International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 8, August 2017)

Detection of Crack in E-Glass Fiber Cantilever Beam Using Vibration Method

Supriya S. Kawade [1], Prof. Dr. A.D Desai [2], Prof. A. B. Bhane [3]

[1]PG- scholar, [2]Professor, [3]Asst. Professor, Department of Mechanical Engineering, Shree Ramchandra College of Engineering, Lonikand, Pune, India

***Abstract*— The presence of crack, changes the physical characteristics of a structure which in turn alter its dynamic response characteristics. Therefore crack identification is key issue. Generally composite beams are used as structural element in mechanical, naval, aeronautical and civil engineering. The existence of crack, which affects the performance of structure as well as vibration parameters such as natural frequency, stiffness and modal damping. Our current work is to model an inclined crack in a E-Glass Fiber 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 considered using specimen having cracks of different depth and position. Experiment is carried out on beam by using FFT analyzer. The objective of this paper is to determine relationship between the natural frequencies, crack location, crack depth analyze. Identification of crack location and crack size is to determine on varying initial three natural frequencies. The experimental analysis is to verify the practical applicability of the analytical method. When crack depth increases then natural frequency decreases. Both Experimental and FEA results are compared and are acceptable**

***Keywords*— Crack location, Crack size, Crack inclination, Finite Element Analysis, Natural frequency.**

I. INTRODUCTION

Damage is one of the important aspects to be considered in structural analysis and engineering. Damage analysis is done to promise the safety as well as economic growth of the industries. Generally damage in a structural element may occur due to normal operations, accidents, deterioration or several natural events such as earth quack or storms. Now a days the plants as well as industries are running round the clock to achieve the industrial goal. During operation, all structures are subjected to degenerative effects that may cause initiation of structural defects such as cracks, which as time progresses, lead to the catastrophic failure or breakdown of the structure. The inspection for quality assurance of manufactured products is thus very much important. To avoid the unexpected or sudden failure, earlier crack detection is essential..

The most common structural defect is the existence of a crack in a machine member. The presence of crack cloud, not only cause a local variation but it could affect mechanical behavior of entire structure to a considerable extent.

The use of composite material as a construction element has substantial over the past few years. The composite material are subjected to various types of damage, mostly cracks and delamination. Strength and stiffness of composite beam may be reduced due to the presence of crack , redistribute the load in a way that the structure may collapse. Therefore, crack is the part of the failure process which may ultimately lead to loss of structural integrity.

Non-destructive testing is preferred over a destructive testing for damage/crack detection in Fiber Reinforced Composite (FRC) beams. Many non-destructive methodologies for crack detection have been in use worldwide. However the vibration based method is fast. The defects in a structural element influence its dynamic behavior and change its stiffness and damping properties. Consequently, the natural frequencies and mode shapes of the structure contain information about the location and dimensions of the damage. Open crack models are considered, as crack remains open during vibration. The open crack leads to a constant shift of natural frequencies of vibration. Numerous methodologies investigated over fast few decades indicate that a real fatigue crack opens and closes during vibration. The field of non-destructive damage methods is very board and covers many techniques, such as, Liquid penetrate test, Ultrasonic testing, Eddy currents, Magnetic particles, Vibration method, Acoustic method and Radiography etc.

II. LITERATURE SURVEY

A. S. Tate et al [1], reviewed a non-destructive technique for crack detection and used in Structural Health Monitoring (SHM) in order to acquire analytical solutions of natural frequencies and dynamic deflections. Based on the changes in dynamic properties such as the stiffness which could lead to changes in mode shapes. Frequency, damping.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 8, August 2017)

N. G. Jaiswal et al [2], described the numerical studies for damage detection in beam structure with mode shape curvatures and its spatial wavelet transform. A small simulated perturbation in the form of transverse slots to be treated as damage in beams and a three stage damage detection process for amplifying the discontinuity was proposed. Vibration data obtained from the perturbed system is processed for mode shapes which were converted into mode shape curvatures and subsequently fed to the wavelet transform.

Rajan K. Behera, et al [3], described the numerical and experimental verification of method for prognosis of inclined edge crack in a cantilever beam based on synthesis of mode shapes to analyze the variation of modal parameters according to the location, size and inclined edge crack. The beam parameters such as measured frequencies and mode shapes were used in their proposed method. Specimen composite beam having inclined edge cracks of different depths, positions and crack inclinations are evaluated experimentally to validate the FEA results. Aniket et al [4], studied identification of crack parameters in cantilever beam using experimental and wavelet analysis. The crack is modeled as rotational spring and equation for non-dimensional spring stiffness is developed. By evaluating initial three natural frequencies using vibration measurements. Curves of crack equivalent stiffness are plotted and the intersection of the three curves indicates the crack location and size. Experiments are performed on cantilever beams with single crack (each at different locations and having varying sizes) using FFT set up to obtain natural frequencies which are compared with those obtain by ANSYS results. Marco A. Perez et al [5], investigated the feasibility of using vibration based methods to identify damages sustained by composite laminates due to low velocity impact. The experimental programme included an evaluation of impact damage resistance and tolerance according to American Society For Testing and Material (ASTM) test methods, characteristics of included damage by ultrasonic testing and qualification and estimation of the remaining bearing capacity. Missoum Lakhdar, et al [6], this work focuses on the detection of damage by vibration analysis; and objective is to exploit the dynamic response of a structure to grab the known damage. The experimental results are compared with those predicated by numerical models to confirm the effectiveness of the approach. The natural frequency decreases as the degree of degradation of the rigidity. The crack location is detectable by comparing a specific vibration node, not enough significant variation in natural frequencies.

D. K. Agarwalla, et al [7], Studied the effect of crack on modal parameter of a cantilever beam subjected to vibration; said that, The crack in the structure changes the frequencies, amplitude of free vibration and dynamic stability areas to an inevitable extent, diagnosis of changes allow the experimenter to identify the cracks without aborting the system applications. The modal parameters of the beam subjected to vibration which is analyzed and numerical method is used to obtain specified results i. e. Finite Element Method (FEM) and the experimental methods are compared. Natural frequencies of the vibrating structures are susceptible to change under the influence of crack depth &crack location. Therefore position and severity of crack are determined by analyzing these changes. The experimental results of cracked beam verified conveniently by comparing the results obtained from Numerical results of cracked beam.

In this experimental work, E-glass cantilever beam is designed, prepared, tested with the help of numerical method Finite Element Method and FFT analyzer.

III. MATHEMATICAL FORMULATION

The cantilever beam with an inclined edge crack is fixed at left side end, right side end is free and has a uniform structure having constant rectangular cross –section. The Euler-bernoulli beam model is assumed. In this experiment crack is assumed as an open crack where damping is ignored. The free bending vibration of an Euler-Bernoulli beam of a constant rectangular cross section is given by the following governing equation:

$$\frac{d^2}{dx^2}\left\{E_1\frac{d^2y}{dx^2}\right\}=\omega^2 my \text{ -------------- (1)}$$

Where E is the young's modulus of elasticity, I is moment of inertia of beam, y is displacement, w is natural frequency, m is the beam mass, m=ρA, a is c/s area, ρ is the material density.

We have following boundary conditions for a cantilever beam

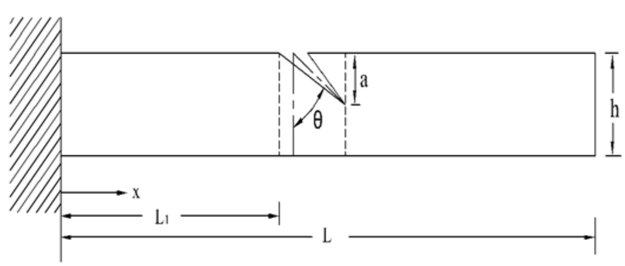

Fig. 1 Representation of open edged inclined crack in cantilever beam.

At $x = 0$, $y = 0$, $\frac{dy}{dx} = 0$

At $x = l$, $\frac{d^2 y}{dx^2} = 0$, $\frac{d^3 y}{dx^3} = 0$

For uniform beam under free vibration from equation (1), we get

$$\frac{d^4 y}{dx^4} - \beta^4 y = 0$$

$$\beta^4 = \frac{\omega^2 m}{El}$$

With the mode shapes for a cantilever beam is given as

$$f_n = A_n \begin{Bmatrix} (\sin \beta_n L - \sinh \beta_n L)(\sin \beta_n x - \sinh \beta_n x) + \\ (\cos \beta_n L - \cosh \beta_n L)(\cos \beta_n x - \cosh \beta_n x) \end{Bmatrix}$$

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

A closed form of the circular natural frequency ω_n , from above equation of motion and boundary conditions can be written as

$$\omega_n = \tau_n^{\,2} \sqrt{\frac{El}{mL^4}}$$

A. Design limitation:

The continuous model of the beam discretized for simplification. According to [1], for inclined edge crack cantilever beam $\frac{L}{w} \geq 12$, $a \leq \frac{h}{2}$ and $\theta = 45^0$ the difference in the two extreme locations is less than 4% of the beam length. The relative crack position range $0.1 \leq c \leq 0.75$ from fixed end and the relative edged crack depth range $0.1 \leq e \leq 0.5$ are tested.

IV. Finite Element Analysis

Finite Element Analysis helps us to obtain new designs to meet the changing conditions in order to avoid material failure equations. Designers use the finite element analysis to know the stresses within the structure by showing failure areas and then designer will predict the failure of the structure. It is an economic method of determining the causes of failure and the way of failure can be avoided.

The modal analysis is used to determine the vibration characteristics (natural frequency) of the structures or machine component while it is being designed. Also It can be more detailed, starting point for another dynamic analysis , a harmonic response analysis or a spectrum analysis.

The modal analysis is used to determine the natural frequency of structures .In the dynamic loading condition of design structure natural frequencies plays very important role. The analysis such as spectrum, mode shapes superposition harmonic or transient the above parameters are required. We can do the modal analysis on pre-stressed structure such as spinning turbine blade modal cyclic symmetry is very important feature which permits the reviewing the modes of shapes by modeling just a sector of cyclically symmetry structure. In the family of ANSYS product modal analysis is a linear analysis. Any non linearity, such as plasticity and contact (gap) elements are ignored.

A. Material Properties:
Material: E-glass Epoxy
Density: 2000 kg/m3
Youngs Modulus: 39000mpa
Possions ratio: 0.30

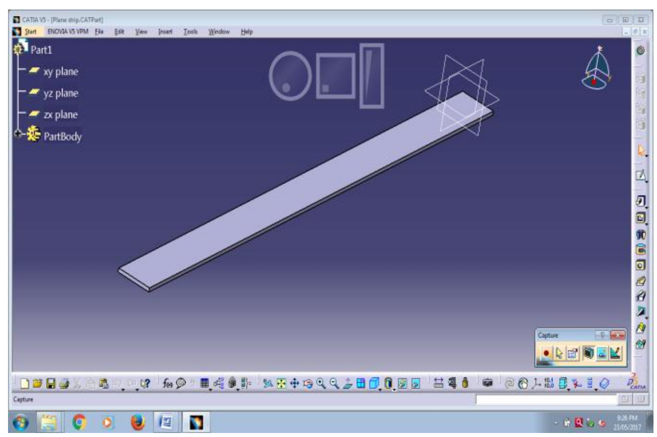

Fig.2 uncracked composite beam

Fig.2 shows that uncracked composite beam which is designed in CATIA V5R20. The dimensions a of composite beam are as length=800mm, width=60mm and depth =6mm.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 8, August 2017)

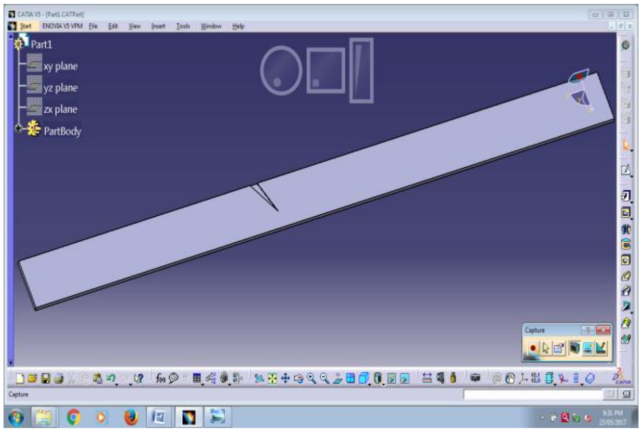

Fig.3 Cracked composite beam

Fig.3 shows the cracked beam with c=the relative crack position from fixed end and e=relative edged crack depth

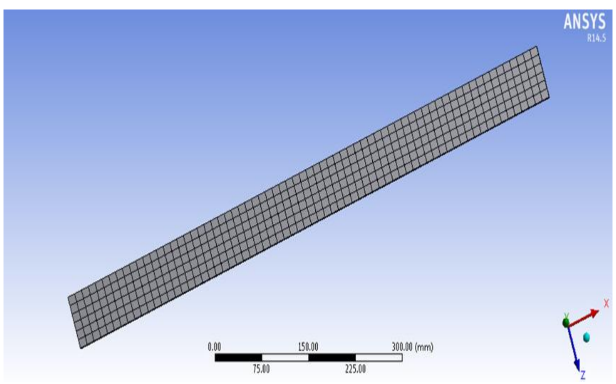

Fig. 4 Meshing of composite beam

Fig. 4 shows the fine meshing of composite beam selected in the sizing of modal analysis of ANSYS workbench 14.5.

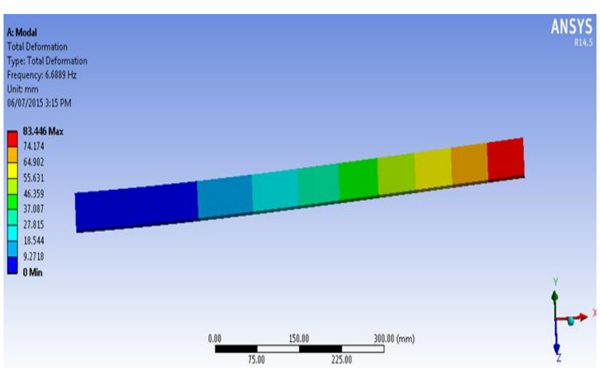

Fig. 5 First natural frequency of uncracked composite beam

The maximum stress of uncracked beam is 83.446N/mm^2

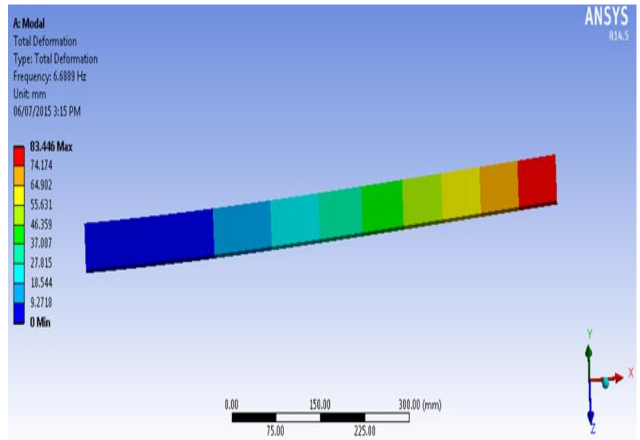

Fig.6 First natural frequency of cracked beam with c=0.25, e=0.30, ϴ=15°

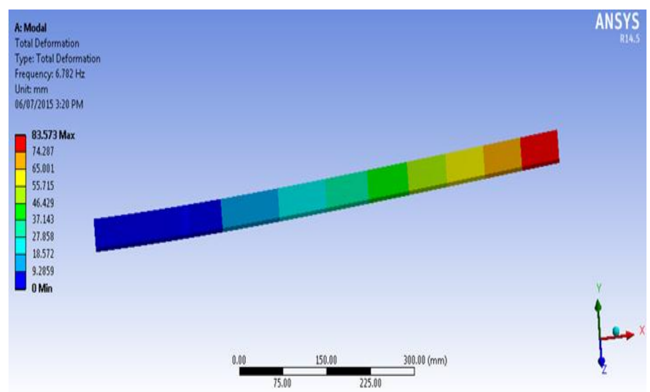

Fig. 7 First natural frequency of cracked beam with constant length (L=400mm), variable depth

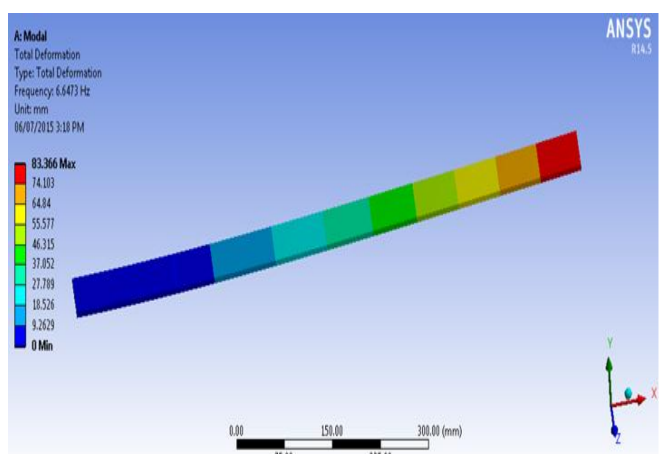

Fig. 8 First natural frequency of cracked beam with constant depth (a=1.8mm), variable length

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 8, August 2017)

V. EXPERIMENTAL ANALYSIS

Experimental modal analysis is performed on the E glass fiber composite beam; An appropriate set of measurements is performed on given structure in order to extract the information on its modal characteristics, i.e. natural frequency and damping factor. Generally, the whole process can be divided into the three main phases as defined in the following sections, which can synthetically restated as:

1. Data Acquisition
2. Modal Parameters estimation
3. Interpretation and presentation of results.

A. specification of FFT analyzer:

The specification of FFT analyzer is used for Experimentation are as follows:

1. Make: Dew soft Technology
2. Measuring range: 10-200 dB
3. Amplitude stability: +0.1 dB
4. Impedance: 10G Ω
5. Frequency limit; 1Hz to 20 KHz
6. Compatible software : DEW software

A. Procedure of FFT analyzer:

a. The cantilever beam is fixed at one end with the c – clamp on to a fixed surface like table in order to form a cantilever beam.
b. The beam is divided in to number of equal parts which are equal to number of nodes for which the analysis is to be performed. In this case the numbers of nodes=3. Hence the beam is divided in two equal parts.
c. The accelerometer is fixed on the beam with the help of adhesive on the face the bar at a suitable position.
d. The accelerometer and the impact hammer are connected to the vibration analyzer channel controller.
e. The vibration analyzer channel controller is then connected to the processor containing compatible software.
f. The channel analyzer is connected to a DC power supply.
g. The excitation force is provided to the beam on various location with the help of impact hammer and they are sensed by the accelerometer and given to vibration analyzer.
h. The required result are obtained by using the software and output frequencies are obtained .
i. The same procedure is repeated for the remaining beams and the resulting comparison is plotted

C. Experimental setup:

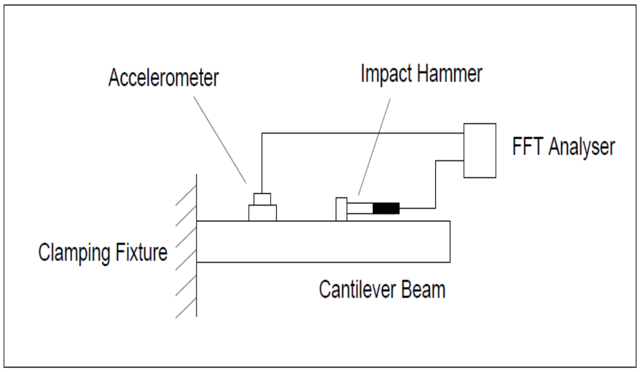

Fig. 9 Schematic set up of experimental Model (FFT)

Fig. 10 Set up of experimental Model

(1. Beam 2. Accelerometer 3. Vibration Analyzer 4. Hammer 5. Display)

VI. RESULTS AND DISCUSSION

The crack of known severity is generated at known location in glass fiber composite beam. Single crack is generated with the help of diamond cutter. The changes in the natural frequencies for the uncracked and cracked beam are measured. The predicted values are determined by the analytical and experimental results. Comparative results of FEA and experimental natural frequencies for the three modes are as follows.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 8, August 2017)

Table I
Comparison between FEA and experimental results of uncracked beam

Sr. No	C % position from fixed end	e depth from surface	FEA Results			Experimental Results		
			ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)	ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)
1	0	0	6.72	42.15	66.67	7.00	43.85	70.00

Table II
Comparison between FEA results and experimental results of cracked beam with crack inclination ϴ=15°

Sr. No	C % position from fixed end	e depth from surface	FEA Results			Experimental Results		
			ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)	ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)
1	0.25	0.30	6.73	42.22	66.69	6.88	43.85	63.53
2	0.35	0.25	6.73	42.21	66.70	6.92	43.36	68.75
3	0.40	0.35	6.73	42.22	66.71	6.87	42.66	67.93
4	0.55	0.40	6.73	42.21	66.71	6.98	42.16	68.26
5	0.70	0.50	6.73	42.18	66.72	7.06	43.08	68.81

Table. III
Frequency results for carcked beam with constant length L_1=400mm and variable depth

Sr. No	Crack depth a	FEA Results			Experimental Results		
		ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)	ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)
1	0.9	6.73	42.12	66.70	6.98	43.28	69.3
2	1.5	6.72	42.04	66.68	6.9105	42.982	67.60
3	1.8	6.72	41.99	66.67	6.9825	43.6525	69.28

Table. IV
Frequency results for cracked beam with constant depth a=1.8 and variable length

Sr. No	Crack Location L1	FEA Results			Experimental Results		
		ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)	ω_1 (Hz)	ω_2 (Hz)	ω_3 (Hz)
1	200	6.70	42.22	66.49	6.886	43.85	63.53
2	280	6.71	42.13	66.58	6.827	43.07	67.82
3	400	6.72	42.00	66.67	6.982	43.65	69.28
4	560	6.74	42.09	66.77	7.023	43.88	69.74

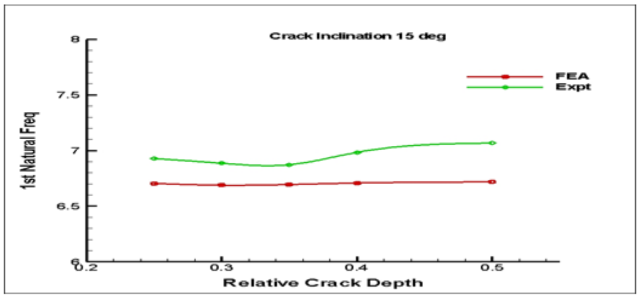

Fig. 11 Relative crack depth v/s First natural frequency at crack inclination ϴ=15°

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 8, August 2017)

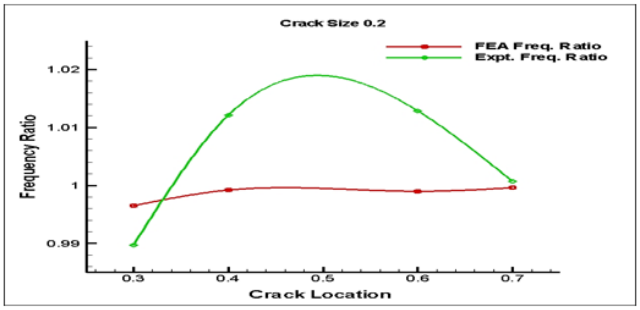

Fig. 12 Crack location v/s Frequency ratio at size 0.2

VII. CONCLUSION

1. It is found that if crack depth and crack inclination are Constant then crack location is increases and natural Frequency also increases.
2. If crack location and crack inclination are constant then crack depth increases and natural frequency is decreases.
3. If crack is nearer to fixed end it imparts more reduction in natural frequency.
4. The results obtained by Finite Element analysis and experimentally are compared and both are acceptable.
5. It has also seen from experimental results that the determination of the crack location is more precise than the determination of the crack size.
6. Mode shapes and natural frequencies of the beam are susceptible to change under the influence of crack depth and crack location.
7. Variation in natural frequencies of the initial three natural frequencies is observed and it is predominant in crack properties.
8. The present study provides an efficient non destructive technique for the detection and prediction of the current size and position of the crack for any composite beam.

REFERENCES

[1] A. S. Tate, M. M. Jadhav , A.A. Jadhav , A.M. Pirjade "Vibration analysis of composite beam with crack: a review" International journal of Innovative Researchin Science and Engineering Vol. No.2, Issue03, March 2016.

[2] N. G. Jaiswal, D. W. Pande "Sensitizing The Mode Shapes Of Beam Towards Damage Detection Using Curvature And Wavelet Transform" International Journal Of Scientific & Technology Research Volume 4, Issue 04, April 2015.

[3] Ranjan K. Behera, Anish Pandey, Dayal R. Parhi, "Numerical and Experimental Verification of a Method for Prognosis of Inclined Edge Crack in Cantilever Beam Based on Synthesis of Mode Shapes", International Conference on Innovations in Automation and Mechatronics Engineering,ICIAME,pp.67-74,2014.

[4] Aniket S. Kamble, D. S. Chavan, "Identification of crack parameters in a cantilever beam using experimental and wavelet analysis", International Journal on Mechanical Engineering and Robotics (IJMER), pp.23-27, 2014

[5] Marco A. Perez, Lluis Gil, Sergio Oller, "Impact damage identification in composite laminates using vibration testing", Composite Structures 108,pp.267–276,2014.

[6] Missoum Lakhdar ,Djermane Mohammed, Labbaci Boudjemâa, , Moudden Bachir, "Damages detection in a composite structure by vibration analysis", TerraGreen 13 International Conference 2013 - Advancements in Renewable Energy and Clean Environment,pp.888-897,2013.

[7] D.K. Agarwalla, D.R. Parhi, "Effect of Crack on Modal Parameters of a Cantilever Beam Subjected to Vibration", Procedia Engineering 51 pp. 665 – 669, 2013

[8] S.P.Mogal, Dr.R.K.Behera, S.Y.Pawar, "Vibration analysis of cracked beam", International Journal of Advanced Engineering Technology, Vol 3, pp.371-377, 2012