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Multiple Crack Detection of Beams

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ABSTRACT

Beam type structures are being commonly used in steel construction and machinery industries, in structures and machines, and fatigue cracks are the main cause of beams failure. Crack occurs in beams to change its dynamic behavior of structure and examining these changes in crack location and crack size are identified. The NDT methods are used for crack detection and which are costly and time consuming. In this paper the beam consider to open transverse cracks. Currently research has focused on using modal parameters i.e. natural frequency used for crack detection. In this paper the modal analysis was performed on cracked beams and a healthy beam, to calculate natural frequency. The first five natural frequencies wear considered for crack detection. To locate the crack i.e. crack depth and crack locations are plotted. The intersection of these contours indicates crack location and crack depth, hence to detect multiple cracks. The experimental results are obtained by using FFT analyzer. Finally the ANSYS result compare with experimental result.

Keywords— **Vibration based detection, multiple crack, crack location and crack depth, natural frequency, frequency contour line.**

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I. INTRODUCTION

The behaviour of members of structure varies as per damaged or undamaged condition. Most of structures fail due to damage like cracks in member. So, many experiments are done to know the dynamic behaviour of members. The cracks cause the reduction in stiffness and natural frequency. In this paper the objective is to get the natural frequency of cantilever beam with multiple cracks which alert from resonance of structure which leads to fail. And also verify the frequency with the experimental and analytical value. Mechanical structures in service life are subjected to combined or separate effects of the dynamic load, temperature, corrosive medium and other type of damages. Beam is widely used in aircrafts and machinery structures. Because of vibration and cyclic loading action it get cracks on it, that is fatigue cracks are the main cause of beam failure. This leads to the change the natural frequency of member. This experiment done to know the effect of crack characteristics (location, depth, number of cracks) on natural frequencies of beam. The importance of an early detection of cracks appears to be crucial for both safety and economic reasons because fatigue cracks are potential source of catastrophic structural failure. Damage identifications methods are mainly based upon the shifts in natural frequencies or changes in mode shapes. [6]

Detection techniques based on the non-destructive testing (NDT) has been preferable due to low cost and operational aspects related to the use of the analysed structure. Themethods for damage detection based on the sensitivity and statistical parameters. Some methods are based on the dynamic characteristics of structures such as natural frequencies. Vibration based modal analysis detection techniques as crack or any damage in a structure changes its dynamic characteristics, i.e. natural frequencies, mode shapes , modal participation factors , modal damping, , and impulse response and frequency response functions etc. The changes in these dynamic properties depend on the sizeand location of damage. Hence, by monitoring the change in any or all of these parameters, damage can be characterized.[4]

The cracks develop in a component that leads to changes its vibration parameter, e.g. a reduction in the stiffness and increase in the damping and a reduction in the natural frequency. They may enable for determination of size and location of a cracks from the vibration data collected from a single and multiple cracks on the component. These changes are mode dependent. Hence it may be possible to estimate the size and location of the crack by measuring the changes in vibration parameters. This technique using changes in natural frequencies as the crack detection criterion has received considerable attention.

The choice of using the natural frequency as a basis in the development of NDE (Non-destructive evaluation) is most attractive. This is due to the fact that the natural frequencies of a beam can be measured from multiplelocations on the beam, thus offering scope for the development of a fast and global NDE technique. Considerable efforts being made to make the method useful in practice. It results in a considerable saving in time, labour and cost for long beam like components, such as rails, pipelines, etc.

Chaudhari and Maiti [23] studied the Frobenius method for solving an Euler-Bernoulli type differential equation. Solving inverse problem requires a lot of mathematical effort and it is time consuming. Lee [8] presented a method based on the Newton-Raphson iteration method. In this method proper selection of the initial guesses of the crack parameters is important. Rizos et al. [24] conducted experiments to detect crack depth and location from changes in the mode shapes of cantilever beams. A major disadvantage of using mode shape based technique is that obtaining accurate mode shapes involves arduous and meticulous measurement of displacement or acceleration over a large number of points on the structure before and after damage. The accuracy in measurement of mode shapes is highly dependent on the number and distribution of sensors employed. Owolabi et al. [18] used natural frequency as the basic criterion for crack detection in simply supported and fixed-fixed beams. The method suggested has been extended to cantilever beams to check the capability and efficiency. There is need to see if this approach can be used for fixed-free beams. There is a very limited data concerning experimental observations. Most of the data available is theoretical. This paper validates [6] approach to fixed-free beam based on experimental data. Mazanoglu and sabuncu [6] have studied a frequency based algorithm for identification of single and double cracked beams for a statistical approach used in experiment. Frequencies contour lines corresponding to measured natural frequency ratios are matched with the interpolated prediction table, called frequency map, and are used for detection of a single crack. The algorithm is tested in the examples employing the frequency map prepared by the theory presented and the input frequency ratios obtained by the commercial finite element program.

II. LITERATURE REVIEW

In this chapter, the literature pertaining to various method of crack detection conducted by earlier researchers is presented.

Thatoi et al. [1] have studied the Cascade Forward Back Propagation (CFBP) network for crack detection in Euler Bernoulli beam like structure through the knowledge of changes in the natural frequencies and their measurements. Labib et al.[2] have studied the free vibration analysis of beams and frames with multiple cracks for damage detection .The problem of calculating the natural frequencies of beams with multiple cracks and frames with cracked beams is studied. The natural frequencies are obtained using a new method in which a rotational spring model is used to represent the cracks .The Wittrick–Williams algorithm is used to compute the natural frequencies in the resulting transcendental eigen value problem. Ghadami et al. [3] have studied a new adaptable multiple-crack detection algorithm in beam-like structures. In this article, a simple method for detecting, localizing and quantifying multiple cracks in beams using natural frequencies is presented. We model cracks as rotational springs and demonstrate a relationship among natural frequencies, crack locations and depths. Jassim et al. [4] present an review on the vibration analysis for a damage occurrence of a cantilever beam. Behzad et al .[5] have studied the method for detection of multiple edge cracks in Euler–Bernoulli beams having two different types of cracks is presented based on energy equations. Each crack is modeled as a massless rotational spring using Linear Elastic Fracture Mechanics (LEFM) theory, and a relationship among natural frequencies, crack locations and stiffness of equivalent springs is demonstrated. Mazanoglu and sabuncu [6] have studied a frequency based algorithm for identification of single and double cracked beams for a statistical approach used in experiment. The algorithm presented in this paper makes it possible to locate the suitable positions of two cracks searched over the frequency map. The algorithm is tested in the examples employing the frequency map prepared by the theory presented and the input frequency ratios obtained by the commercial finite element program. Therefore, this paper also presents a statistical approach called 'recursively scaled zoomed frequencies (RSZF)' for minimising the deviations caused by sensitivity and resolution lack in measured natural frequencies. Lee [7] have studied cracks are modeled as massless rotational springs and the forward problem is solved using the finite element method. The inverse problem is solved iteratively for the crack locations and sizes using the Newton–Raphson method and the singular value decomposition method. Lam and Yin [8] have studied statistical detection of multiple cracks on thin plates utilizing dynamic response. The number of cracks is first identified by adopting the Bayesian model class selection method in the first phase. In the second phase, the posterior (updated) probability density function (PDF) of the crack parameters, such as crack locations, lengths and depths are identified following the Bayesian statistical identification framework. Prabhakar [9] studied the vibration analysis of cracked beam. The vibration analysis of a cantilever beam with two open transverse cracks considers, studying the response characteristics. The results obtained numerically are validated with the results obtained from the simulation. The simulations have done with the help of ANSYS software. It is verified from both computational and simulation analysis that the presence of crack decreases the natural frequency of vibration. The mode shapes also changes considerably due to the presence of crack. Sekhar [10]present study is to summarize the different studies on double/multi-cracks and to note the influences, identification methods in vibration structures such as beams, rotors, pipes, etc. And thus this paper brings out the state of the research on multiple cracks effects and their identification. Veidt et al. [11] studies the measured transient vibration data in the detection of multiple cracks on beams by following the Bayesian probabilistic framework. Douka et al. [12] have studied a method for determining the location and depth of cracks in double-cracked beams .The influence of two transverse open cracks on the antiresonances of a double cracked cantilever beam is investigated both analytically and experimentally. Kisa and Gurel [13] present on presents a novel numerical technique applicable to analyse the free vibration analysis of uniform and stepped cracked beams with circular cross section. Yanilmaz [14]studied the damage detection in beams by wavelet analysis .The method was based on the energies that were calculated from the CWT coefficients of vibrational response of a cantilever beam. A transverse cut at varying depths was introduced. The presence and location of crack was investigated by processing experimentally acquired acceleration signals. Chasalevris and padopoulos [15] present on identification of multiple cracks in beams under bending. In the present paper the dynamic behaviour of a cracked beam with two transverse surface cracks is studied. Khiem and Lien [16] have studied the multi-crack detection for beam by the natural frequencies. The natural frequencies has been formulated in the form of a non-linear optimization problem, then solved by using the MATLAB functions. The spring model of crack is applied to establish the frequency equation based on the dynamic stiffness of multiple cracked beams. The equation is the basic instrument in solving the multi-crack detection of beam. Patil and Maiti [17] present on experimental verification of a method of detection of multiple Cracks in beams based on frequency measurements . A method for prediction of location and size of multiple cracks based on measurement of natural frequencies has been verified experimentally for slender cantilever beams with two and three normal edge cracks. Ruotolo and surace [18] have present on natural frequencies of a bar with multiple cracks. In this paper the smooth function method, previously proposed for bending vibrations, is extended to the calculation of longitudinal natural frequencies of a vibrating isotropic bar with an arbitrary finite number of symmetric transverse open cracks. Owolabi et al. [19] have present on crack detection in beams using changes in frequencies and amplitudes of frequency response functions. The work reported in this paper is part of an ongoing research on the experimental investigations of the effects of cracks and damages on the integrity of structures, with a view to detect, quantify, and determine their extents and locations. Patil and Maiti [20] have studied the method for detection of multiple open cracks in a slender Euler–Bernoulli beams is presented based on frequency measurements. Chinchalkar [21] present on determination of crack location in beams using natural frequencies. Chaudhary and Maiti [22] have studied the modelling of transverse vibration of beam of linearly variable depth with edge crack. In this paper modelling of transverse vibration of a beam of linearly variable depth and constant thickness in the presence of an open edge crack normal to its axis has been proposed using the concept of a rotational spring to represent the crack section and the Frobenius method to enable possible detection of location of the crack based on the measurement of natural frequencies. The method can also be used to solve the forward problem.

In the present topic, a number of papers published so far have been surveyed, reviewed and analyzed. A substantial amount of work has been conducted on natural frequency and mode shape based damage detection methods in the past. Frequency response functions, on the other hand, are used only to detect the damage by searching for the nonlinear features of frequency response functions. Some of the approaches use finite element method as a tool for analysis and they are iterative and require an initial guess. As a result the error in the solution is remarkably influenced by the initial guess. Most of the researchers studied the effect of a single and multiplecrack on the dynamics of structures. A lot of studies using natural frequency as a damage detection tool are being carried out in the vibration based damage detection field. Recently, a new vibration based damage detection technique that utilizes a shift in natural frequencies has been the focus in this thesis. Results obtained from these studies seem more promising in terms of damage identification when compared to modal analysis results. The signals obtained in defect-cantilever cracked beams were compared in the frequency domain. Simulations are obtained by the FEA software such as Ansys.

In this topic, a new method to detect and locate a crack in a structural component is introduced. The method proposed is an extension of a recently developed technique for identification of damage in cantilever beams. The method exploits the frequency response functions for the detection and identification of cracks in structures. Therefore an attempt has been made to formulate a Smart Technique for localization and identification of multiple cracks cantilever beams.

III. RESEARCH METHODOLOGY

In this case, for a given problem, it is necessary to measure or compute the first five transverse natural frequencies of the beam with a crack and the corresponding uncracked beam. For each mode, a variation of normalized natural frequencies with crack location and crack depth is obtained by plotting three dimensional surfaces. As stated earlier, both the crack location and the crack depth influence the changes in the natural frequencies of a cracked beam. Consequently, a particular frequency could correspond to different crack locations and crack depths. On this basis, a contour line, which has the same normalized frequency change resulting from a combination of different crack depths and crack locations (for a particular mode) could be plotted in a curve with crack location and crack depth as its axes. Then plot contour lines from different modes on the same axes. The point of intersection, common to all the three modes, indicates the crack location, and crack depth

IV. MODEL ANALYSIS USING FEM

Numerical Modelling of Beam

To create a numerical model of laboratory specimen beams, the commercial finite element (FE) analysis package

ANSYS14.5 is used. The dimensions of the numerical model are based on the measurements of the laboratory beams: 240mm,long, 20mmX12mm, cross section. If values are close it reflects the excellent quality of finite element models prepared with the help of ANSYS14.5. The element type used is SOLID PLANE 183. This element is chosen as it is recommended by ANSYS documentation for three dimensional modelling of solid structures and because wire cut damage can easily modelled for this element. According to manufacturer's specifications of the laboratory steel beams, the modulus of elasticity is set to be 210Gpa, the poissons ratio to 0.3 and density to 7860kg/m3.

V.EXPERIMENTAL SETUP

A. Experimental Model Description

Mild steel beams are use for the experimental investigation. To use fixed-free ends beams. Each beam model cross-sectional area 20mmX20mm with a length of 300 mm from fixed end. The following material properties: Young's modulus, E=210Gpa, density, _=7860 Kg/m3, the Poisson ratio, μ=0.3.

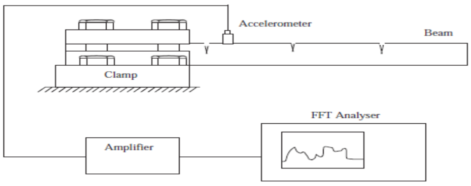

Fig.1. Experimental set-up.

B. Experimental Procedure

The fixed–free beam models are clamped at one end. The beam excitation with an impact hammer. The first five naturalfrequencies of the uncracked beam were measured. Then, cracks were generated to the desired depth using a wire cut EDM (around 0.35mm thick); the crack always remained open during dynamic testing. Beams models are test with cracks at different locations starting from a location near to fixed end. The dynamic responses of the beam model were measured by using light accelerometer placed on the model as indicated in Fig. 1. The response measurements were acquired, one at a time, using the FFT analyzer.

VI. PROBABLE OUTCOMES

By using modal parameters like natural frequency use to detect multiplecracks in beams.

VII. CONCLUSION

Crack changes the dynamic behavior of the structure and by examining this change, crack size and position can be identified. Non destructive testing (NDT) methods are used for detection of crack which are very costly and time consuming. Currently research has focused on using modal parameters like natural frequency, mode shape to detect crack in beams. In this paper a method for detection of two transverse crack in a slender Euler–Bernoulli beam is presented. When the beams have two cracks, contour lines cannot be directly used due to the necessity of plotting contours for all different location and depth combinations of cracks. This problem is solved by project. The efficiency is verified using then a natural frequency ratio obtained by both the experiments and the commercial finite element program (ANSYS).Hence for detecting multiple cracked cantilever beams. The experimental results of frequencies are compared with the numerical results of frequencies using Finite element code. The experimental frequency can be obtained using Fast Fourier Transform analyzer.

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