Vibration Analysis of Cracked Cantilever Beam – A Review

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Abstract - The aim of this paper is diagnosis of various vibration based crack detection technique by various researches. For detection of damage in a fibre reinforced composite and non composite structure, this method compare finite element analysis and experimental modal analysis. Damage / crack present in structure affect on its static as well as dynamic response characteristics. Crack in a beam alter the natural frequency, mode shape & stiffness. To note down all results it's possible to find out crack depth and crack position.

Key Words: Cantilever beam, Vibration Analysis, composite, Fractal Dimensional Analysis, Wavelet analysis, Finite element Method.

1. INTRODUCTION

It is required structure must safely work during its service life. Crack in a structure hazardous due to static and dynamic loading, so the crack detection plays an important role in structural health monitoring application. Many of researchers develop various non destructive techniques for early detection of crack location, crack depth and crack size. There are many techniques to evaluate the problem of a cracked beam such as numerical, analytical, and experimental. FEM (Finite Element Method) is a common technique to obtain the stiffness matrix of the cracked beam element. During last few decades, intensive research on the detection of crack using the vibration based techniques has been done. In this present paper number of literatures published so far have been surveyed, reviewed and analysed. This paper focus on various cost effective reliable, numerical and experimental techniques developed by various researchers for vibration analysis of cracked beams.

2. LITERATURE REVIEW

Murat Kisa, M. Arif Gurel[1] explained that, in which the finite element analysis and component mode synthesis methods are used together, the beam is separated into parts from the crack section. Numerous techniques, such as non-destructive monitoring tests, can be used to veil the condition of a structure. Novel techniques to identify structural defects should be explored. A crack in a structural element alters its stiffness, dynamical performance and damping properties. The mode shapes and natural frequencies of the specimen hold information relating to the location and dimension of the crack. Vibration analysis allowing online inspection is an attractive method to identify cracks in the structures. These sub-structures are joined by using the flexibility matrices taking into account the interaction forces derived by fracture mechanics theory as the inverse of the compliance matrix found with stress intensity factors and strain energy release rate expressions. To reveal the accuracy offered method, a number of numerical examples are given for free vibration analysis of cantilever beams with transverse non-propagating open crack. Numerical results showing good agreement with the results of other possible studies, address the effects of the depth and location of the cracks on the natural frequencies and mode shapes of the damaged beam. Modal characteristics of a cracked beam can be employed in the crack recognition process.

Saidi abdelkri, Benahachelif souad[2] explained that, dynamic characteristics of damaged and undamaged materials are very different. The dynamic properties of a structure can be found by FEM modal-simulations (Finite Element Analysis), or by experimental modal analysis. Crack formation due to cycling loads leads to fatigue of the structure and discontinuities in the interior configuration. Cracks in vibrating parts can initiate catastrophic failures. Therefore, here is a need to know the dynamics of cracked structures. The aim of this study is to analyze the vibration characteristics of concrete beams both experimentally and using ANSYS subjected to the crack under free vibration cases. Besides this, information about the place and depth of cracks in cracked concrete beams can be obtained using this technique. When the location of the crack increases stars from the clamped end of the beam, natural frequencies of the beam and the amplitude of high frequency also increase, but the amplitude of low frequency vibration decreases. It was shown that as the depth of the crack increases, the magnitude of amplitude of vibration also increases at high frequencies but the natural frequencies decrease. This is right because of the stiffness reducing is inversely proportional to the depth of a crack.

P. K. Jena,. R. K. Parhi[3] explained that, the identification of Multi cracked slender Euler Bernoulli beams through the knowledge of change in the natural frequencies and their measurements. The method is based on the modelling a crack by rotational spring. The model of crack is applied to establish the frequency equation on the dynamic stiffness of multiple damaged beams. Theoretical expressions for natural frequencies have been developed to find out the effect of crack depths on mode shapes and natural frequencies. The equation is the basic instrument in solving the multiple crack detection of beam. The significant changes in mode shapes are observed at the local area of crack location. The locations of the cracks in relation to each other affect changes in the frequencies of the natural vibrations in the case of an equal corresponding depth of the cracks. Any decrease in the natural frequency is higher if the cracks are near to each other; when the distance between the damages increases the frequencies of the beam natural vibrations also tend to the natural frequencies of a system with a single crack. In the case of two cracks of different depth, the big crack has the most significant effect on the natural vibration frequencies. For other modes of vibration this is not so clear, because the effect of a crack location at a node is negligible. These changes in natural frequencies and mode shapes will be helpful in forecasting of crack location and its intensity.

S.P.Mogal, Dr.R.K.Behera, S.Y.Pawar [4] explained that, vibration analysis conducted on a cantilever beam with two open cracks to determine the response characteristics. In first phase civic compliance matrices of different degree of freedom have been used model transverse crack in beam on available expression of strain energy release rate and stress intensity factor. The results obtained numerically are validated with results obtained from simulation (FEM). The simulations have been done with the help of ANSYS software. It is verified from both computational and simulation analysis that the presence of crack decrease the natural frequency of vibration. The mode shapes also changes considerably due to presence of crack. The presence of crack in structure member introduces local flexibilities which can be computed and used in structural analysis. The problem involves calculation of natural frequencies and mode shapes for cantilever beam without a crack and with two cracks of different crack depths. The results calculated analytically are validated with the results obtained by simulation analysis. The frequency of cracked cantilever beam decreases with increase crack depth for the all mode of vibration. A neural network for the cracked structure is trained to approximate the response of the structure by the data set prepared for different crack sizes and locations. Training data to train the neural network are properly prepared.

Pankaj Charan Jena, Dayal R. Parhi, Goutam Pohit[5], explained that, fault detection in a single cracked beam has been worked out. To identify location and the depth of crack in a beam containing single transverse crack is done through conceptual and experimental analysis respectively. It has come to noticed that a crack in a beam has great effect on dynamic characteristics of beam. The strain energy density function also applied to examine the few more flexibility produced because of the presence of crack. Considering the flexibility an additional stiffness matrix is taken away and it is used to obtain the natural frequency and mode shape of the cracked beam of different end conditions. The difference of mode shapes of cantilever beam, simply supported beam and Clamped – Clamped beam in between the first three mode shapes of cracked and un-cracked respectively beam with its amplified view at the location of the crack are studied. The theoretical analyses are carried out of the crack structure. Finally for the validation of result are matched with the both theoretical and experimental analysis. It is found that the agreed between their results is excellent. The comparisons of result in both methodologies written above are performed. The future work on the problem of fault recognition of a cracked beam can be carried by using more advanced hybrid techniques with the help of finite element method and artificial intelligence technique.

Kaushar H. Barad, D. S. Sharma, Vishal Vyas[6] explained that, detection of the crack presence on the surface of beam type structural element using natural frequency is discovered. First two natural frequencies of the cracked beam have been obtained experimentally and used for detection of crack location and size. Obtained crack locations and size are compared with the actual results and found to be in good agreement. All structures are prone to damage, may be due to over-stressing in operation or due to extreme environmental conditions or due to any accident. Crack present in the specimen may grow during service and may result in the component failure once they develop beyond a critical limit. It is desirable to investigate the damage occurred in the structure at the earlier stage to protect the structure from possible failures. Thus, Vibration Based Inspection (VBI) can be a effective method for crack detection. Though, there has been an intense study on crack detection through vibration based inspection, it is essential to develop an effective and economically appropriate approach. The natural frequency is highly affected by crack depth and crack location. Using this approach, damage detection can be done using natural frequency. The present method to detect crack location and size is fast and efficient. Crack with larger crack depth ratio (a/h) imparts higher reductions in natural frequency than that of the smaller crack depth ratio. Hence, the accuracy of results enhance as crack depth increases. Crack present near to fixed end affect greater reductions in natural frequency than away from the fixed end.

Missoum Lakhdar, Moudden Bachir[7], explained that, this work focuses on the detection of damage by vibration analysis, whose main aim is to exploit the dynamic response of a structure to detect the damage. The experimental results matched with those predicted by numerical models to confirm the effectiveness of the approach. The choice of composite materials has no longer restricted to specific applications. Replacement of metallic materials by composite one is often based on an economy of mass (low density). In addition, they offer to their low density, high mechanical parameters and some cases specific and adapted. The natural frequency decreases as the degree of degradation of the rigidity (EI).The position of the crack is probably detectable by comparing a specific vibration mode, i.e. if the crack is to be submit on a vibration node, none enough significant variation in natural frequencies. The experimental situations are significant on the dynamic behavior of the structure. The beam geometry can also be altered by the direction of a crack change. The heterogeneity of the structure gives always critical sections that can enhance the embrittlement and propagation of small cracks. These may change by the vibration effect and shocks, causing the structure damaged.

Prasad Ramchandra Baviskar, Vinod B. Tungikar[8] ; explained that, the method of multiple cracks detection in moving parts or beams by monitoring the natural frequency and forecasting of crack location and depth using Artificial Neural Networks (ANN). Detection of crack properties like depth and location is vital in the fault diagnosis of rotating machine components. For the theoretical analysis, Finite Element Method (FEM) is used wherein the natural frequency of beam is calculated whereas the experimentation is done by using Fast Fourier Transform (FFT) analyzer. In experimentation, simply supported beam with one crack and cantilever beam with two cracks are considered. The experimental results are validated with the results of FEM (ANSYS) software. This formulation can be extended for various boundary conditions as well as varying cross sectional areas. The database obtained by FEM is used for prediction of crack location and depth using Artificial Neural Network (ANN). To investigate the validity of the proposed method, some predictions by ANN are compared with the results given by FEM. It is found that the method is capable of predicting the crack location and depth for single as well as two cracks. This work may be useful for improving online conditioning and monitoring of machine components and integrity assessment of the structures.

FB Sayyad, B Kumar and SA Khan[9], explained that, to develop suitable methods that can serve as the basis to detection of crack location and crack size from measured axial vibration data. Cracks develop gradually through time that lead finally to catastrophic failure. Therefore, crack should be monitored regularly with more care. This will lead to more effective preventive measure and ensure continuous operation of the structure and machine. Damage in structure alters its dynamic characteristics. The change is characterized by change in modal parameters, that is, modal frequencies. Thus, vibration technique can be suitably used as a non-destructive test for crack detection of component to be tested. This method for detection of crack from measurement of natural frequencies of cracked free–free beam for axial vibration is developed. Analysis of this approximate model results in algebraic equations, which relate the natural frequencies of beam and crack location. These expressions are applied to studying the inverse problem, that is, identification of crack location from frequency measurements. For crack size an integrated approach is used, which gives a relation between frequencies' changes, crack location, and crack size in the beam. The error in prediction of crack location and crack size by theoretical and experimental analysis is less than 16%. The proposed method is confirmed by comparing it with results of ANSYS FEM results. The proposed method is found to be both simple and accurate.

D.K. Agarwalla, D.R. Parhi[10] explained that, 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 analyzed and the results obtained from the numerical method i.e. finite element method (FEM) and the experimental method are compared. Mode shapes and natural frequencies of the vibrating structures are susceptible to change under the affect of crack depth & crack location. Mode shapes in magnifying views allow the researchers to get an idea of the major changes at the crack location. Therefore position and severity of crack can be determined by analyzing these changes. The experimental results can be confirmed conveniently by comparing the results obtained from cracked beam numerically.

Ranjan K. Behera, Anish Pandey, Dayal R. Parhi[11] explained that, A crack in the vibrant structures can lead to premature failure if it is not detected in early stages. The failure rate increases as the crack growth increases due to the structure becomes weaker. Therefore, crack detection and type of crack is a key issue. The existence of cracks which affect the performance of structure as well as the vibration characteristics such as; natural frequencies, mode shapes, stiffness and modal damping. This paper presented model an inclined open edge crack in a cantilever beam and analyzes the model using a finite element analysis, as well as experimental approach. When the natural frequency increases, the crack location also increases. At particular crack location of a beam, the amplitude is minimum with respect to other beams having varying crack location. The crack inclination angles are valid up to 45 ° for examining the transverse vibration. The crack position in the cantilever beam can be projected for crack size of more than 10% of depth. It has also been seen from examples that the determination of the crack location is more precise than the determination of the crack size.

Aniket S. Kamble, D. S. Chavan[12] explained that, evaluating first three natural frequencies using by vibration measurements, curves of crack stiffness are plotted and the intersection of the three curves indicates the crack location and size. Cantilever beam with single crack (different location and different size) using ANSYS package to obtain natural frequency, which are compared with FFT results. Both the FEM and FFT results show that the adequate accuracy and high sensitivity for small cracks. As the crack depth increases the estimated error of the crack location increases. This method provides effective, simple and fast non- destructive techniques by using the continuous wave technique tool. This method can be extended for damage detection of complex structures.

Amit Banerjee, G Pohit[13] explained that, presence of crack in a structural member alter the local flexibility and vibration response characteristics. Crack changes natural frequency and mode shape of structure. This paper investigates location and depths of transverse open multiple cracks in rotating cantilever beam. Mode shape and natural frequencies of rotating cantilever beam find out by using finite element simulation. By using Fractal dimension method mode shape and damage detected. Subsequently, both the results obtained finite element analysis and fractal dimension method to evaluate crack depth and crack location.

Marco A. Perez, Lluis Gil, Sergio Oller[14] explained that, experimental analysis conducted to evaluate the feasibility of vibration based method to identify crack sustained by composite laminates due to low velocity. According to ASTM (American society for Testing and Materials) method, experimental based program evaluation of resistance offered by impact damage and tolerance. The results of experimental analysis on a set of composite laminates were discussed and explained, characteristics of induce damage, evaluation of impact damage, effect on vibration response and impact damage resistance.

3. MATERIALS AND METHODS

Vibration analysis of various materials like Aluminium, Mild steel, concrete is followed by authors by their methods such as experimental, finite element analysis, Artificial Neural Networks, Wavelet analysis, MATLAB. Study of E-glass fibre epoxy resin, Glass/polyester, fibre glass is done by using compliance matrix numerical model analysis, and numerical, experimental methods.

4. DISCUSSION

Many of researcher used different non-destructive techniques for detection of crack in vibrating structure. According to the researcher, presence of crack alters the dynamic characteristics of structure. This change in dynamic source used as a information source. Researchers done lot of work on effect of crack depth, crack location and crack inclination on natural frequency and mode shape. Researcher used transfer matrix method as an input data. Physical properties, boundary condition, crack depth, crack inclination ,crack inclination ,orientation and number of cracks greatly influence the dynamic response of the structure. Some have used wavelet analysis for detection in vibrating structure. Many researcher worked on the Artificial Neural

Network and Fuzzy logic techniques for identification of crack in beam structure. Researchers used concept like strain energy, stress intensity factor and fracture mechanics for detection of crack in cantilever beam.

5. CONCLUSION

It is found that detection of crack size, crack location in cantilever beam depends on natural frequencies and mode shapes. Many researcher studied dynamic behaviour of structure by varying crack location, crack inclination and crack depth. Researchers develop much technique for analysing vibration system. Now-a-days many researcher using artificial neural network (ANN), genetic algorithm and fuzzy logic techniques for damage detection in structure. Researcher developed various theories and concept like transverse crack, longitudinal crack, slant crack, breathe, surface crack, open crack etc for identify dynamic characteristics of structure.

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BIOGRAPHIES

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