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Review Article

A REVIEW ON IDENTIFICATION OF CRACKS IN ALUMINIUM CANTILEVER BEAM THROUGH FINITE ELEMENT ANALYSIS (ANSYS)

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ABSTRACT

In past era of time, a wide range of researches and study works have been made and concluded by various researchers/ authors in the development of techniques for the identification of cracks (structures). It is verified by the various studies that the dynamic behavior of any structure changes causes presence of any defects such as cracks in a body of structure. Therefore, it is vital to identify the defects in structures and its components; which is generally called crack and analyze them. The present work conducted to review analytical as well as experimental investigation/studies conducted by the researchers for the identification of cracks in an aluminum cantilever beam with rectangular cross section. The main purpose of this review is to examine and to verify the extent of harm to the beam (structure) with the critical location of the crack in a cantilever beam.

Keywords: Finite Element Method (FEM), ANSYS software, Aluminum cantilever beam.

INTRODUCTION

To identify the critical crack location and to examine the degree of damage in a beam; various experimental studies have been conducted and several methods were proposed by the authors very frequently in recent years. Cantilever elements are an essential part of a structures in a various filed of science and it very closely relates to the human daily life in this modern era. Cantilever structures are mainly applicable in the field of Civil, Mechanical as well as Aerospace engineering.

The function which mainly relates to the cantilever structures in the field of engineering is their capability to withstand high level of stress, strain and their other mechanical properties. Therefore, to design best durable cantilever beams or other cantilever element, the designer have to know the effects of cracks (faults) on beam, if occurred or generated in a body of cantilever beam. Some methods have been generated by the researchers in past time; such as ultrasonic method, magnet field method, radiograph, eddy-current methods etc. It was observed that all those experimental methods are bounded in some specified criteria. In the field of civil engineering various natural agencies such as frequent rise and fall of temperature, temperature difference, rainfall, heavy wind, flood and earthquakes damages the constructional form of a structures and generates constructional defects; which is generally known as expansion and shrinkage of concrete can form cracks in a body of structure. It is theoretically and experimentally verified that the cracks can affect the durability and life time of the structure in a serious manner; which is very harmful to the structure. As cracks may cause serious damage of the structure with due course of time hence it is very important to detect in early stage. It is always very difficult to detect fine cracks through visual inspection techniques.

Availability of Cracks in vibrating element of a structure can make serious consequences on the workability of the structure and up to some extent it may convert to a ruinous failure of a structure. Hence, there is a need to determine and identify the dynamics behavior of cracked structures (Chati M, Rand R, 1997). Moreover, the author Kam and Lee, 1992 uses the finite elements method on a cantilever beam for determining the location of crack and its effect on a structure.

Furthermore, the author Jinhee Lee [1] has proposed a technique for the identification of cracks in a beam by using boundary element method. For the detection of crack in a beam, the author designed a crack in such a way that the crack is not modeled as a massless rotational spring, and the forward problem is solved for the natural frequencies using the boundary element method. The inverse problem is solved iteratively for the crack location and the crack size by the Newton-Raphson method. The present crack identification procedure is applied to the simulation cases which use the experimentally measured natural frequencies as inputs, and the detected crack parameters are in good agreements with the actual ones. The present method enables one to detect a crack in a beam without the help of the massless rotational spring model. For the experimental identification of cracks, the author Akhilesh Kumar, J.N. Mahato [2] was proposed experimental investigation of cracks in aluminum cantilever beam using Vibration monitoring technique. In this study Analysis of such phenomena is useful for fault diagnosis and the detection of cracks in structures. An experimental setup is designed in which an aluminum cantilever beam with cracks is excited by a power exciter and accelerometer attached to the beam provides the response. The cracks are assumed to be open to avoid non-linearity. The effects of crack and positions on the fundamental frequencies of slender cantilever beams with edge cracks are investigated experimentally. The experiments are conducted using specimens having edge cracks of different depths at different positions to validate the numerical results obtained. The experimental results of frequencies can be obtained from digital storage oscilloscope (DSO).

The first three natural frequencies were considered as basic criterion for crack detection. To locate the crack, 3D graphs of the normalized frequency in terms of the crack depth and location are plotted.

The objective of this review is to quantify and to determine the extent of the damage magnitude and the location of the cantilever beams. In analytical study, finite element method (FEA) software was used in developing the model. The results showed that, by monitoring the change of the natural frequency it is a feasible and viable tool to indicate the occurrence of damage and its magnitude.

Literature Review - In this section of paper introduces various different recent efforts made by various authors on identification of cracks in a cantilever beam using wide range of techniques. That provides us guidelines to investigate and to develop a new and more efficient system for the identification of cracks.

In referred paper [3] author focused on Experimental Investigation of Crack detection in Cantilever Beam Using Natural Frequency as Basic Criterion. The author was noticed Non destructive testing (NDT) methods are used for detection of crack which are very costly and time consuming. Therefore, currently research has focused on using modal parameters like natural frequency, mode shape and damping to detect crack in beams. In this paper, the author presented a method for detection of open transverse crack in a slender Euler–Bernoulli beam.

Experimental Modal Analysis (EMA) was performed on cracked beams and a healthy beam. The first three natural frequencies were considered as basic criterion for crack detection. To locate the crack, 3D graphs of the normalized frequency in terms of the crack depth and location are plotted. The intersection of these three contours gives crack location and crack depth. Out of several case studies conducted the results of one of the case study is presented to demonstrate the applicability and efficiency of the method suggested.

In this experimental set up a mild steel beam were used with its 49 beam model and fixed free ends condition. Each beam model having cross sectional area 20mm x 20mm with a length of 300 mm from fixed end having specific Young modulus, density and Poisson ratio.

For the identification of cracks, the beam with fixed–free end conditions model was clamped at one end, between two thick rectangular steel plates, supported over a short and stiff steel I-section girder. The beam was excited with an impact hammer. The first three natural frequencies of the uncracked beam were measured and recorded. Then, cracks having 0.35 mm thick were generated to the desired depth using a wire cut EDM; the crack always remained open during dynamic testing Total 49 beam models were tested with cracks at different locations starting from a location near to fixed end. The crack depth varied from 1.5mm to 14mm at each crack position. Each model was excited by an impact hammer. This served as the input to the system. It is to be noted that the model was excited at a point, which was a few millimeters away from the center of the model. This was done to avoid exciting the beam at a nodal point (of a mode), since the beam would not respond for that mode at that point. The dynamic responses of the beam model were measured by using light accelerometer placed on the model and the response measurements were acquired, one at a time, using the FFT analyzer.

In this study, the author for the first three modes of vibrating cantilever beams conclude that it is evident that the vibration behavior of the beams is very sensitive to the crack location, crack depth and mode number. A simple method for predicting the location and depth of the crack based on changes in the natural frequencies of the beam is also presented, and discussed. This procedure becomes feasible due to the fact that under robust test and measurement conditions, the measured parameters of frequencies are unique values, which will remain the same (within a tolerance level), wherever similar beams are tested and responses measured. The experimental identification of crack location and crack depth is very close to the actual crack size and location on the corresponding test specimen.

However, In referred paper (4) the authors Qwolabi, Swamidas and Seshadri were conducted a research on "crack detection in beams using changes in frequencies and amplitude of frequency response functions". In this paper the author made an attempt to detect the presence of a crack in beams, and determine its location and size, based on experimental modal analysis results. The results were obtained from measurements of dynamic responses of cracked beams. Changes in natural frequencies and frequency response function (FRF) amplitudes as a function of crack depths and locations were used in the crack detection methodology.

In this experimental set up two set of aluminum beams were used for experimental study. Each set consisted of seven beams, first set had fixed ends and the second set was simply supported ends. Cracks were located at seven different locations from one end to other end for each set by using crack depth ratio from 0.1d to 0.7d under dual channel frequency analyzer.

The basic linear differential equation of motion, of a multi-degree-of-freedom (m.d.o.f.)

structure, is given by

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{F(t)\} \text{ -- -- -- -- -- -- -- -- -- } (1)$$

where [M] is the mass matrix, [C] the damping matrix, [K] the stiffness matrix, {x(t)} the

displacement vector, $\{\dot{x}(t)\}$the velocity vector, and $\{\ddot{x}(t)\}$the acceleration vector. The above equation balances the structure's internal forces, which are a combination of mass (inertial), damping (dissipative), and stiffness (elastic restoring) terms (referred to the spatial model) with the externally applied forces. Defects existing in a structure cause a change in its stiffness, and could also affect its mass distribution, and damping properties. Consequently, there would also be a change in the dynamic response of the structure. In addition to Eq. (1) shown above, the linear dynamics could also be represented by other equivalent expressions such as the FRF, modal parameters or the impulse response function. Therefore, if the acquired FRF, modal parameters or the impulse response of the structure undergoes a change, there will be a corresponding change in its mass, damping, and/or stiffness properties. This is the basis for using modal analysis in damage detection.

In referred paper (5), the authors Z.A. Jassim, N.N. Ali b, F. Mustapha, N.A. Abdul Jalil were analyzed that Identification of defects in structures and its components is a crucial aspect in decision making about their repair and total replacement. The objective of this review is to quantify and to determine the extent of the damage magnitude and the location of the cantilever beams. Mode shapes indicated good sensitivity to detect the damage magnitude for all crack parameters.

The basic theory of vibration-based structural damage identification is the changes in structural properties such as stiffness and mass. The presence of damage influences the vibration response as well as the dynamic properties (natural frequencies, mode shapes and damping ratio) of the structure. These properties are used as the damage indicators of the tested structure. In order to ensure structural safety and reliability, it is necessary to perform long-term, mid-term and short-term continuous health monitoring of the structure during its service life. One of the most important dynamic property is the stiffness, which could lead to changes in the mode shape as well as reduction in frequencies and increases damping. Based on these changes, it could be possible to locate and determine the magnitude of the crack.

In vibration-based structural damage identification, it is very critical to extract model parameters information based on structural response measurements. Global information of a structure provides accuracy and critical data for determining the structural status of the structure. These model parameters are necessary for the classification of structural damage and structural health monitoring. The effects of structural damage can be classified as linear or nonlinear. Defines a classification system for damage identification methods as follows:

First Stage 1 : Damage is detected.
Second Stage 2 : Damage is localized.
Third Stage 3 : Damage severity.
Fourth Stage 4 : Prognosis.

The author's analyzed Vibration analysis by three different way or methods, those are;

Vibration analysis using Euler-Bernoulli Beam theory

Vibration analysis with fatigue crack
Vibration analysis using Timoshenko Beam theory

After analyzing the beam at each stage and parameters, the authors conclude that the vibration analyses for cantilever beam with crack were illustrated analytically, theoretically and experimentally; with the beams having various properties and dimensions. In computing the Damage Magnitude Index one needs to rely on the frequency and mode shape (MAC) and inherently the damage localization can be defined by using mode shape (COMAC) and Curvature Change Index (CCI).

In referred paper (6), the authors H. Nahvi_, M. Jabbari were investigated a scope for the detection of cracks in beams by adopting experimental modal data and finite element model". In this paper the authors adopted an analytical, as well as experimental approach for the detection of crack in cantilever beams by establishing vibration analysis. An experimental setup is designed in which a cracked cantilever beam is excited by a hammer and the response is obtained using an accelerometer attached to the beam. To avoid non-linearity, it is assumed that the crack is always open. To identify the crack, contours of the normalized frequency in terms of the normalized crack depth and location are plotted. The intersection of contours with the constant modal natural frequency planes is used to relate the crack location and depth. A minimization approach is employed for identifying the cracked element within the cantilever beam. The proposed method is based on measured frequencies and mode shapes of the beam.

Generally, detection of crack in a beam is performed in two steps. First, by establishing a finite element model of the cracked cantilever beam. The beam is discretized into a number of elements, and the crack position is assumed to be in each of the elements. Next, for each position of the crack in each element, depth of the crack is varied. Modal analysis for each position and depth is then performed to find the natural frequencies of the beam. Using these results, a class of three dimensional surfaces is constructed for the first three modes of vibration, which indicate natural frequencies in terms of the dimensionless crack depth and crack position.

First Step : Behavior of Cracked element

Second Step : Identification of cracks location

Finally the author's concluded that from the theoretical analysis and experimental measurements, it is found that the crack location, as well as crack size, has noticeable effects in the first and second natural frequencies of the cantilever beam. Natural frequencies decrease significantly as the crack location moves towards the fixed end of the beam. The identification procedure presented in this study is believed to provide a useful tool for detection of medium size cracks in a beam. For such size of cracks, the method gives reliable and accurate results (within 1%) for crack depth. The relative error at crack location is also acceptable.

Moreover, In referred paper (7) the authors Irshad A Khan, Dayal R Parhi worked on "Finite Element Analysis of Double Cracked Beam and its Experimental Validation". The authors reported that the main objective of this paper is to quantify the effects of crack depth on natural frequency and mode shape of beam; Cantilever and fixed fixed beam are engaged for analysis. 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.

Moreover, the authors conclude that on the behalf of his experimental validation that the oblique cracks is a harsh risk on the performance of the structures. It reduces the rigidity (stiffness) of the structures; which guide to upset the vibration signatures such as natural frequency and mode shape. This investigation 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 natural frequencies increase and mode shapes decrease as the crack depth increases.

CONCLUSION

There are various method of detection of cracks in any structural members. Every method has its own specified criteria to perform it. Cracks are the serious damages in any structure and they affected the durability as well as its strength.

Various theoretical and experimental methods of detection of cracks and effects are discussed earlier, but small cracks; which was appeared in earlier stage cannot be detected by these methods. Finite Element analysis is an excellent method; which can be used for the identification of cracks and for the study of its effects, because this method is based on discritisation of any element and the whole mass will get in a number of small elements. There are various software available; which are based on FEA (Finite element analysis). ANSYS is one of them, In our next article will be use ANSYS for detection of cracks in specified beam. In next article; we will identify the cracks and its effect in an aluminum cantilever beam by using ANSYS software and compare its results from the article (2) Akhilesh Kumar, J.N. Mahato "experimental investigation of cracks in aluminum cantilever beam using Vibration monitoring technique".

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