Verification of Vibration of Composite Beam with Crack by using Finite Element Method and Experimental Method

Abhijeet S. Tate, Manoj M. Jadhav, Sanjay B. Zope

Abstract*: This paper presents evaluation of analytical and experimental result discussion for vibration analysis of composite beam with crack. Beams and beam like elements are principal constituents of many mechanical structures and used widely in high speed machinery, aircraft and light weight structures. Finite Element Analysis is carried out using ANSYS 14.5. The model of beam is prepared and used for Finite Element Analysis. The model analysis is used to determine the natural frequencies and mode shapes of a structure. The experimental analysis is conducted by using a Fast Fourier Transform (FFT) device which is used to detect the potential faults and checking the status of the machine through the vibration analysis.

Index Terms*: Composite Beam, Finite Element Analysis/ Method (FEM), Fast Fourier Transform (FFT).

I. INTRODUCTION

Composite materials have the beauty due the various features including high strength, resistance to corrosion low weight, impact resistance and high fatigue strength. Along with these the other advantages include flexibility in design, ease of fabrication and variable material characteristics to suit almost any application. The composite material has high ratios of strength to weight and stiffness to weight, therefore these materials are becoming important in present days applications.

Also it has been increased the interest in modeling epoxy-based composites with the growth the computer aided design and manufacturing. Pre-impregnated fibres have been widely used to produce high quality composite parts. The key factor in utilizing the strength and uniqueness of laminated composite beams is the proper understanding for its structural response under different work load conditions.

Fiber-reinforced laminated beams compose the major category of structural members, which are widely used as movable elements, such as robot arms, rotating machine parts, and helicopter and turbine blades. Beams are also subjected to dynamic excitations as other structural components. The major requirement of an engineer is to reduce the vibrations of such structures.

One of the methods to reduce the vibration of a structure is to move its natural frequencies away from frequency of excitation force. There are different methods to modify the natural frequencies of beam structures. [4] [7] [8].

II. OBJECTIVES OF THE RESEARCH

The main objective of this work is to use the FEM and FFT method to for vibration analysis of composite beam with crack to determine:

1. The natural frequency of composite laminate without crack.
2. The natural frequency of composite laminate with crack at different location.
3. The natural frequency of composite laminate with multiple cracks.

III. VIBRATION ANALYSIS METHODS

To validate the results, it is necessity to compare the results achieved from FEM and experimental results obtained with FFT. By using the validity between FEM and Experimental result, the natural frequency of composite laminate can be evaluated.

A.Finite Element Analysis:

The Finite Element Analysis is one of the techniques for the analysis of vibration. Most of the researchers have discussed and demonstrated the different methods for vibration analysis in composite beam structures. [3][5][6]. The Finite Element Analysis is executed using ANSYS 14.5. The model of beam is prepared and used for Finite Element Analysis. The modal analysis is used to determine the natural frequencies and mode shapes of a structure.

Manuscript published on November 30, 2019.
***** Correspondence Author**,**

Mr. Abhijeet S. Tate* Department of Mechanical Engineering, Assistant Professor, Annasaheb Dange College of Engineering & Technology, Ashta, Sangli, Maharashtra, (India)

Mr. Manoj M. Jadhav, Research Scholar, VTU Research Centre, Belgavi.

Assistant Professor, Department of Mechanical Engineering, Annasaheb Dange College of Engineering & Technology, Ashta, Sangli, Maharashtra, (India)

Dr. Sanjay B. Zope, Researcg Guide, VTU RRC (PG Section), Belgavi.

Principal, Sahyadri Valley College of Engineering and Technology, Rajuri Pune, Maharashtra, India.

The element used in Finite Element Analysis is PLANE 82: Two dimensional (8- Node Structural solid). PLANE 82 is a higher order version of the two-dimensional, four-node element (PLANE42). It provides more precise results for mixed (quadrilateral-triangular) automatic meshes and can tolerate irregular shapes without beating of accuracy.

The assets of the material are as discussed in Section which shows the natural frequencies of simply supported beam with single crack and different locations determined using ANSYS. The crack location of first crack with reference to left support is fixed and the other crack is varied. Results obtained from FEA (ANSYS 14.5) method of natural frequency are as follows.

Table 1: Natural Frequencies at different crack location by ANSYS

Sr. No	Location	ANSYS Natural frequency in Hz
1	Specimen without Crack	142.71
2	100 mm from fixed support	153.9
3	200 mm from fixed support	159.6
4	300 mm from fixed support	147.06
5	Specimen with multiple crack	150.03

B. Experimental Method with FFT Analyzer:

The different experimental observations and analysis of multiple cracks detection in beams have been studied and discussed in various researches [1][2]. A Fast Fourier Transform (FFT) is a system which is used to detect the potential faults location and checking the condition of the machine through the vibration analysis. In this, accelerometers often come with a calibration certificate stating the exact reference sensitivity. The certificates often do not show the frequency response in tabular form (i.e. stating sensitivities at various frequencies) but instead of showing values, it plots from the lowest rated frequency to the highest.Composite beam of epoxy glass fibres with dimensions 30mm X 20mm X 400mm were made using hand layout techniques. In this beam Crack depths with respect to fixed different locations are taken separately for experimental analysis. A total of four layers of uniform thickness with matrix used for preparation of beam and prepared using hand layout techniques. The mechanical properties of the composite beams are recorded.

At the time of preparation of composite beams, the surface cracks were introduced at different locations of the beam individually with the help of sharp thin smooth plate. The surface cracks were located at different locations from one end of the beam to the point of study where the dynamic characteristics changes. Firstly the results were taken with a beam without crack. The composite beam with fixed boundary condition considered. For each experiment the crack locations changed where boundary conditions and crack depth ratio was constant. Distance was fixed ranging from 100 mm, 200 mm and 300 mm steps along the length and it considered for crack location for each experiment with a specified boundary conditions. The experiments were repeated for various boundary conditions and calculations. The experimental setup is shown in figure; the beams were put into the holder for test with different boundary conditions. External excitation was created in the beam with an impact hammer initially at mid position of beam.

a. Experimental Setup:

In this experimental setup the frequency response functions are captured by using piezoelectric, miniature type unidirectional accelerometer. It is mounted on the beam with the help of mounting clips and also it is mounted near the crack to capture the correct signal. The impact hammer is used to excite the beam whose frequency response function has to be captured. For every experimental test, the location of impact of hammer is kept constant. Impact hammer has the range of excitation 1to4000 Hz. The beam is tapped gently with the impact hammer. The experiments are performed on manufactured composite beam with simply supported boundary conditions having crack.

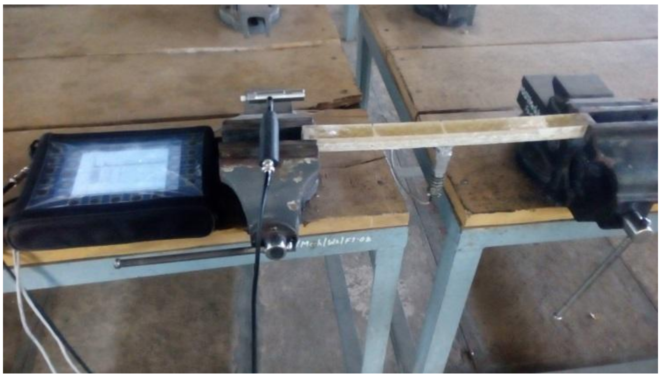

Figure 1: Experimental Setup

b. FFT Analysis:

The graph illustrated in fig.2 shows the FFT experimental analysis on a specimen without Crack. From the graph it is obvious that the natural frequency of actual specimen without crack is 125 Hz.

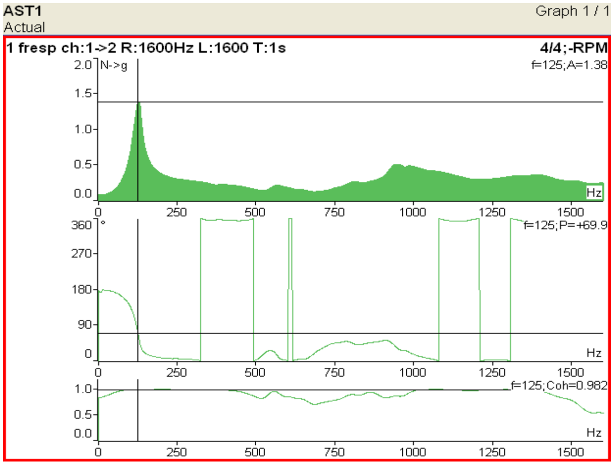

Figure 2: Specimen without Crack

The graph presented in Fig. 3 graph shows the natural frequency of actual specimen with crack at distance 100 mm from first end of fixed support is 135 Hz. Fig. 4 graph shows the natural frequency of actual specimen with crack at distance 200 mm from both end of fixed support is 140 Hz.

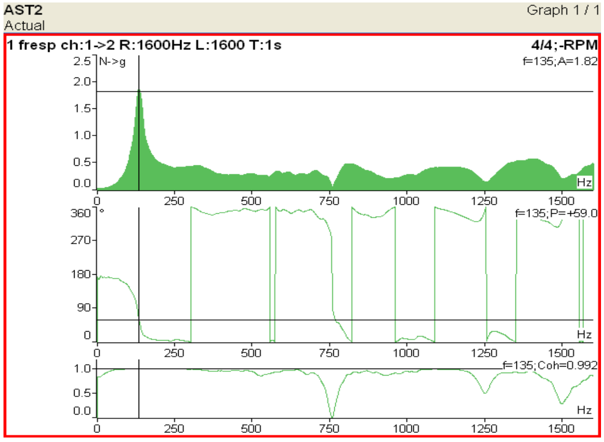

Figure3: Specimen with Crack at 100mm distance from fixed support

Fig. 5 graph shows that the natural frequency of actual specimen with crack at distance 300 mm from first end of fixed support is 133 Hz. Whereas the fig. 6 graph shows that the natural frequency of actual specimen with crack at distance 300mm from first end of fixed support is 129 Hz.

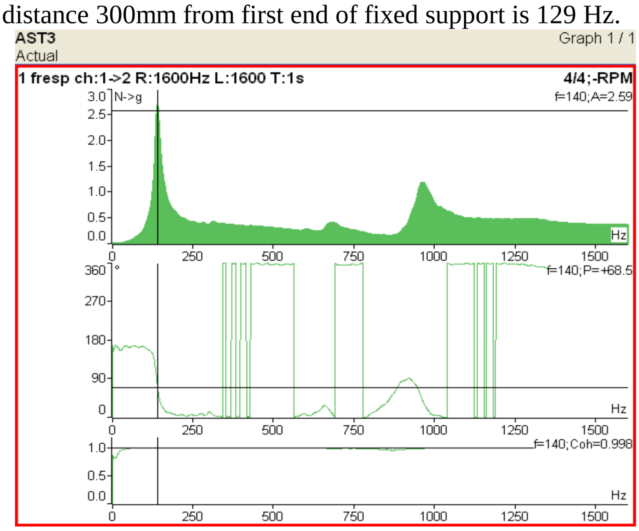

Figure 4: Specimen with Crack at 200mm distance from fixed support

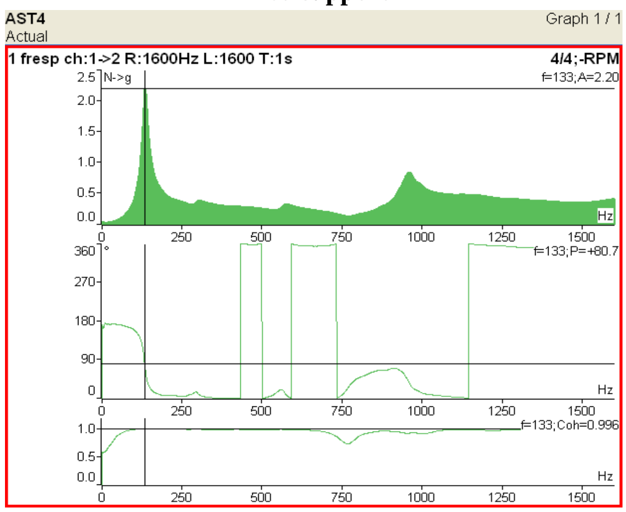

Figure 5: Specimen with Crack at 300mm distance from fixed support

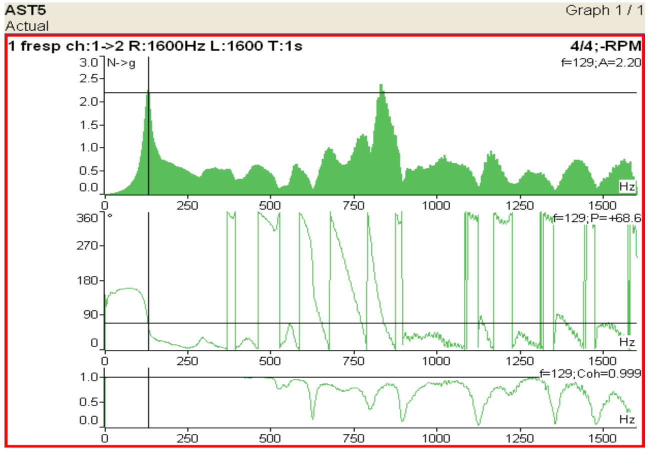

Figure 6: Specimen with multiple cracks

From the graph it is obvious that the natural frequency of 100 mm distance from fixed end of simply supported beam is less as compare to natural frequency 200 mm distance from same end of simply supported beam. The experimental results are enlisted in following table.

Table 2 Experimental results for different crack location

Sr. No	Particulars	Experimental Natural frequency in Hz
1	Specimen without Crack	127
2	Specimen with crack at 100mm distance from fixed support	135
3	Specimen with crack at 200mm distance from fixed support	140
4	Specimen with crack at 300mm distance from fixed support	129
5	Specimen with multiple crack	130

IV. RESULTS AND DISCUSSION

Comparison between FEM and Experimental results:

Following table 3 provides the assessment of experimental results and ANSYS results of natural frequencies for cracked simply supported beam. An ANSYS result shows good concurrence with experimental results. The average percentage error is 10 – 20.

Table 3 Comparison between FEM and Experimental result

Sr. No	Crack location	Natural Frequency in Hz		Percentage Error
		Experimental	ANSYS	
1	Specimen without Crack	127	142.71	12.3
2	100 mm from fixed support	135	153.9	14
3	200 mm from fixed support	140	159.6	14
4	300 mm from fixed support	129	147.06	14
5	Specimen with multiple crack	130	150.03	15.4

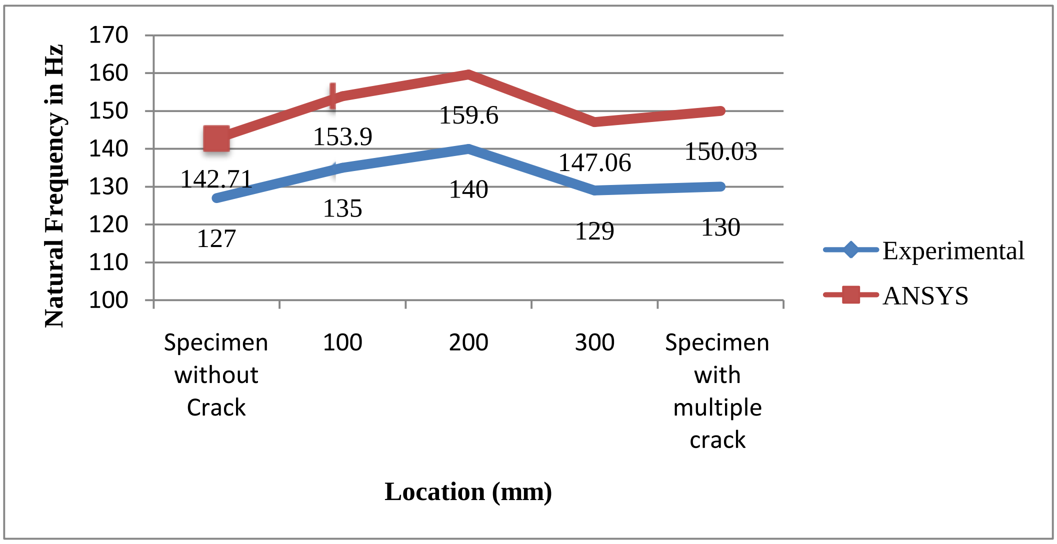

Figure 7: Comparison between FEM and Experimental result

From above ANSYS and Experimental results, graphs are plotted to find out the effect of crack location on natural frequency.The vibration results of the beam included the effect of crack location. The method studied to evaluate the natural frequency of beam with crack location effect, by using ANSYS Program Version 14.5.

Above fig.7 provides ANSYS and experimental results for natural frequency and how natural frequency changes with different crack position without crack, 100mm, 200mm, 300mm and multiple cracks. Natural frequency increases with increase in crack position due to stiffness of beam decreases.

V.CONCLUSION

The vibration analysis for composite beam with crack is illustrated and evaluated analytically, theoretically and experimentally with the beams having several properties and dimensions. The location of the crack in the composite beam can be easily detected and also the magnitude of the crack can be measured. The natural frequencies obtained from experimental results have measured and compared with ANSYS. If the crack exists close to the fixed end expose greater reductions in natural frequency than that to present at afar from the fixed end. The enlarging the beam length results in increase in the natural frequencies of the Composite beam. The effect of cracks is more pronounced near the fixed end than at far free end. It is Concluded that the first, second and third natural frequencies are mainly influenced when the cracks located at the near to the fixed end, the middle of the beam and the free end, respectively. The intensity of natural frequency increases with the increase in the crack location from fixed end.

REFERENCES

1. A.V. Deokar, V. D. Wakchaure, "Experimental investigation of crack detection in cantilever beam Using natural frequency as basic criterion", December, 2011.
2. D.P. Patil, S.K. Maiti. "Experimental verification of a method of detection of multiple cracks in beams based on
3. frequency measurements", Journal of Sound and Vibration 281 (2005) 439–451.
4. Erdogan Madenci and Ibrahim Guven "The Finite Element Method and Applications in Engineering using ANSYS" Springer, 2006.
5. K. H. Barad, D. S. Sharma, V. Vyas, "Crack detection in cantilever beam by frequency based method", Procedia Engineering, 2013.
6. Pankaj Charan Jena, Dayal R. Parhi, Goutam Pohit, "Theoretical, Numerical (FEM) & Experimental Analysis of Composite Cracked Beams of Different Boundary Conditions using Vibration Modes Shape
7. Curvature", International Journal of Engineering & Technology, Vol 6, No 2, pp. 509-518, May 2014.
8. P. C. Jena, D. R. Parhi, G.Pohit, "Theoretical, Numerical(FEM) and Experimental Analysis of composite cracked beams of different boundary conditions using vibration mode shape curvatures", IJET, Vol.6 No.2.May 2014.

9. S. Chinchalkar, "Determination of crack location in beams using natural frequencies, Journal of sound and vibration, 247(3), 417-429, 2001.
10. T.D. Chaudhari, S.K. Maiti, "A study of vibration of geometrically segmented beams with and without crack", International Journal of Solids Structures, 2000.

AUTHORS PROFILE

Mr. Abhijeet S. Tate He is working as an assistant professor at Annasaheb Dange College of Engineering and Technology, Ashta, Sangli, Maharashtra (India). He has completed BE in Mechanical Engineering in 2014 and ME (CAD/CAM/ CAE) in 2017 from Shivaji University, Kolhapur (India). He is having 05 years of teaching experience. His area of interest is Vibration Analysis and manufacturing of composite beam in the field of Mechanical Engineering. He has published four papers in International Conferences and published in International Journals. He has also published a book 'Basic Mechanical Engineering' in Wiley India Publications in 2018.

Mr. Manoj M. Jadhav, He is working as an assistant professor at Annasaheb Dange College of Engineering and Technology, Ashta, Sangli, Maharashtra (India). He has completed BE in Mechanical Engineering in 2003 and ME (Mechanical Design) in 2012 from Shivaji University, Kolhapur (India). Now he is pursuing Ph. D from VTU, Research Centre, Belgavi. He is having 10 years of teaching experience and 01 year industrial experience. His area of interest is Vibration Analysis in the field of Mechanical Engineering. He has published 05 papers in International Journals and presented 06 papers in National conferences and International Conferences. He is Life member of Indian Society for Technical Education (ISTE)

Dr. Sanjay B. Zope, He is working as a Principal at Sahyadri Valley College of Engineering and Technology, Rajuri, Pune, Maharashtra, India and Research Guide at VTU RRC, (PG Section), Belgavi. He has PhD from College of Engineering, Pune in Mechanical Engineering. He has achieved various milestone in his career as a teacher, administrator at various institutes and as a Director, Deccan Management Consultant and Finishing School Pune.