Analysis of the Performance Parameters of Composite Beam Vibration with Crack

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Abstract*:* This paper presents comparison 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 performed using ANSYS 14.5. The model of beam is generated and used for Finite Element Analysis. The modal analysis is used to determine the natural frequencies and mode shapes of a structure. The experimental analysis is carried out by using a Fast Fourier Transform (FFT) device which is used to detect the potential faults and checking the condition of the machine through the vibration analysis. Accelerometers often come with a calibration certificate stating the exact reference sensitivity.

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

INTRODUCTION

Composite materials are expanding attractiveness 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. Due to the high ratios of strength to weight and stiffness to weight of composite material, these materials are becoming important in most of present day applications. Now days there has been an increased interest in modelling epoxy-based composites with the growth the computer aided design and manufacturing. Pre-impregnated fibres or prepegs 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 of its structural response under different work load conditions.

Fiber-reinforced laminated beams constitute 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. Similar to other structural components, beams are subjected to dynamic excitations. Reducing the vibration of such structures is a basic requirement of engineers. One method 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]. In this paper an attempt is made to apply the FEM and FFT method to for vibration analysis of composite beam with crack to determine:the natural frequency of composite laminate with, without and multiple crack. Also the natural frequency of composite laminate with crack at different locationis determined

VIBRATION ANALYSIS METHODS:

There is need to validate the results obtained from FEM, for that experimental results with FFT were obtained. Now both these results will be compared for validation. By using the validity between FEM and Experimental result, the natural frequency of composite laminate can be measured.

Finite Element Analysis:

The Finite Element Analysis is one of the method of vibration analysis most of the researchers have discussed [3] [5] [6]. The Finite Element Analysis is performed using ANSYS 14.5. The model of beam is generated and used for Finite Element Analysis. The modal analysis is used to determine the natural frequencies and mode shapes of a structure. The element used in Finite Element Analysis is PLANE 82: 2-D8-Node Structural Solid. PLANE82 is a higher order version of the two-dimensional, four-node element (PLANE42). It provides more accurate results for mixed (quadrilateral-triangular) automatic meshes and can tolerate irregular shapes without loss of accuracy. The properties of the material are as mentioned 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	153.9
3	200	159.6
4	300	147.06
5	Specimen with multiple crack	150.03

EXPERIMENTAL METHOD WITH FFT ANALYZER:

The different experimental verification of multiple cracks detection in beams has been discussed. [1] [2]. A Fast Fourier Transform (FFT) is a device which is used to detect the potential faults and checking the condition of the machine through the vibration analysis. 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 show a plot from the lowest rated frequency to the highest.

Composite beam of epoxy glass fibres with dimensions 30mm×20mm×400mm were prepared using hand layout techniques. Crack depths with respect to fixed different locations are taken separately for experimental analysis. A total of four layers of uniform thickness with matrix put alternately were prepared using hand layout techniques. The mechanical properties of the composite beam recorded.

The surface cracks were created at different locations of the beam individually by inserting sharp thin smooth plate at time of preparation of composite beams. The surface cracks were located at different locations from one end of the beam to study the changes in dynamic characteristics. The results were compared with a beam without crack. The composite beam with fixed boundary condition considered. For each experiment the crack location were changed for different boundary fixations keeping the crack depth ratio constant. Pre fixed distance of ranging from 100mm, 200mm and 300mm steps along the length were considered for crack location for each experiment with a specified boundary fixation. The experiments were repeated for various boundary fixations and investigation. The experimental setup is shown in figure the beams were put into the holder for test with different boundary fixations. External excitation was created in the beam with a impact hammer initially at mid position of beam.

Experimental Setup:

In this setup the piezoelectric, miniature type unidirectional accelerometer is used to capture the frequency response functions. The accelerometer is mounted on the beam using mounting clips. The accelerometer 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 test, the location of impact of hammer is kept constant. Impact hammer has the range of excitation 1-4000 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

FFT Analysis:

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

Fig. 3, graph shows that the natural frequency of actual specimen with crack at distance 100mm from first end of fixed support is 135 Hz. Fig. 4 graph shows that the natural frequency of actual specimen with crack at distance 200mm from both end of fixed support is 140 Hz. Fig. 5 graph shows that the natural frequency of actual specimen with crack at distance 300mm 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.

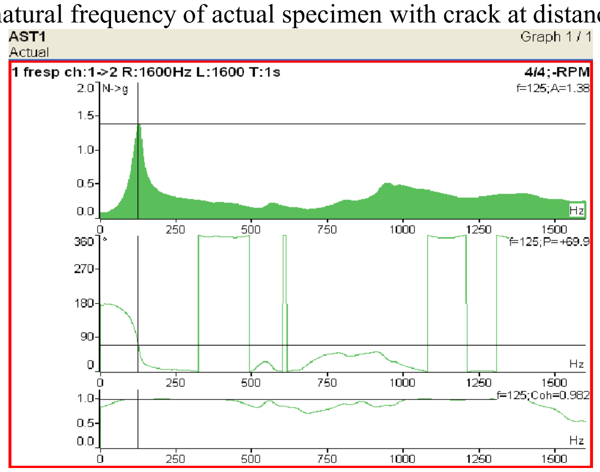

Figure 2: Specimen without Crack

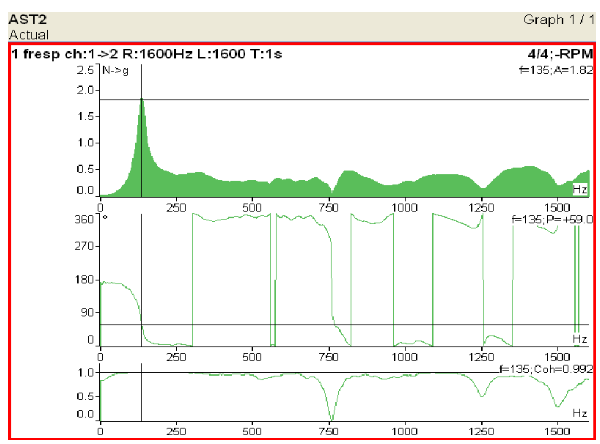

Figure3: Specimen with Crack at 100mm distance

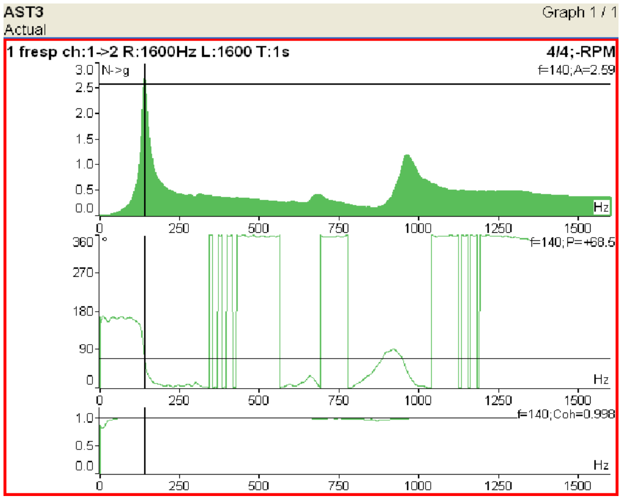

Figure 4: Specimen with Crack at 200mm distance

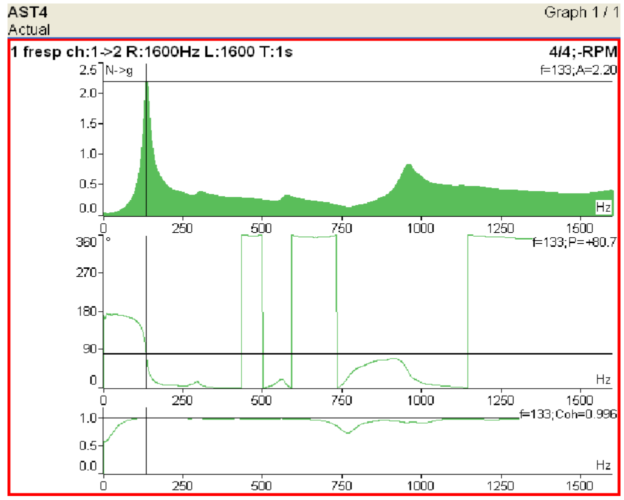

Figure 5: Specimen with Crack at 300mm distance

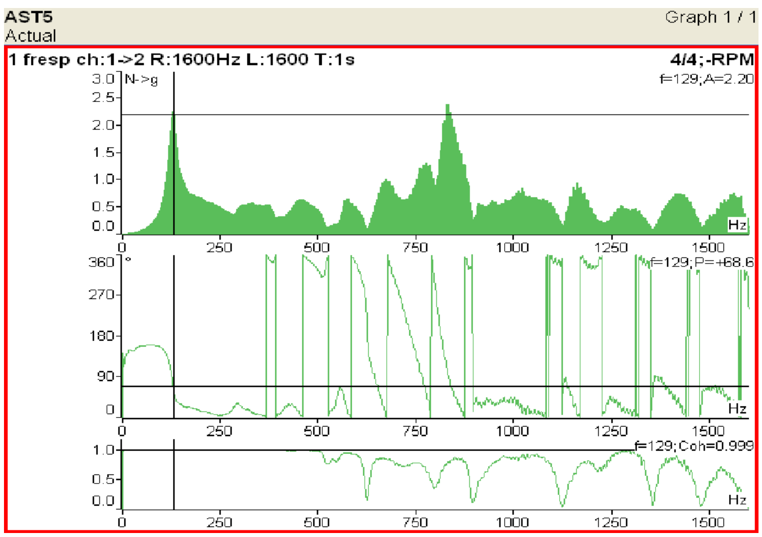

Figure 6: Specimen with multiple cracks

From the graph it is clear that the natural frequency of 100mm distance from fixed end of simply supported beam is less as compare to natural frequency 200mm 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	135
3	Specimen with crack at 200mm distance	140
4	Specimen with crack at 300mm distance	129
5	Specimen with multiple crack	130

RESULTS AND DISCUSSION:

Comparison between FEM and Experimental results:

Following table 3 shows, the comparison of experimental and ANSYS results of natural frequency for cracked simply supported beam. An ANSYS result shows good agreement 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	135	153.9	14
3	200	140	159.6	14
4	300	129	147.06	14
5	Specimen with multiple crack	130	150.03	15.4

From above ANSYS and Experimental results, graphs are plotted to find out the effect of crack location on natural frequency.

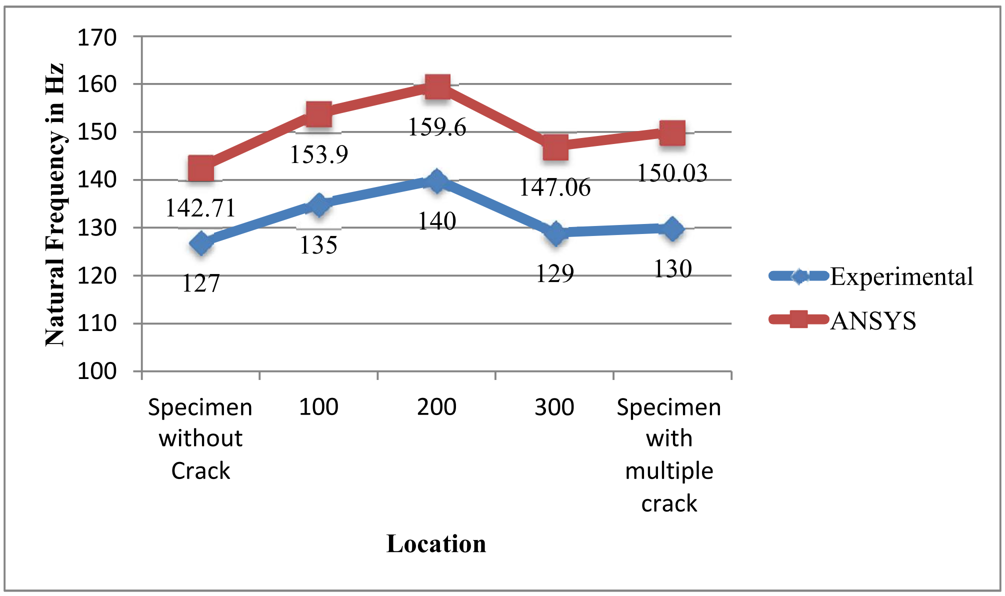

Figure 7: Comparison between FEM and Experimental result

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 shows 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 because of stiffness of beam decreases.

CONCLUSION:

The vibration analyses for composite beam with crack were illustrated analytically, theoretically and experimentally with the beams having various properties and dimensions. The location and the magnitude of the crack can be determined. Experimental natural frequency is measured and these were compared with ANSYS. Crack present near to fixed end imparts greater reductions in natural frequency than that to present at away from the fixed end. The increase of 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 most affected 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.

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