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Experimental Study on Natural Frequency of Composite Box Beam for Multiple Cracks

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Abstract

Cracks are common damages in composites, which can significantly reduce the structural stiffness, which changes the dynamic response of the structures and it changes modal parameters such as natural frequency and mode shape. This paper presents effect of cracks and locations on the natural frequencies of composite cantilever box beam. The experimental study is carried out for Natural Frequency of composite beam in undamaged condition. Then, beam is damaged by producing cracks at different locations such as Root, Mid and Tip of the beam. Initially, crack is produced near Root (fixed end) of the beam and results are found out for change in frequency in damaged condition. Then, crack is produced at mid and tip of the beam and results are carried out for change in natural frequency with multiple cracks. The natural frequency of composite beam is changes with multiple cracks i.e. crack near root (fixed end), at mid and at tip. It is observed that natural frequency decrease when cracks in beam increases. Finally, obtained results in undamaged and damaged condition (with one to multiple cracks) are compared to find the percentage change natural frequency with different mode shapes.

***Keywords**:* Composite Cantilever Beam, Undamaged, Damaged, Crack, Natural Frequency.

1. Introduction

The importance of the use of composite materials has been increasing in different industries like mechanical engineering, aerospace engineering due to their enhanced desirable properties. One of the most important properties that structures made of composites has very large stiffness to weight ratio. Composites have an excellent combination of high strength and stiffness. Composite beam are widely used in different areas due to their easy fabrication and effectiveness and due to their versatility in the orientation of the fibers and reinforcement. Despite of their benefits composite materials have their disadvantages. Composite materials are prone to different types of failures due to their nature of layers, interaction between the materials, fibers, matrix, etc. The most common type of failure is delamination and crack, which can cause irreversible damage. This type of failure causes the separation of the layers due to cracks in beam which results in loss of mechanical strength. Crack is the most dangerous defect in composite materials because it can appear suddenly without any notice and it will collapse the whole structural member. Composite materials with the defect of crack can lose their stiffness and still remain visibly unchanged. Since crack damage leads to loss in stiffness, its structure, modal properties like natural frequencies, mode shapes and damping ratio will also varies. [1]

The researches have been conducted on composite box beams. I. V. Tate, Sajal Royb, et al. [1] Delamination Detection of Composite Cantilever Beam Coupled with Piezoelectric Transducer Using Natural

Frequency Deviation, the Effectiveness of the proposed methodology is evaluated by numerical simulation of three delamination scenarios, i.e. delamination near fixed end, at center and at free end. It is observed that natural frequency decrease when length of delamination increases. Onur Sayman, et al. [2] Effect of the Root Crack on Natural Frequencies of Sandwich Composite Beams, Natural frequencies in a thin sandwich composite cantilever beam with root crack is determined. The crack with various lengths is opened between the face sheet and foam core, such as 50, 100, 150 and 200 mm. free vibration tests of these samples are carried out. Jeslin Thalapil, S.K.Maiti, et al. [3] Detection of longitudinal cracks in long and short beams using changes in natural frequencies, An analytical method has been developed to address both forward problem of determination of natural frequencies knowing the beam and crack geometry details as well as inverse problem of detection of crack with the knowledge of changes in the beam natural frequencies.

This paper presents effect of cracks and locations on the natural frequencies of composite cantilever box beam are presented. It is observed that natural frequency decrease when number of cracks in beam increases. Finally, obtained results in undamaged and damaged condition (with one to multiple cracks) are compared to find the percentage change natural frequency for different mode.

2. Experimental Study

Composite cantilever box beam (unidirectional beam) of length 800 mm and width 60mm is considered for experimental study, the experimental setup for this study is shown in Figure 1. Figure 2 shows the cross section of the unidirectional beam. Beam has 8 layer of carbon fiber, thickness of each layer is 0.5 mm and therefore thickness of the box beam is 4 mm.

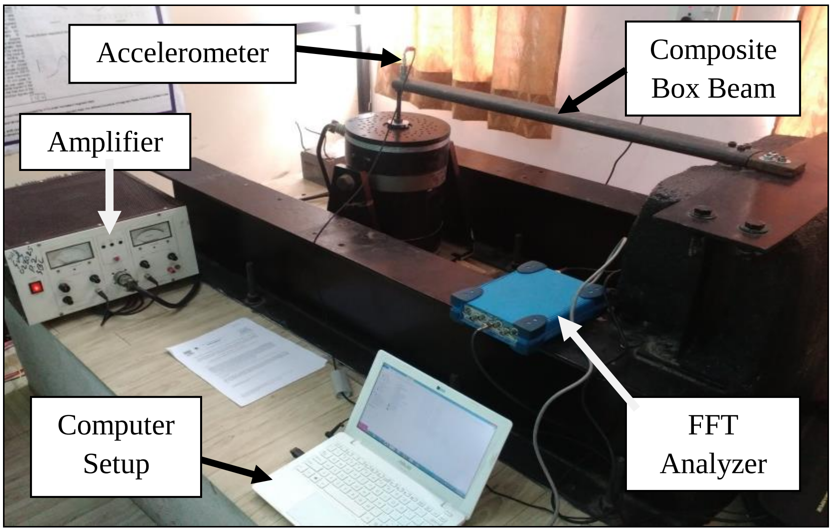

Figure 1: Experimental setup for Natural Frequency

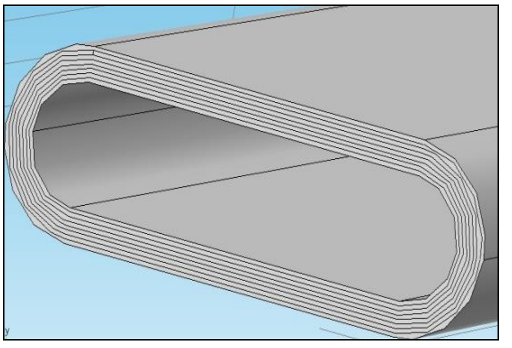

Figure 2: 8 Layer composite box beam

2.1 Natural Frequency in Undamaged condition of beam:

In this study the composite box beam is fixed like a cantilever beam, shown in figure 1. Initially, there is no any crack produced on beam. The experimentation is carried out for undamaged beam to find its natural frequency for different mode shapes. Before damaging the natural frequency of beam is 30.625 Hz. Also we calculate it for different mode shapes to find % change in natural frequency to each mode after damaging. The experimental results of natural frequency of undamaged beam for different modes are presented in following table.

Table 1: Natural Frequency in undamaged condition

Mode	Without Crack (Hz)
1	30.625
2	61.25
3	92.5
4	123.25
5	184.37
6	215

2.2 Natural Frequency in damaged condition of beam:

2.2.1. Crack near Root (fixed end) and at Mid of the beam:

For damage analysis first crack is produced near fixed end of the beam. The crack is produced manually of 50 mm length, width 5 mm and depth 4 mm. The damaged beam is fixed like a cantilever beam. Then, analysis is carried out for beam with only one crack. The proposed setup for this analysis is same as undamaged beam. The composite box beam with root crack is shown below.

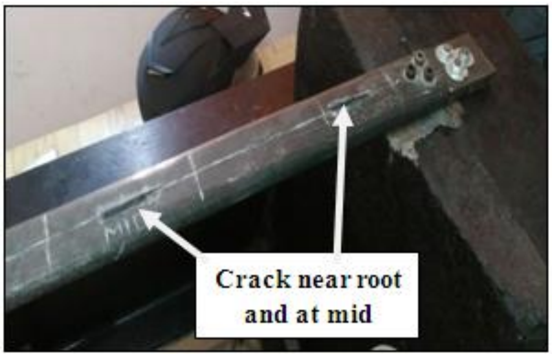

Figure 3: Damaged beam by producing crack near root **Figure 4:** Damaged beam by producing crack at mid

Then, second crack is produced at mid of beam by same above dimensions. Then, analysis is carried out for beam with two cracks. But beam with crack near root and at mid having same frequency change. Therefore, percentage change in natural frequency without and with crack is presented below.

Table 2: Percentage change in natural frequency for 50 mm crack near Root and at Mid

2.2.2. Crack near Root (fixed end), at Mid and at Tip of the beam:

In this case, one additional crack is produced at tip (free end) of the beam. Then, this damaged beam with multiple cracks is used for analysis. In this condition the natural frequency of beam is reduced up to 29.375 Hz. The beam with three is shown below.

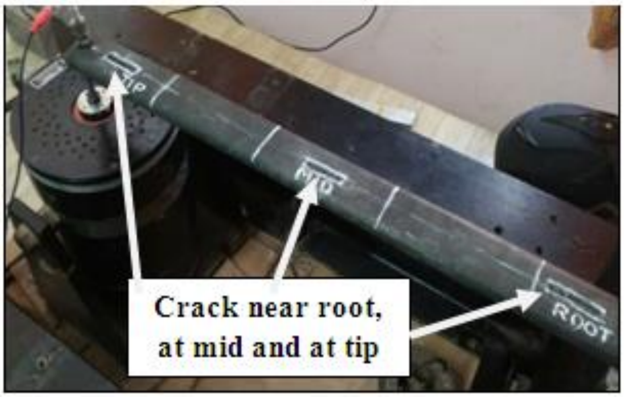

Figure 5: Damaged beam with multiple cracks

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Mode	Without Crack (Hz)	Crack near Root and at Mid (Hz)	% change in frequency
1	30.625	30	2.04
2	61.25	60	2.04
3	92.5	90	2.70
4	123.25	120	2.63
5	184.37	180	2.37
6	215	210	2.32

Table 3: Percentage change in natural frequency with multiple cracks (Three Cracks)

Mode	Without Crack (Hz)	Crack near Root, at Mid and at Tip (Hz)	% change in frequency
1	30.625	29.375	4.08
2	61.25	59.37	3.06
3	92.5	88.75	4.05
4	123.25	118.125	4.16
5	184.37	147.5	19.99
6	215	206.87	3.78

Also, percentage change in natural frequency for different mode is shown by the following graph.

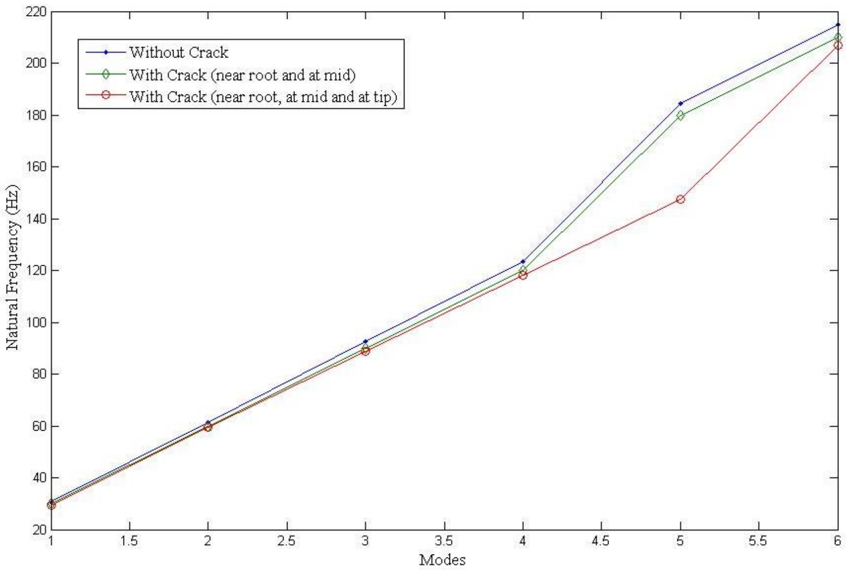

Figure 6: Change in natural frequency for different crack locations

3. Conclusion

Crack is the most dangerous defect in composite materials because it can appear suddenly without any notice and it collapses the whole structural member. Since crack damage leads to stiffness loss of the structure, the modal properties like natural frequencies, mode shapes. In this study, the effect of one and multiple cracks on the natural frequencies of a composite cantilever box beam is investigated experimentally. Based on the experimental frequency values, following conclusions are drawn,

1. The existence of the crack affects the natural frequencies of the composite beam.

2. The natural frequency of composite box beam in undamaged condition is calculated experimentally and it is of 30.625 Hz.

3. The beam is damaged by producing crack of 50 mm length near root and at mid. Due to this damage stiffness of beam will get reduced which reduces the frequency from 30.625 Hz to 30 Hz.

4. The beam with three cracks is analyzed, and natural frequency is decreases up to 29.375 Hz.

5. The percentage change in natural frequency for multiple cracks is greater than change in crack near root and at mid. And it is also represented by graphical form as shown in figure 6.

6. It is observed that natural frequency decrease when number of cracks in beam increases.

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A Brief Author Biography

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