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Detection of Cracks Present in Composite Cantilever Beam by Vibration Analysis Technique.

Khalate A.B. *1, Bhagwat V.B. *2
*1PG Student, Department of Mechanical Engineering, VPCOE, Baramati, Pune.
*2 Asst. Professor Department of Mechanical Engineering, VPCOE, Baramati, Pune.
**1 amitkhalate1990@gmail.com (9764483366/8888384084)*

Abstract

From the last few years , large amount of research is carried on the detection of crack using the vibration based techniques also other methods are developed to find the crack locations by researchers. In the present paper, detection of the crack presence on the surface of E-glass/Epoxy composite cantilever beam-type structural element using natural frequency is carried out. The frequency analysis of the cracked beam have been obtained experimentally and used for detection of crack parameters. The obtained crack parameters such as locations and depth are compared with the actual results and we found good accuracy in between them. Also, the effect of the crack parameters on the natural frequency of composite beam is presented. We are carried out a experimental free vibration modal analysis to find out its mode shapes and corresponding frequencies of cracked beam. Along with change in location and depth of crack its natural frequency gets varies. It is observed that, experimental results are more accurate to the actual results also we can check the results through simulation (Ansys 14.5).

Keywords- E-glass fiber, composite cantilever beam, Mode shape, Natural frequency, Vibration Analysis, Crack parameters**.**

1. Introduction

Damage is defined as any deviation introduced to a structure, either deliberately or unintentionally, for example during manufacturing can affect the present and further behavior of that system. This definition clears that the comparison is needed between two states of a structure. Cracks are among the most encountered damage types in the structures due to fatigue or manufacturing defects. Crack will initiate in a structure when the stresses near the crack tip will exceed the permissible limit. Cracks found in structural elements may arise due to fatigue cracks are occurs during actual working due to continuous cyclic loading over that element and due to manufacturing defects in it, as in the case of turbine blades of turbine engines, and Compressor blades or may be because of defects due to manufacturing processes. Mechanical accidents, fatigue, erosion, corrosion, as well as environmental attacks, are issues that can lead to a crack in a mechanical structure.

Beams are widely used as machine elements and structural elements in civil, mechanical, naval and aeronautical engineering& quite complex design features of turbine blades or compressor blades as tapered beam of uniform thickness. In many applications non-uniform beams and applications to satisfy special functional requirements and provides a greater strength. The machines and structural elements are designed with considerations to withstands against external loading for safety factors, and are inspected regularly. After that also there is failure of element are takes place. In order to increase the life of machinery and structures, there is no any other way rather than monitoring the conditions of structural critical elements. Damage detection by visual inspection is a time consuming one. Also finding the characteristics of vibrating body is difficult rather than measuring frequency. Thus, vibration based method based on measurement of natural frequencies can be a potential method for crack detection.[1,2]

2. Literature Review

Murat Kisa, [1] in Free Vibration Analysis of Cantilever Composite Beam with Multiple Cracks ,the analysis of vibration characteristics of beam are carried out. This paper develops a new concept for the theoretical analysis of composite cantilever beam under the free vibration with number of open and non-propagating cracks. Kaushar H.Borad et al, [2] the analysis of cracks in cantilever beam are carried out by frequency based method also it can detects its fatigue life and depth of crack. Using this approach, damage detection can be done using natural frequency. K. Oruganti et al, [3] the damage within the composite beam of Epoxy can be calculated accurately by both the methods, deviation Mode shape analysis as well as curvature mode shape analysis .Jialai Wang, Pizhong Qiao [4]in this work , the fundamental issues such as crack depths and locations, orientations as well as geometry etc also nonuniform damage detection method are addressed in it. Wahyu Lestari, Pizhong Qiao [5] the damage detection of fiber-reinforced polymer honeycomb sandwich beams carried out in this paper. The damage detection and structural health monitoring procedure are briefly described to analyze the structure is developed. Pizhong Qiao, Guiping Zou, Julio F. Davalos [6] the flexural-torsional buckling of fiber-reinforced plastic composite cantilever I-beam are discussed in this paper. The combined analytical and experimental study is carried out in this paper to

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find out the behavior of torsional buckling phenomenon of pultruded FRP composite cantilever I-beams.Mohamed S .Issa ,S.M .Elzeiny, [7] the use of fiber reinforced polymer in civil engineering for concrete structures are increased from the recent few years commonly due to their properties, such as good fatigue strength, hardness, high load carrying capacity, corrosion resistance etc. J.C. Norman,[8] in recent years, considerable growth can be made in the areas of using the reinforced composites in aircraft structures and wind mill blades. L.S. Dhamade et al,[9] presented a sandwich materials which is commonly used for fabricating the aerospace body due to their properties, such as lower in weight, good fatigue strength, corrosion resistance and load carrying capacity. Krishnan Balasubramanaiam et al,[10] in this paper the detection of transverse cracks in composite beam using new combined concept. Irshad A. Khan et al,[11] fault diagnosis of cracked beam by RBFNN are discussed in this paper. The current investigation is adopted for diagnosis of fault in a cantilever composite beam structure present in form of transverse cracks. Dr. K.B Waghulde et al ,[12] vibration analysis of a beam is presented in this paper. The behavior of beam structure under different loading conditions and its corresponding modal analysis are discussed under loading. A. L. Gawali et al,[13] new techniques for vibration analysis of a cracked beam are proposed in this paper ,the mathematical analysis are carried out in this paper also importance of boundary conditions in vibration analysis are described in details in recent years different there are large numbers of techniques are developed to analyze the health of composite cantilever beam with appropriate boundary conditions. But out of that methods vibration analysis are most superior and efficient method to detect the crack parameters.

3. Requirement of Vibration Analysis Technique for Body

Vibration analysis of structure are carried out by using its elements such as accelerometer, filter, analog to digital converter, digital display unit, memory storage device, CRO display etc. are shown in figure1 given below.

1. Vibrating machine or structure
⇩
2. Vibration transducer or pickup (Accelerometer)
⇩
3. Signal conversion instrument
⇩
4. Display unit, memory storage computer
⇩
5. Data analysis
⇩
6. CRO Display

Fig.1.Procedural steps in vibration analysis technique.

Transducer pick up the vibrations and gives to signal converter to convert the input vibration signal into frequency, after that analysis of collected data is carried out and display it on display unit, generally cathode ray oscilloscope display are most commonly used for displaying the frequency spectrums of different mode shapes and stores all data in memory for future purposes.

The predicted result by this method should in good agreement with actual values. This nondestructive method are very much suitable to identify the locations and depth of cracks from fixed end of cantilever beam .It can gives more accurate results compared to other methods such as liquid penitent, magnetic testing, ultrasonic method of testing, visual inspections also it can requires less time for analysis. Hence we are increasing the life of machines and structures efficiently by detecting the cracks and its extent through vibration analysis technique.

4. Experimental Model Analysis.

Fig.2. Experimental setup for crack detection of cantilever beam with single crack

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The experimental setup which is shown in above figure-2 is used to measure the natural frequencies of beam. As per shown in figure cantilever beam are fixed into the fixture, placing the accelerometer on the surface of beam connected to pulse analyzer as per shown in figure6. The accelerometer is fixed on the beam near the clamped end to monitor its vibration. The accelerometer is attached to the beam using magnetic base .The excitation is applied parallel to neutral plane of beam. To apply the excitation to the beam an impact hammer is used. After carrying out the experimentation, the beam response is analyzed by the FFT analyzer from the responses, natural frequencies are measured using FRF.

The frequency response functions obtained were curve-fitted. The natural frequencies measurement of a whole system is a function of the physical parameters, material properties and boundary conditions of the system. Hence, the frequency response function of the test beam should remain in variant under ideal conditions irrespective of the point of measurement and the point of excitation. The clamping of the beam is very critical. Repeated impacts on the beam may cause loosening of the bolts in the clamps. The location of accelerometer is decided avoiding the nodal points between free end and clamped support. The impact of the hammer should be quick and sharp. Also for low and high frequency range analysis a soft and hard hammer tip should be used respectively.

5. Modal Analysis Using Ansys

The ANSYS 14.5 workbench was used for free vibration of cracked and uncracked composite cantilever beams. To create a numerical model of laboratory tested beams, ANSYS 14.5 is used. The dimensions of the numerical model are based on the measurements of the laboratory beams: 900 mm long, 25 mm width and 14 mm depth. The horizontal crack was modeled with a 0.7 mm width on the top surface of the beam and a crack going through the depth of the beam. In modeling of our composite cantilever beam by using ansys 14.5 are carried out .We are taking free vibration modal analysis of composite beam to find out the first three mode shapes of beam for different crack locations and its depths. Means we are finding first three natural frequencies of cracked beam by fixing one end of beam and other for vibrating. and orientation of crack is rectangular having 0.7 mm thickness. The solid model for cracked beam are shown in figure 3 given below. This fig. shows the three dimensional view of cracked beam with fine meshing this is very much important to take fine meshing for getting the more accurate results. Table which is given below means table no. 1 gives properties of composite cantilever beam. According to testing of the composite cantilever beam its properties are given below.

Table 1: Properties of e-glass/epoxy

Sr. No.	Material Properties	Value
1	Elasticity (Ex), MPa	34000
2	Elasticity (Ey), MPa	6530
3	Elasticity (Ez), MPa	6530
4	Tensile Strength in MPa	900
5	Compressive Strength in MPa	450
6	(Gxy), MPa	2433
7	(Gyz), MPa	1698
8	(Gzx), MPa	2433
9	Poisson ratio along XY	0.217
10	Poisson ratio along YZ	0.366
11	Poisson ratio along ZX	0.217
12	Mass Density in Kg/m^3	2600

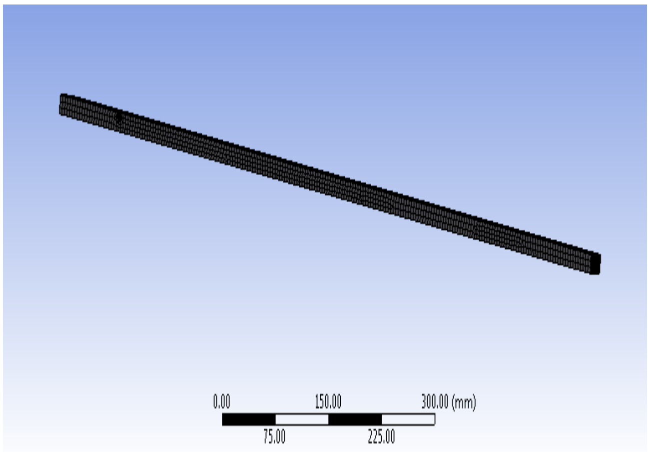

Fig. 3.Three dimensional finite element mesh model of the cracked beam

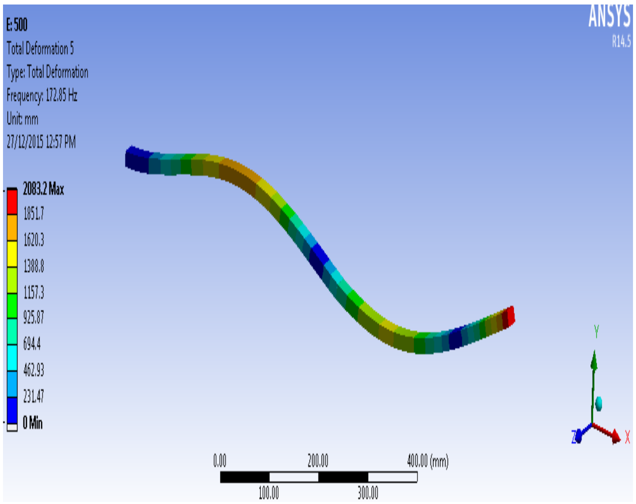

Fig.4. Displacement and stress distribution pattern for cracked composite cantilever beam (for 0.5555 location and 0.4 depth ratio)

Table 2: Natural frequencies of cracked beam by using experimentation (for 0.4 crack depth ratio)

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Normalized Crack Location	**Crack Depth Ratio**	**Experimental Natural Frequency in (Hz)**		
		Fn1	***Fn2***	***Fn3***
0.1111	0.4	9.21	60.90	173.62
0.3333	0.4	9.42	60.98	166.37
0.5555	0.4	9.66	59.62	173.15
0.7777	0.4	9.86	61.38	168.35
Uncracked beam	-	9.90	61.52	174.21

Table 3: Natural frequencies of cracked beam by using ansys (for 0.4 crack depth ratio)

Normalized Crack Location	**Crack Depth Ratio**	**ANSYS Natural Frequency in (Hz)**		
		Fn1	***Fn2***	***Fn3***
0.1111	0.4	9.29	61.51	174.46
0.3333	0.4	9.73	61.66	167.54
0.5555	0.4	9.99	59.39	172.85
0.7777	0.4	10.08	61.96	165.97
Uncracked beam	-	10.09	62.92	174.81

6. Results and Discussions

The experimental data is conducted for healthy and cracked beam. Crack identification 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. Normalized natural frequency is a ratio of cracked beam frequency to uncracked beam frequency. The natural frequency is greatly affected by crack depth and crack location. Above figure shows effect of normalized crack location on the first three natural frequencies for the various crack depths. From this we conclude that along with increasing the crack depth ratio the natural frequencies are decreases and vice versa.

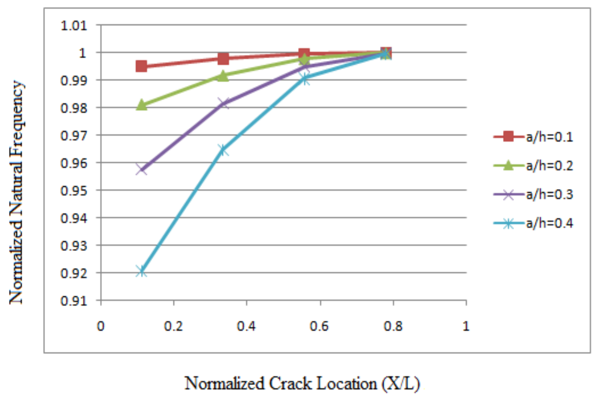

Fig.5. Effect of normalized crack location on the normalized natural frequency

The predicted result should in good agreement with actual values. This nondestructive method are very much suitable to identify the locations and depth of cracks from fixed end of cantilever beam.

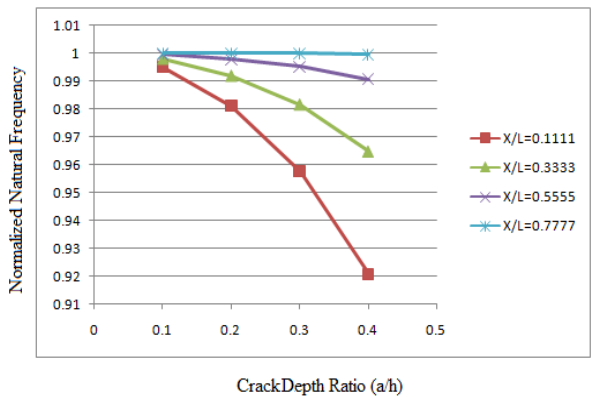

Fig.6. Effect of crack depth ratio on the normalized natural frequency

Crack depth ratios are plotted against the normalized natural frequency for the various normalized crack locations are shown in figures. In this figures we are plotted first three natural frequencies and it can gives the same nature of graph hence we can conclude that crack present near the fixed end reduces the natural frequency of beam higher than the crack having same size and shape closer to the free end. Also we can observe that the higher crack depth ratios has more effect on the normalized natural frequency than the smaller crack depth ratio.

7. Conclusion

Hence we conclude that the detection of cracks in cantilever beam by using vibration analysis technique in order to optimize the performance of machines and structures with more faster, accurate and efficient way. Identification of crack parameters are carried out by experimental setup which can gives the more accurate locations and depth of cracks. First one is the crack near to the fixed end gives the greater reduction in natural frequencies and the cracks away from the fixed end gives the higher frequency range. And the second is the larger depth cracks reduces the natural frequency significantly than the smaller crack depth. Through this method we can predict approximate crack location and depth. The experimentally predicted result should in good agreement with actual values and justified through simulation. This nondestructive method are very much suitable to identify the locations and depth of cracks from fixed end of cantilever beam .It can gives more accurate results within less time as compared to other testing methods such as liquid penitent, magnetic testing, ultrasonic method of testing, visual inspections etc. Hence we are increasing the life of machines and structures efficiently by detecting the cracks and its extent through vibration analysis technique.

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