-type structural element using natural frequency. First two natural frequencies of the cracked beam have been obtained experimentally and used for finding of crack location and size. Amit Banerjee [6] has presented to obtain information about the location and depth of transverse open multiple cracks in a rotating cantilever beams. Mode shape of damaged rotating beam is obtained using finite element simulation. Using fractal dimension of mode shape profile, damage is detected.

FEM. Murat Kisa [7] have presented a novel numerical technique applicable to analyse the free vibration analysis of uniform and stepped cracked beams with circular cross section. It is revealed that the knowledge of modal data of cracked beams forms an important aspect in assessing the structural failure. N.V.Narasimha Rao L [8] has presented vibration analysis of a cracked cantilever beam with transverse crack. A fuzzy logic inference system is used to analyze the crack in cantilever beam. Saidiabdelkrim [9] has presented to analyse the vibration behavior of concrete beams both experimentally and using FEM software ANSYS subjected to the crack under free vibration cases. FB Sayyad [10] has presented efforts are made to develop suitable methods that can serve as the basis to detection of crack location and crack size from measured axial vibration data. This method is used to address the inverse problem of assessing the crack location and crack size in various beam structure.

A. Dixit [11] has presented damage measure which relates the strain energy, to the damage location and magnitude.

The strain energy expression is calculated using modes and natural frequencies of damaged beams that are derived based on single beam analysis considering both decrease in mass and stiffness. The method is applicable to beams, with notch like non-propagating cracks, with arbitrary boundary conditions. The analytical expressions derived for mode shapes, curvature shapes, natural frequencies and improved strain energy based damage measure, are verified using experiments. The damage measure was shown to be extremely sensitive to the damage as both the discontinuity in stiffness and also the curvature are contained in the damage measure. A limitation of the damaged measure was that it depended on accurate measurement of damaged mode shapes. Mousa Rezaee [12] has presented the energy balance method is proposed for free vibration analysis of a cracked cantilever beam by taking into account both the structural damping and the damping due to the crack. The stiffness changes at the crack location are considered to be a nonlinear amplitude-dependent function which causes the frequencies and mode shapes of the beam to vary continuously with time.

S.P.Mogal [13] has presented vibration analysis is carried out on a cantilever beam with two open cracks to study the response characteristics. In first phase local compliance matrices of different degree of freedom have been used model transverse cracks in beam on available expression of stress intensity factor and strain energy release rate. The results obtained numerically are validated with results obtained from simulation (FEM). Patil Amit V [14] has presented measurement of natural frequencies is presented for detection of the location and size of a crack in a cantilever beam. Numerical calculations has been done by solving the Euler equation for un-crack beam and cracked beam to obtain first three natural frequencies of different modes of vibration considering various crack positions for the beam. ANSYS software is used for analysis of crack and un-crack cantilever beam. Pankaj Charan Jena [15] has presented the strain energy density function also applied to examine the few more flexibility produced to because of the presence of crack. Considering the flexibility an additional stiffness matrix is taken away and consequently, it is used to find the natural frequency and mode shape of the cracked beam of different end conditions of beam. The difference of mode shapes of cantilever beam, simply supported beam and Clamped –Clamped beam in between the first three modes of cracked and un-cracked respectively beam with its amplified view at the zone of the crack locale are studied.

3. MATERIAL & METHODS

Structural steel beams have been considered for making specimens. The specimens were cut to size from ready-made square bars. Total 05 specimens were cut to the size as length 700 mm and cross section area is 10mmX10mm. The modulus of elasticity and densities of beams have been measured to be 210GPa and 7850 Kg/m3 and analysis on material is followed by methods such as theoretical analysis, experimental analysis, and FEA analysis.

1) Theoretical analysis is done by Euler’s beam theory.
2) Experimentation will be conduct on FFT analyser.
3) Finite Element Analysis will be performing on ANSYS.

3.1 Material Geometry

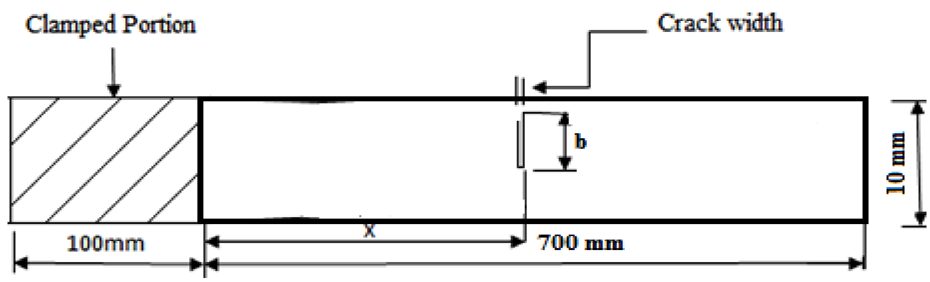

Fig.1 Cracked Square Beam Specimen

Table-1: Different Beam models and their dimensions

Beam Model No.	Material	Cross section dimension (mm)	Cracked/Uncracked	Position and location of crack	
				Crack depth (mm)	Crack location(mm)
1	Structural Steel E= 210×10^9 N/m^2, ρ = 7850 Kg/m^3, length = 0.7m.	10×10	Uncracked	0	0
2		10×10	Cracked	1	175
3		10×10	Cracked	2	175
4		10×10	Cracked	1	350
5		10×10	Cracked	2	350

3.2 Theoretical Analysis

After preparing the crack on the different beam models, Natural frequencies are calculates by using Euler's beam theory are as follows:

Table-2: Theoretical natural frequencies for the beam models

Beam model no.	Relative Crack Depth	Relative Crack Length	First Natural Frequency	Second Natural Frequency	Third Natural Frequency
1	0	0	17.06	107.22	299.11
2	0.2	0.25	17.04	107.14	298.82
3	0.4	0.25	16.98	106.76	297.84
4	0.2	0.5	17.04	107.14	298.82

5	0.4	0.5	16.98	106.76	297.84

4. DISCUSSION

Earlier, cracked vibrating structures are effectively analyzed by various researchers using the different nondestructive evaluation and non-destructive techniques. According to some researcher changes in dynamics characteristics can be used as an information source for detecting of vibrating beam or structure in presence of crack. Researchers working on various structures have studied the effect of crack location, crack depth, crack inclination on natural frequency of a cracked beam subjected to vibration. Transfer matrix method uses the input data of changes in mode shapes and natural frequencies for determination of crack location and crack depth. The physical dimensions, boundary conditions and the material properties of the structure play important role for the determination of its dynamic response. The position, depth ratio, orientation and number of cracks are greatly influence the dynamic response of the structure. Many researchers have worked on the application of artificial neural network and fuzzy logic concept for diagnosis of crack in a vibrating beam structure. Some have worked on the application Continuous Wavelet analysis for detecting of crack in vibrating beam. Concept of fracture mechanics, stress intensity factor and knowledge of strain energy release rate has been used for analysis of crack detection.

5. CONCLUSION

It has been observed that the changes in natural frequencies are the important parameter that determine crack size and crack location respectively. Some researchers have considered composite structures in their study to analyse the effect of various parameters like crack location, crack size, crack depth, crack inclination on the dynamic behavior of structures subjected to vibration. Researchers are presently focusing on using the concept of fuzzy Logic, Artificial Neural Network (ANN) and genetic Algorithm as an effective tool for vibration analysis of structures. Various models have been developed by researchers using various theories and concepts to study the dynamic characteristics of damaged vibrating structures having various types of crack like Transverse, Longitudinal, Slant, Gaping, Surface, Subsurface, breathing, open edge crack and internal cracks.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support of the Department of Mechanical Engineering of Pravara Rural Engineering College, Loni-413736 Tal- Rahata, Dist- Ahmednagar (M.S.), India

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