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Crack Analysis of Composite Cantilever Beam by Using Vibration Analysis Technique

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Abstract - Cantilever beam is widely used in engineering application such as military, naval and aeronautical. Crack initiate due to different kinds of loading. The presence of crack alters the physical as well as dynamic characteristics of structure. Therefore detection of crack is major issue. The existence of crack affects vibration parameter such as natural frequency, mode shape and stiffness. In this paper change in natural frequency, mode shape is analyzed by using finite element analysis as well as experimental. It is observed that specimen having different crack inclination, crack location and crack depth its natural frequency get varies.

Keywords – Composite cantilever Beam, Crack depth, Crack location, Crack inclination, Vibration Analyzer, Finite Element Analysis.

I. Introduction

The composite structure finds its application in various fields like aircraft structure, military equipment, high speed machinery and civilian product. The presence of crack changes structural as well as dynamic response characteristics of structure. So it's more important to detection of crack in early stage. For detection of crack lot of non- destructive techniques are available but they are tedious and costly.

Gade Ganesh G.,Mhaske M.S.[1] explained that, open edge in steel cantilever beam analyzed by using finite element analysis as well as experimental. This method measure natural frequency of beam. Pankaj Charan Jena, Dayal R. Parhi, Goutam Pohit[2] explained that, identification of single crack in aluminum cantilever beam by varying crack location and crack depth. This method compare theoretical as well as experimental. D.K.Agrawalla , D.R.Parhi[3] explained that, effect of open crack modal parameter of a aluminum beam vibrate more frequency in the presence of crack away from the fixed end. FB Sayyad [4] explained that, approximate analytical method for damage detection in free- free beam by measurement of axial vibration .Khushar H.Barad, D.S.Sharma, Vishal Vyas[5] explained that, detection of crack of a beam type structure element using vibration parameter such as natural frequency. Saidi Abdelkrim[6] explained that, dynamic characteristics of damaged and undamaged beams are too different. The object of this study is analyzed the vibration behavior of concrete beam both experimentally ad FEA software subjected to free vibration cases. Ranjan K.Behran[7] explained that, detection of crack in cantilever beam on synthesis of mode shapes. This method compare mode shapes numerically and experimentally. Amit Banerjee,G Pohit[8] explained that, fractal dimension analysis for detection of crack in rotating cantilever beam.

II. Design Model of cantilever beam

The continuous model of the beam has been separated for simplification. According to R. K. Behera, for inclined crack beam, $(L/W) \geq 12, a \leq (h$ and $\theta = 45°$, the difference in the two extreme location is less than 4% of the beam length

Design model of cantilever beam as shown in figure 1.

L = Length of cantilever Beam

L_1= Length of a crack from fixed end

a = Crack depth

h = Depth of beam

θ = Crack inclination

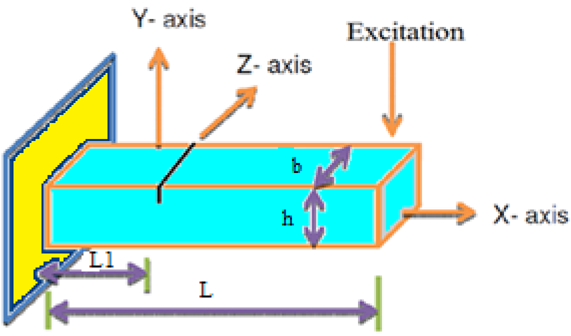

Figure1 Design model of cantilever beam

III. Theoretical Analysis

The beam with an inclined crack is fixed at left side, free at right side and it has a uniform structure having a constant rectangular structure. The Euler Bernoulli beam theory was assumed. The crack is considered as open crack and damping has ignored in this study. The free vibration of an Euler Bernoulli of a constant rectangular cross section is given by the following governing equation:

$$\frac{d^2}{dx^2} EI \frac{d^2y}{dx^2} = \omega^2 my \qquad ......(1)$$

Where E is Young's modulus of elasticity, I is the moment of inertia of beam, y is the displacement, ω is natural frequency, m is the mass of beam, m=ρA, A is the cross sectional area, ρ is the material density.

$$\text{at } x = 0, \quad y = 0, \quad \frac{dy}{dx} = 0 \qquad ......(2)$$

$$\text{at } x = l, \quad \frac{d^2y}{dx^2} = 0, \quad \frac{d^3y}{dx^3} = 0 \qquad ......(3)$$

Reduced form,

$$\frac{d^4y}{dx^4} - \beta^4 y = 0 \qquad ......(4)$$

$$\beta^4 = \frac{\omega^2 m}{EI} \qquad ......(5)$$

The mode shape of continuous cantilever beam is given as

$$F_n = A_n\{(\sin\beta_n L - \sinh\beta_n L)(\sin\beta_n X - \sinh\beta_n X) + (\cos\beta_n L - \cosh\beta_n L)(\cos\beta_n X - \cosh\beta_n X)\} \qquad ....(6)$$

Where, n=1, 2, 3----∞ and $\beta_n L = n\pi$

IV. Finite element analysis

FEA helps the designer know all the theoretical stresses within the structure by indicating all the problem in detail and thus helping the designer to predict the failure of the structure. It is a cheap method of finding the causes of failure and the way the failures can be avoided. The model of beam with and without crack is originated and used for Finite Element Analysis. The modal analysis of inclined cracked and cracked cantilever beam to determine natural frequency and mode shapes at different location, inclination and depth is carried out. The material property of Young's modulus of elasticity (E) is 39 GPa, Poission ratio (υ) is 0.3, Density (ρ) is 2000 kg/m³. The following figure shows first three natural frequencies and corresponding mode shapes of composite cantilever beam by using Ansys R14.5. The cantilever beam having c = 0.20, e = 0.10 and θ = 45°. The first mode shape of cracked cantilever beam as shown in figure 2.

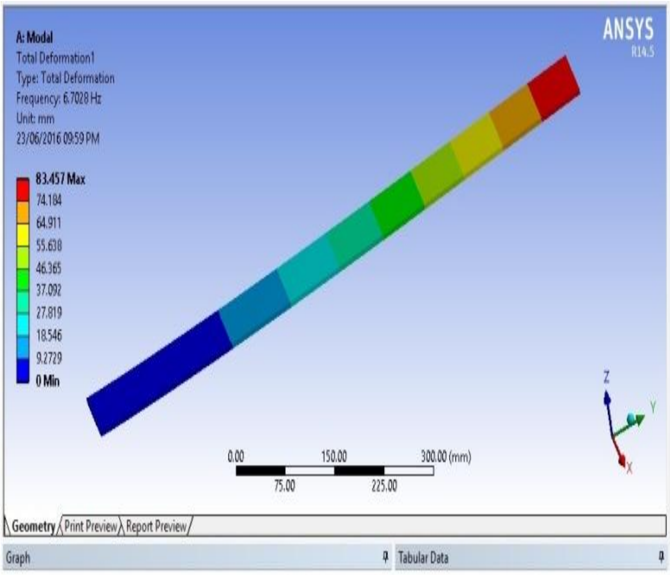

Figure 2 First Mode shape of cracked beam with c=0.20, e=0.10, θ=45⁰

The second mode shape of cracked cantilever beam as shown in figure 3.

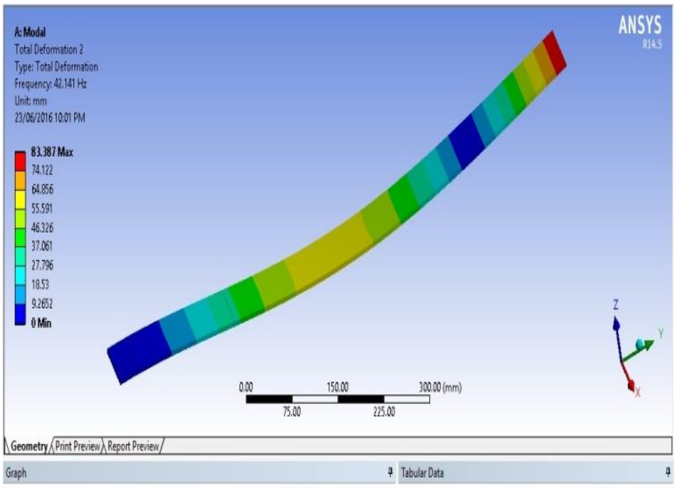

Figure 3 First Mode shape of cracked beam with c=0.20, e=0.10, θ=45⁰

The third mode shape of cracked cantilever beam as shown in figure 4.

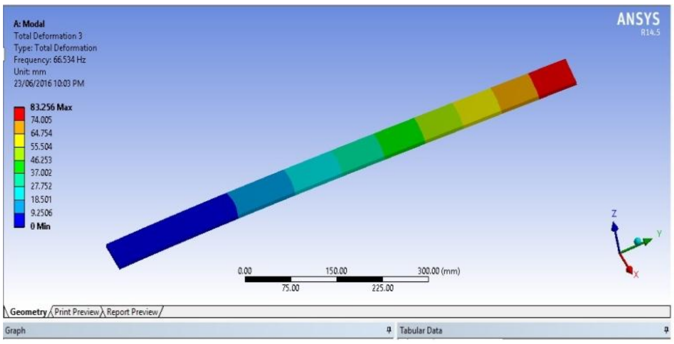

Figure 4 Third mode shape of cracked beam with c=0.20, e=0.10, θ=45^0

V. EXPERIMENTAL ANALYSIS

The experimental modal analysis consist of piezoelectric accelerometer, impact hammer, data acquisition card, smart office software are the working element of conducting free vibration analysis for identification of crack. The schematic setup of experimental is as shown in following figure.

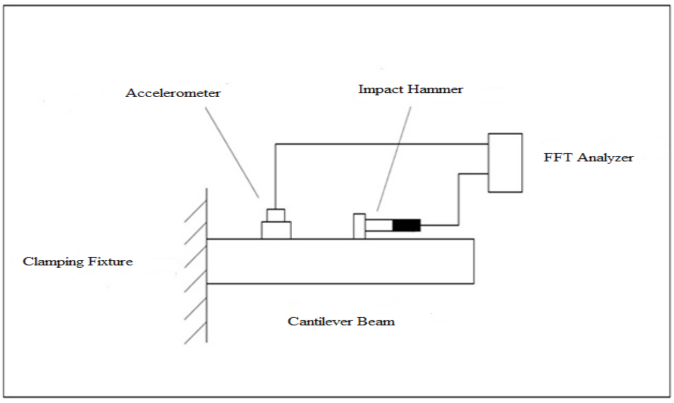

Figure shows Schematic setup of experimental model

The experimental setup which is shown in above figure is used to find the natural frequencies of beam. Figure shows that cantilever beam placing the accelerometer on the surface of beam connected to analyzer. The E Glass fiber 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. The accelerometer is kept near the crack to capture the correct signal. The impact hammer is used to excite the cantilever beam whose frequency response has to be captured. For every test, the location of impact hammer is kept constant. 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 inclination, crack location and crack depth.

VI. RESULTS

Crack detection technique using changes in natural frequencies for identifying crack parameters are discussed in this portion. Measuring the first three natural frequencies will be sufficient to find out the crack parameters for a cracked composite beam. The following table shows the first three natural frequencies of cantilever beam by using finite element analysis and FFT. Comparison of FEA & experimental results of uncracked beam is shown in following tables.

Table 1 Comparison between FEA and Experimental results of uncracked beam

FEA			Experimental		
FNF Hz	SNF Hz	TNF Hz	FNF Hz	SNF Hz	TNF Hz
6.7352	42.194	66.688	7.001	43.95	70.014

Table 2 Comparison between FEA and Experimental results of cracked beam (L1=400mm)

Sr. No	L1	a	FEA			Experimental		
			FNF Hz	SNF Hz	TNF Hz	FNF Hz	SNF Hz	TNF Hz
1	400	0.9	6.7255	42.09	66.663	6.88	43.23	69.2
2	400	1.5	6.7149	41.712	66.614	6.780	43.13	69.02
3	400	1.8	6.701	41.633	66.636	6.720	43.002	69.001

Table 3 shows frequency Results for Cracked Beam with Length Constant and Variable Depth (L=480mm)

Sr. No	L1	a	FEA			Experimental		
			FNF Hz	SNF Hz	TNF Hz	FNF Hz	SNF Hz	TNF Hz
1	480	1.5	6.7245	42.001	66.664	7.05	44.03	69.754
2	480	2.1	6.7222	42.107	66.607	6.813	43.15	68.456
3	480	2.4	6.7206	41.779	66.642	6.9005	42.960	67.41

Table 4 shows frequency Results for Cracked Beam with Length Constant and Variable Depth (L=560mm)

Sr. No	L1	a	FEA			Experimental		
			FNF Hz	SNF Hz	TNF Hz	FNF Hz	SNF Hz	TNF Hz
1	560	1.2	6.725	42.099	66.672	7.020	43.78	69.66
2	560	1.8	6.7248	42.015	66.663	7.013	43.15	68.70
3	560	3.00	6.721	41.712	66.654	7.003	43.062	68.61

Table 5 shows frequency Results for Cracked Beam with Constant Depth and Variable Length (a=1.8 mm)

Sr. No	L1	a	FEA			Experimental		
			FNF Hz	SNF Hz	TNF Hz	FNF Hz	SNF Hz	TNF Hz
1	200	1.8	6.7028	42.141	66.534	6.6862	43.75	63.545
2	280	1.8	6.7175	41.961	66.63	6.7265	43.646	67.70
3	400	1.8	6.72	41.933	66.636	6.9720	43.5625	69.20

Table 6 shows frequency Results for Cracked Beam with Constant Depth and Variable Length (a=1.2 mm)

Sr. No	L1	a	FEA			Experimental		
			FNF Hz	SNF Hz	TNF Hz	FNF Hz	SNF Hz	TNF Hz
1	280	1.2	6.7121	42.07	66.607	6.7265	43.0646	67.70
2	320	1.2	6.709	42.026	66.644	7.001	43.01	68.02
3	560	1.2	6.725	42.099	66.672	7.003	43.15	68.70

VII. Conclusion

Hence, we conclude that the detection of cracks in composite cantilever beam by using vibration analysis technique in order to optimize the performance of machines and structures with more faster, accurate and efficient way.

1. First three natural frequency of uncracked cantilever beam by using FEA are 6.7352, 42.194 and 66.688.

2. First three natural frequency of uncracked cantilever beam by using FFT are 7.001, 43.95 and 70.014.

3. First three natural frequencies of cracked beam at different location and different depth also compared.

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

5. Crack is near to fixed end it largely reduces natural frequency.

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

7. If crack location and crack depth is kept constant then crack location increases natural frequencies increases.

The results obtained by FEA and experimentally are compared and they match well.

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BIOGRAPHIES

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