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TWO CRACK DETECTION IN TAPERED CANTILEVER BEAM USING NATURAL FREQUENCY AS BASIC CRITERION

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ABSTRACT

Crack in a vibrating component changes the physical characteristics of a structure which in turn alter its dynamic response characteristics. Crack depth and crack location are main parameters for analysis. In this project a method has been proposed for the detection of open cracks based on frequency measurements on tapered cantilever beams. The present method enables one to detect a crack in a beam without the help of the massless rotational spring model. Both forward and inverse problems are solved and results are presented.In forward problem,the natural frequencies are determined by FEA software i.e. Ansys 18.1. In the experimental study, on cracked tapered cantilever beam Experimental Modal Analysis was performed and measuring the frequency changes. Good agreement is obtained between numerical and experimental natural frequencies. To identify the crack, contours of normalized frequency in terms of crack location and depth are plotted. The error between numerical and experimental is well within the limit, which validates the crack model.

Keywords: *Crack,Natural frequency,Tapered cantilever beam,Ansys*

I. INTRODUCTION

All content Cracks are potential source of catastrophic failure in mechanical machines, civil structures and in aerospace engineering. To avoid the failure caused by cracks, many researchers have performed extensive investigations over the years to develop structural integrity monitoring techniques. Most of the techniques are based on vibration measurement and analysis because, in most cases, vibration based methods can offer an effective and convenient way to detect fatigue cracks in structures. It is always require that structures must safely work during its service life, however damage initiates a breakdown period on the structures. It is unanimous that cracks are among the most encountered damage types in structures. Crack in structures may be hazardous due to their dynamic loadings. So crack detection is important for structural health monitoring applications. As beam type structures are being commonly used in steel construction and machinery industries, focus of the present dissertation work is to develop a newer technique for crack identification and localization. In the Literature review several studies based on structural health monitoring for crack detection are being discussed. Damage in the form of crack affects the natural frequencies and modes shapes of vibrating beam. The deviation of natural frequencies and modes shapes mainly dependents on location and intensity of the crack.

II. REVIEW OF LITRATURE

Chaudhari and Maiti (1999) proposed the method for solving an Euler-Bernoulli type differential equation. Solving inverse problem requires a lot of mathematical effort and it is time consuming.

Owolabi (2003) reported 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

Rizos(2010) 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.

Dr.Mauwafak, A.Tawfik (2014)proposed detection method is based on the structural dynamics of the wind turbine blade. A wind turbine blade undergoes remarkable change in natural frequencies. The artificial neural network technique is used. Using ANN technique the crack location and its depth can be finding by using the first three relative natural frequencies as inputs.

Dackermann (2010) proposed the viability of using dynamic based ‘damage fingerprints’ in combination with artificial neural network (ANN) techniques and principal component analysis to identify defects in civil engineering structures The first is based on damage index (DI) method while the second approach uses changes in FRF data as damage fingerprints.

Prabhakar (2009) carried out vibration analysis of a cantilever beam with two open transverse cracks, to study the response characteristics. In first phase local compliance matrices of different degree of freedom have been used to model transverse cracks in beam on available expression of stress intensity factors and the associated expressions for strain energy release rates.

III. OBJECTIVE

The objective of this project is to analyze experimentally and numerically (by FEA software e.g. Ansys) the vibration characteristics of the cracked cantilever beams. Use the data of forward problem to detect crack location and calculate crack depth using changes in natural frequencies.

IV. EXPERIMENTAL MODAL ANALYSIS

Mild steel beams have been considered for making specimens. The specimens were selected of size having cross sectional area 60mm×10mm at one end and 30mm×10mm at other end. The specimens were cut to size from ready-made rectangular bars. Total 6 specimens were cut to the size of length 400mm. The modulus of elasticity and densities of beams have been measured to be 2.1×105MPa and 7800Kg/m3. The poisons ratio is 0.3. The crack was introduced by wire cut machining of 0.35 mm width.

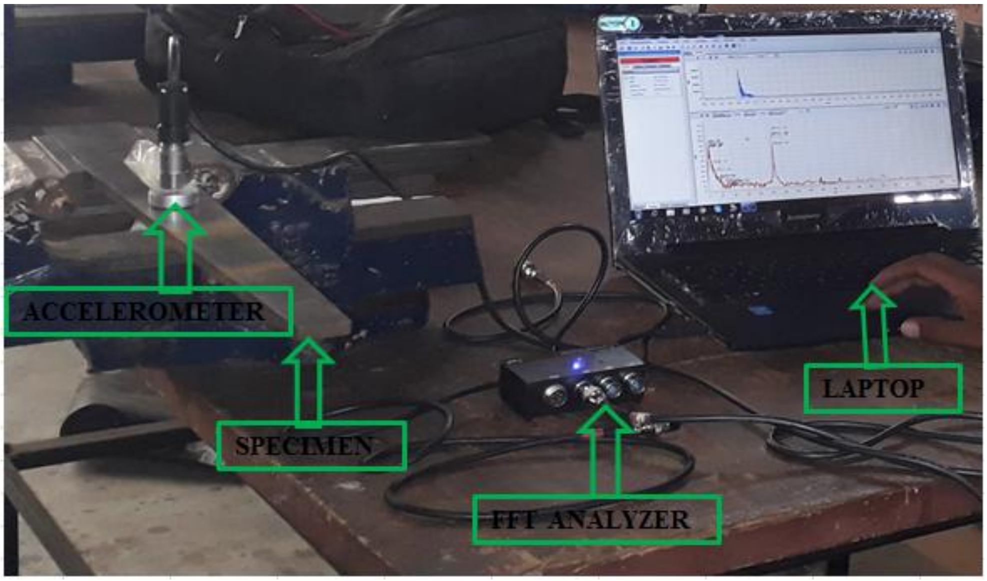

Figure 1: Experimental Set Up

Experimental Modal Analysis was performed to find out the five modal transverse natural frequencies of a cracked tapered cantilever beam. Experimental modal analysis is used to identify the modal response of an existing structure to solve a vibration problem. Fig.1 shows the experimental set up. A beam of mild steel material was used as a tapered cantilever beam. The fixed end was made by fixing the beam with the help of clamp fixed on the table. Accelerometer was placed at the free end of the cantilever beam, to measure the vibration response. The accelerometer used in the experiments includes accelerometer with sensitivity 100mV/g, 0.32-15 KHz frequency range. To apply the excitation to the beam an impact hammer type Bruel & Kjaer 8206-55940 is used. All the data was recorded obtained from the vibrating beam with the help of ERBESSD FFT analyzer model LAN-XI 51.2 KHz with 2 channels input module and accelerometer is attached to it. Repeat the whole experiment for all un-cracked, cracked beams. The whole set of data was recorded and then the data was imported into the PC by using the DigivibeMX M20 analysis software. The natural frequencies measurement of a whole system is a function of the physical parameters, material properties of the system.

V. MODAL ANALYSIS USING ANSYS

The effects of a crack, present at different locations, on the first five modal frequencies have been determined in this project. Before the experiments were carried out, the first five natural frequencies of the beams were determined by FEA. From the results obtained, it was decided that using a frequency range up to 10 kHz for experimental measurements would be sufficient to include the first five natural frequencies. For free vibration of cracked & un-cracked beams the ANSYS 18.1 was used. To create a numerical model of laboratory tested beams, the commercial finite element analysis package ANSYS 18.1 is used. The dimensions of the numerical model are based on the measurements of the laboratory model.The horizontal crack was modeled with a 0.35mm width on the top surface of the beam and this crack is going through the depth of the beam. The element type used is SOLID95, which is an orthotropic three-dimensional structural solid defined by 25652 nodes. It can tolerate irregular shapes without as much loss of accuracy.Fig.2 shows the finite element mesh model of the beam generated in ANSYS 18.1.

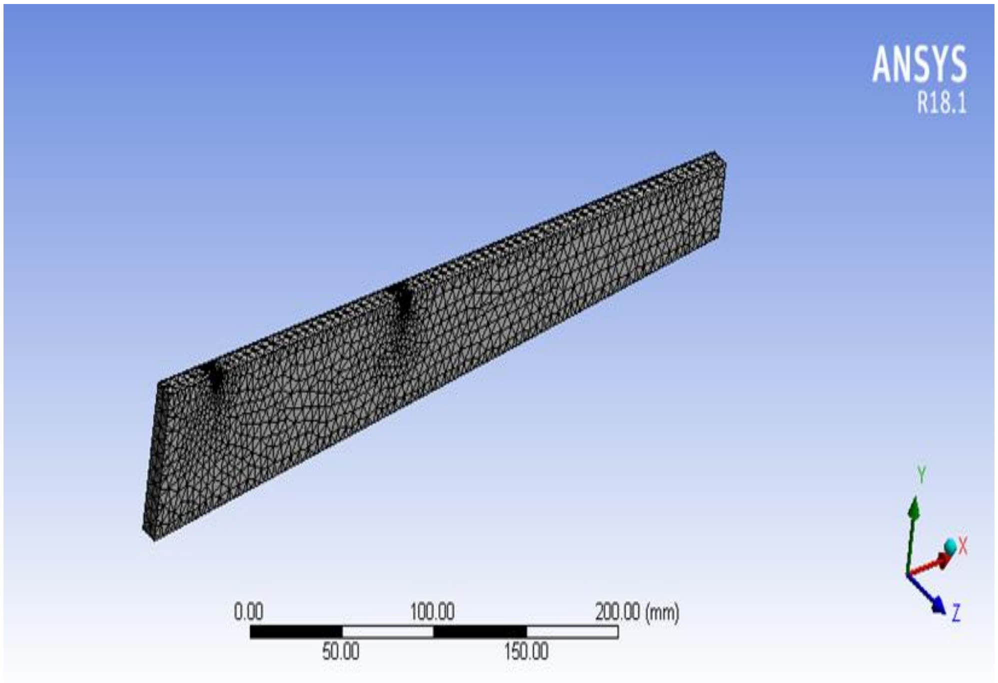

Figure 2: Finite element mesh model of the cracked beam

VI. RESULT AND DISSCUSSION

Validation of experiment is must. A correlation analysis between numerical and experimental data is conducted for 6 beams. It is technique to examine quantitatively and qualitatively the correspondence and difference between analytically and experimentally obtained.

Table 1: Comparison between experimental and numerical values of fundamental natural frequency

CASE NO.	LOCATION OF CRACK (X1 & X2) 'mm'	CRACK DEPTHS (a1 & a2) 'mm'	ANSYS FRIST NATURAL FREQ.(Hz)	EXPT. FRIST NATURAL FREQ.(Hz)	NFERROR (%)
1	35	3	57.455	54.23	5.61
	170	6			
2	60	3	60.402	55.21	8.60
	205	4			
3	100	5	57.97	55.38	4.47
	230	5			
4	160	4	60.976	55.9	8.32
	255	5			
5	185	4	61.688	55.93	9.33
	280	3			
6	HEALTHY BEAM		62.572	56.67	9.43

From table 1 it is concluded that the natural frequency value matches very well and the numerical model is able to represent the experimental model. Therefore, this numerical model can be used in this study as a representation of experimental beam structures for application of proposed damage identification methods. From the Table 1 it is noted that the '%error' values are mostly less than 10%. The deviations of the numerical results compared to the experimental ones may be due to some possible measurement errors such as human errors, measurement noise, positioning of the accelerometers and their mass, non-uniformity in the specimens properties.

In this paper, based on the changes of natural frequency, a method for identifying a crack location and crack depth is presented. Normalized frequency term is used which have a ratio of cracked beam frequency to healthy beam frequency. On this basis, contour lines plotted. Counter line has the same normalized frequency change resulting from a combination of different crack depths and crack locations for a particular mode. Curve is plotted with crack location and crack depth as its axes. To identify the presence of multiple cracks in the beam, an essential step is to require that is a sufficient number of natural frequencies of the beam to be computed by using ANSYS 18.1. The number of cracks on the beam determines the required number of frequencies to be measured or computed. For a single crack, measuring the first three natural frequencies will be sufficient to determine the crack location, and the crack depth of a beam. Based on crack identification theory,curves of crack location verses crack depth have been plotted with three measured frequencies.

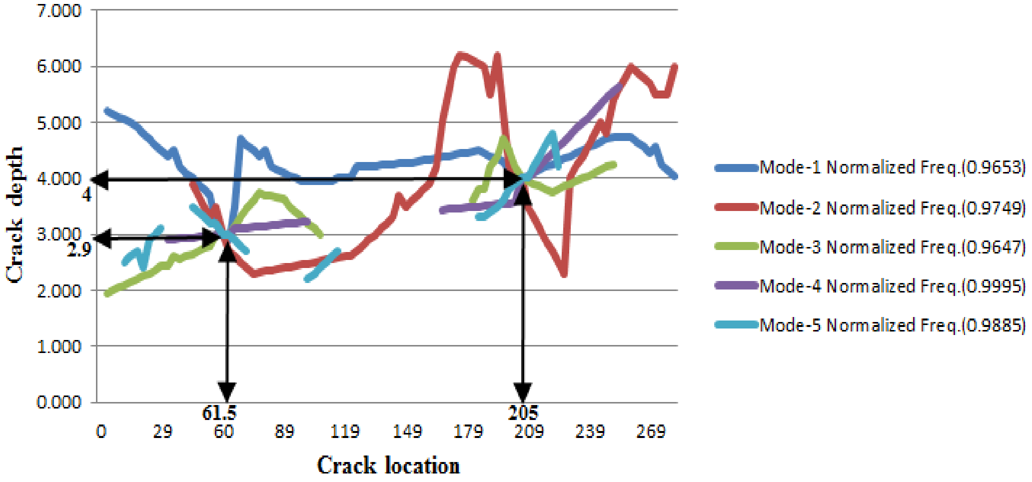

Figure 3: Crack identification technique by using frequency contours of the first five modes of beam

The plotted three contour lines give two common point of intersection. This point of intersection indicates the crack location and the crack depth. The experimental results are in very good agreement with FEA results. So the effectiveness of crack identification through vibration measurements is verified.

Table 2: Accuracy in detecting crack location and crack depth of tapered cantilever beam

Parameters	Actual Values	Proposed values	Accuracy
Crack location 1	60	61.5	97.56%
Crack location 2	205	205	100.00%
Crack depth 1	3	2.9	96.67%
Crack depth 2	4	4	100.00%

VII. CONCLUSION

Vibration-based method having natural frequency as basic criterion has been extended to long tapered cantilever beams. In this project, the methodology adopted by Owolabi (2003) has been extended to multiple cracked long cantilever beams which are more simplified and accurate as compared to massless rotational spring model. The results are encouraging. Very good accuracy of the method associated with the prediction of location can be exploited for quickly locating a crack in practice for long beam-like components.

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