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Crack Identification of Cantilever Beam by Using Vibration Analysis

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ABSTRACT

Beams are widely used as structural element in civil, mechanical, naval & aeronautical engineering. The presence of cracks changes the physical characteristics of a structure which in turn alter dynamic response characteristics. Therefore crack identification is key issue. The existence of crack, which affect the performance of structure as well as vibration parameters such as natural frequency, mode shape, stiffness and modal damping. Our current work is to model an inclined crack in a composite material cantilever beam and analyze the model using FEA as well as experimental. The proposed method is based on measured frequencies and mode shape of the beam.FEA results are achieved using specimen having cracks of different depth and position. Experiment is carried out on beam by using FFT analyzer. The relationship between the natural frequencies, crack location, crack depth has been studied. It is found that if crack depth increases then natural frequency decreases.

Keywords— **crack inclination, crack location, crack depth, vibration analysis, FEA, composite Material**.

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I. INTRODUCTION

Crack detection is important aspect in engineering. To avoid sudden failure of structure it is essential to detect the crack in early stages. The presence of cracks changes dynamic response characteristics. It changes natural frequency, mode shapes and stiffness of component. There are various Non-destructive techniques are available for detection of crack in structural elements. They are efficient but time consuming, expensive. Replacement of metallic materials by composite material due to its properties like low density, high mechanical properties. Rajan K.Behera, Anish Pandey, Dayal R.Parhi[1] is said that, inclined open edge crack in aluminum cantilever beam and analyze that using finite element analysis as well as experimental approach. This method is based on measured frequencies and mode shapes of beam. Aniket S. kamble, D.S.Chavan[2] is said that crack is modeled as a rotational spring equation for non-dimensional spring stiffness was developed. The time-amplitude data obtained further used in wavelet analysis for obtaining time-frequency data. Missoum Lakhdar et al. [3] is said that detection of damage of composite material by vibration analysis, whose objective is to exploit the dynamics response of a structure to detect damage. Kaushar H. Barad et al. [4] is said that detection of the crack presence on the surface of beam-type structural element using natural frequency. First two natural frequencies of cracked beam have been obtained experimentally. D.K.Agarwalla, D.R.Parhi [5] is said the effect of open crack on modal parameters of a cantilever beam subjected to free vibration is analyzed by analytically and experimentally. It is observed that structure vibrate with more frequency in the presence of a crack away from the fixed end. Prasad Baviskar, Vinod B. Tungikar[6] is said that simply supported beam with single crack and cantilever beam with two cracks are considered. The results obtained by FEM are used for prediction of crack location and depth using Artificial Neural Network. FB Sayyad [7] is said that to develop suitable method to detection of crack location and crack size from measured axial vibration data. P.K.Jena [8] presented the fault detection of multi cracked slender Euler Bernoulli beams through knowledge of changes in the

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natural frequencies and their measurement. Spring model of crack is applied to establish frequency equation.

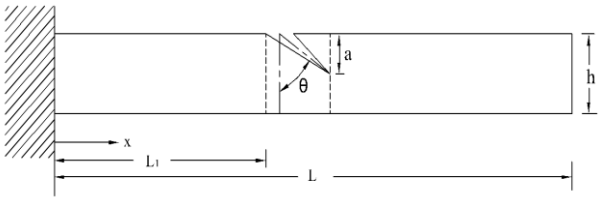

Fig. 1 Design Model of Cantilever beam

II. VIBRATION ANALYSIS OF INCLINED CRACK CANTILEVER BEAM

The cantilever beam with an inclined crack has a uniform structure having constant rectangular cross section. The Euler Bernoulli beam model was assumed. System is considered as continuous system in which the beam mass is considered as distributed along with the stiffness of beam, the equation of motion can be written as

$$d^2/dx^2\{EId^2Y/dx^2\}= \omega^2 mY \quad (1)$$

Where, E is the young's modulus of beam material, I is moment of inertia of beam cross-section, Y is displacement in y direction, ω is natural frequency, m is the mass per unit length, m=ρA

For cantilever beam we have following boundary condition at x=0, Y=0, dY/dx=0 (2)

At x=L, $d^2Y/dx^2= 0$, $d^3Y/dx3=0$, (3)

From (2) and (3) we get

$$d^4Y/dx^4-\beta^4Y= 0 \quad (4)$$

$\beta^4= (\omega^2 m)/ (EI)$

Mode shapes of the vibration can be given by,

F=An{[sinβnL-sinhβnL][sinβnx-sinhβnx]+[cosβnL-coshβnL][cosβnx-coshβnx]}

Where n=1, 2, 3-----∞ and βnL=nπ

III. EXPERIMENTAL ANALYSIS

The instrument used for experimental analysis i.e. measurement of natural frequencies are Fast Fourier transform (FFT) analyzer, accelerometer, impact hammer and related accessories. The E Glass epoxy cantilever beam specimen with dimensions (800mm x 60mm x 6mm) with and without an inclined crack is subjected to no. of experimentation is carried out for determining the natural frequencies. To achieve reproducibly first three natural frequencies of the structure under consideration. The accelerometer is attached to near to crack to achieve good signals. The impact hammer is used to excite beam. Experimental modal analysis is carried out to determination of dynamics properties such as natural frequency and mode shape. Cracks are developed at different location from fixed end with different specimens with the help of diamond cutter. The natural frequencies of first three modes are noted with different crack location crack depth and crack inclination.

Fig. 2 Experimental set up for detection of a cantilever beam with crack

IV . FINITE ELEMENT ANALYSIS

Finite Element Analysis is performed using ANSYS workbench 14.5. The model of beam with and without crack is generated and used for Finite Element Analysis. The modal analysis of uncracked and inclined crack cantilever beam to determine the natural frequencies and mode shapes at different crack depth, different crack location and crack inclination is carried out. The material properties as follows, Young's Modulus of elasticity (E) =39GPa Poisson ratio (υ) =0.3 Density (ρ) =2000 Kg/m^3

The first three natural frequencies and corresponding mode shapes are calculated by FEA using ANSYS workbench 14.5.

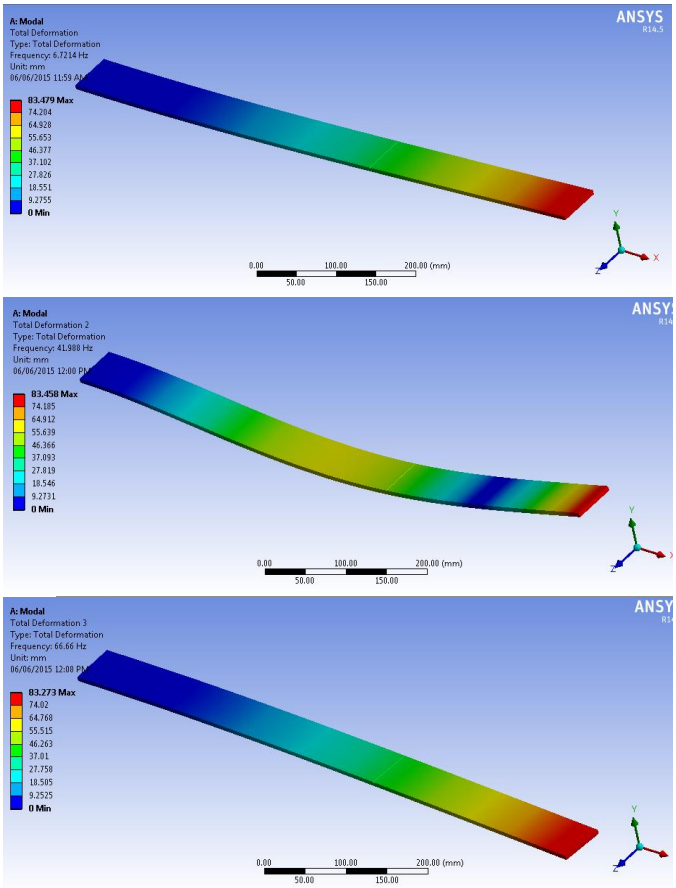

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Fig. 3 mode shapes variation of 1st, 2nd, 3rd mode of beam with crack at c=0.60, e=0.25, Θ=45^0

V . RESULTS

The changes in natural frequencies for the uncracked and cracked cantilever beam are measured. The predicted values are determined by experimentally and analytically.

Table 1 Natural Frequency for uncracked cantilever beam

Experimental			FEA		
ω_1 Hz	ω_2 Hz	ω_3 Hz	ω_1 Hz	ω_2 Hz	ω_3 Hz
7.000	43.85	70.004	6.7282	42.15	66.671

Table 2 Natural Frequency for cracked cantilever beam

Sr. No	c	e	Experimental			FEA		
			ω_1 Hz	ω_2 Hz	ω_3 Hz	ω_1 Hz	ω_2 Hz	ω_3 Hz
Crack Inclination(θ)=15^0								
1	0.25	0.30	6.886	43.85	63.535	6.688	42.163	66.49
2	0.35	0.25	6.928	43.36	68.757	6.704	42.118	66.573
3	0.40	0.35	6.872	42.663	67.9315	6.695	41.798	66.518
4	0.55	0.40	6.983	42.16	68.263	6.708	41.47	66.597
5	0.70	0.50	7.067	43.082	68.81	6.718	41.426	66.648
Crack Inclination(θ)=30^0								
6	0.20	0.40	6.7936	43.1782	67.60	6.647	42.184	66.243
7	0.35	0.30	6.8275	43.0756	67.82	6.700	42.071	66.551
8	0.50	0.30	6.9825	43.6525	69.28	6.722	41.919	66.629
9	0.60	0.40	6.9105	42.982	67.60	6.715	41.639	66.629
10	0.70	0.20	7.005	43.28	68.82	6.725	42.076	66.68
Crack Inclination(θ)=45^0								
11	0.2	0.1	7.102	43.78	70.000	6.782	42.38	66.69
12	0.40	0.05	7.092	43.28	69.3	6.729	42.131	66.666
13	0.50	0.15	6.98	43.28	69.3	6.729	42.131	66.666
14	0.60	0.25	7.09	44.08	69.846	6.7214	41.988	66.66
15	0.70	0.30	7.023	43.88	69.74	6.7233	42	66.67

VII. CONCLUSION

It is found that if crack depth and crack inclination is constant then crack location is increases natural frequencies are increases.

If crack location and crack inclination is constant then crack depth is increases natural frequencies are decreases.

Crack is near to fixed end it imparts more reduction in natural frequency,

The results obtained by Finite element analysis and experimentally are compared and they are good in match.

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