Modal Analysis of Bi-directional Composite with Transverse Crack

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***Abstract*— This study is an investigation of the effects of cracks on the dynamical characteristics of a cantilever bi-directional composite beam, made of glass fibre and epoxy resin. The finite element analysis was also used to model the problem. A transverse crack was introduced on the beam. The beam was then subjected to vibration which was then analyzed experimentally and modally. The effects of the location and depth of the cracks on the natural frequencies and mode shapes of the beam with transverse non-propagating open crack is explored. The results of the study lead to the conclusion that by using the drop in the natural frequencies and the change in the mode shapes, the presence and nature of cracks in a structure can be detected.**

Keywords - Bi-directional composite beam, Free vibration, Natural frequency, Transverse crack

I. INTRODUCTION

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. Thus, the importance of inspection in the quality assurance of manufactured products is well understood. Several methods, such as non-destructive tests, can be used to monitor the condition of a structure. Cracks or other defects in a structural element influence its dynamical behaviour 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. Vibration analysis, which can be used to detect structural defects such as cracks, of any structure offers an effective, inexpensive and fast means of non-destructive testing.

II. DETERMINATION OF NATURAL FREQUENCY OF COMPOSITE BEAM WITHOUT CRACK

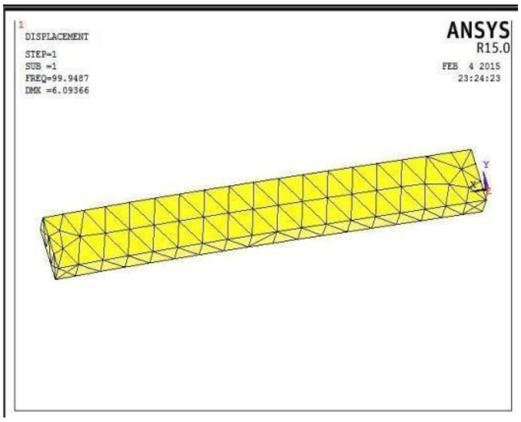
2.1: Natural Frequency Using ANSYS Software

The natural frequency of the composite beam was found out using ANSYS software and experimentally. The beam dimension used for the analysis was 214 mm x 27 mm x 10 mm. The density of the material was found to be 1860 kg/m3.

2.1.1 ANSYS results

The element selected was a 20 node element. The frequencies obtained using ANSYS software for the first, second and third natural frequencies are 99.921 Hz, 621.74 Hz and 1716.21 Hz.

The first, second and third modes obtained are shown in Fig 1.



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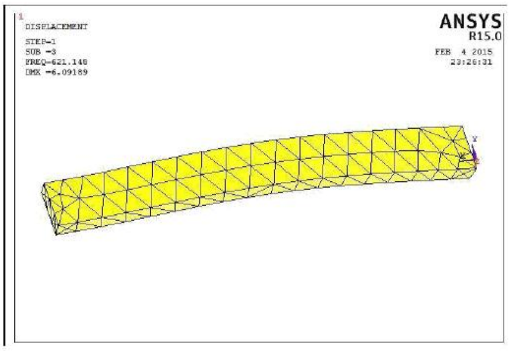

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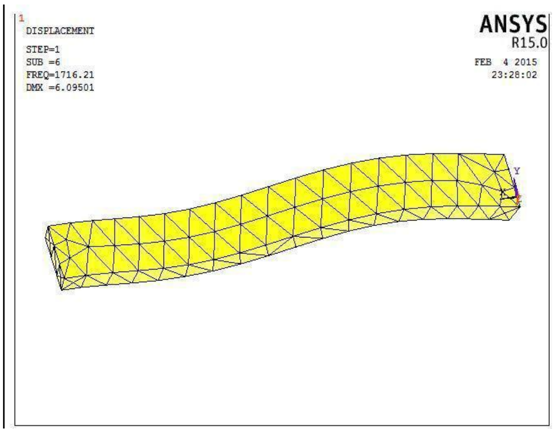


(c)

Fig.1 (a) First Mode, (b) Second Mode, (c) Third Mode of composite beam without crack

2.2: Natural Frequency Using Experimental Set-Up

The natural frequency of the composite beam was found using cantilever beam test using the apparatus shown in Fig.2.

Fig.2 Cantilever composite beam test set up

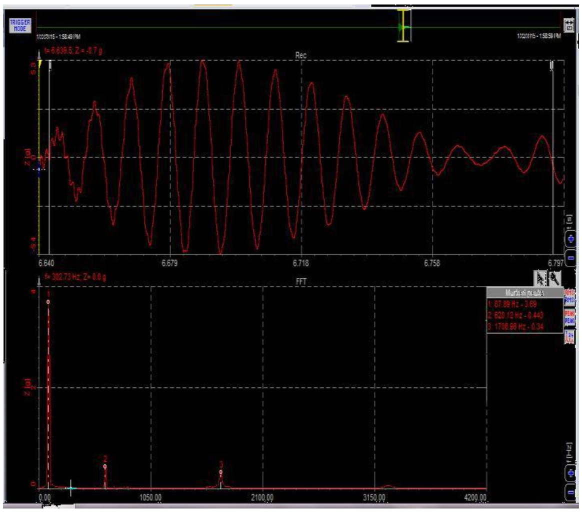


Fig.3 Result from experiment of composite beam without crack

Table 1: Comparison of experimental and ANSYS results of composite beam without crack.

Composite Beam	First mode	Second mode	Third mode
Experimental	87.78Hz	620.12Hz	1708.96Hz
ANSYS	99.921Hz	621.74Hz	1716.21Hz

The experimentally obtained results are shown in the Fig.3 Natural frequencies obtained experimentally and using ANSYS software are shown in Table 1. The values are in good agreement. The small variation in the first mode can be attributed to the initial transients in free vibration.

III. DETERMINATION OF NATURAL FREQUENCY OF COMPOSITE BEAM WITH CRACK

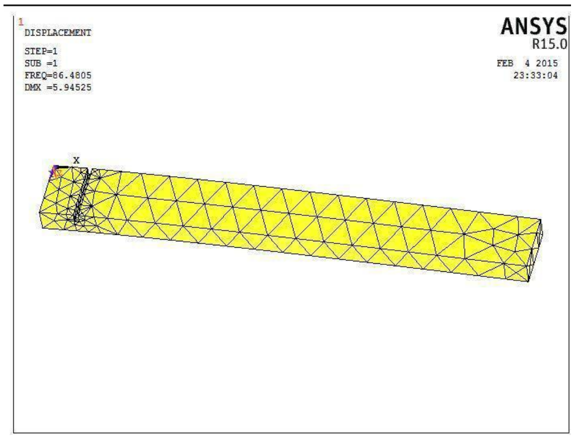
This study is an investigation of the effects of cracks on the dynamical characteristics of a cantilever composite beam, made of glass fibre-reinforced along with epoxy resin. The finite element and the component mode synthesis methods are used to model the problem. The cantilever composite beam was divided into several components from the crack sections. The effects of the location and depth of the cracks, and the volume fraction and orientation of the fibre on the natural frequencies and mode shapes of the beam with transverse non-propagating open cracks, are explored. The results of the study lead to conclusions that, presented method is adequate for the vibration analysis of cracked cantilever composite beams, and by using the drop in the natural frequencies and the change in the mode shapes, the presence and nature of cracks in a structure can be detected [2].

A crack of dimension 2mm x 27mm x 4mm was provided and two cases were analysed, one with the crack closer to the fixed end and the other away from the fixed end.

3.1 Crack Closer To Fixed End

3.1.1 ANSYS Results

The ANSYS results for the first, second and third modes are shown in Fig 4.



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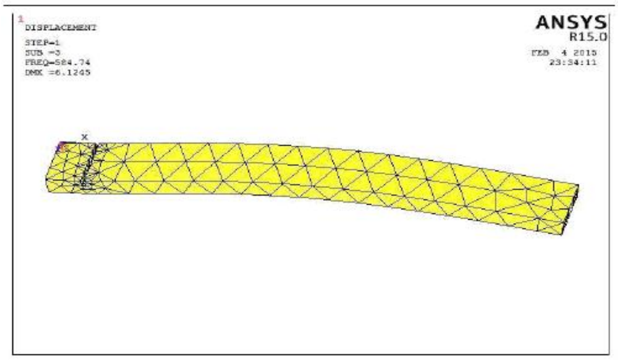

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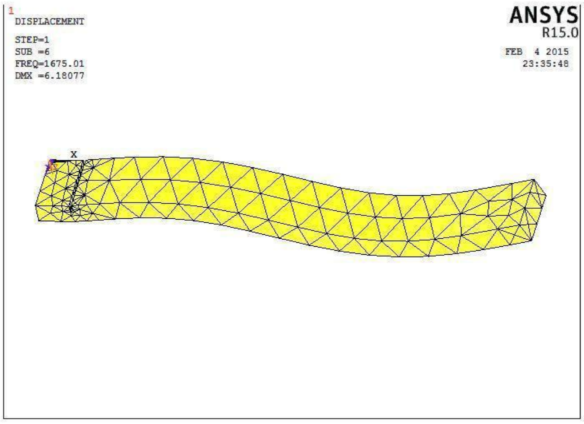

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Fig.4: (a) First mode, (b) second mode and (c) third mode of composite beam with crack closer to the fixed end

3.1.2: Natural frequency using Experimental Set-Up

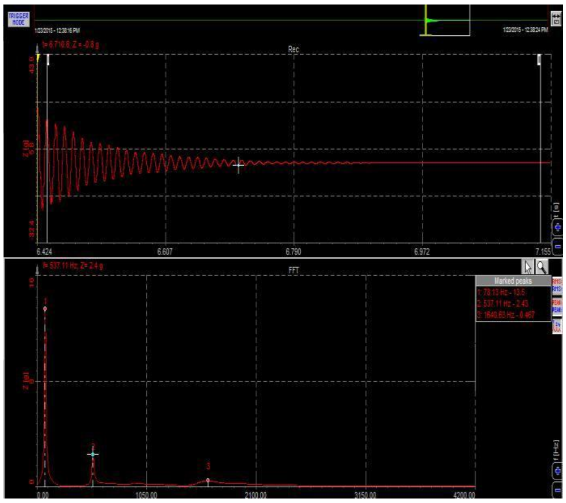


Fig.5: Results from experiment of composite beam with crack closer to the fixed end

The experimental result is shown in Fig.5.

Table 2: Comparison of experimental and ANSYS results of composite beam with crack closer to fixed end

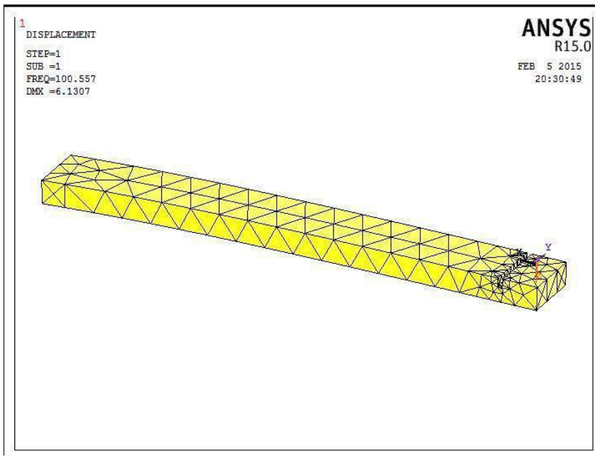
Composite Beam	First mode	Second mode	Third mode
Experimental	78.13Hz	537.11Hz	1649.63Hz
ANSYS	86.48Hz	584.7Hz	1675.01Hz

A comparison of the experimental and ANSYS is shown in Table 2. The results obtained by both the methods are almost similar.

3.2: Crack Away From the Fixed End

3.2.1 ANSYS Results

The ANSYS result is shown in Fig.6.



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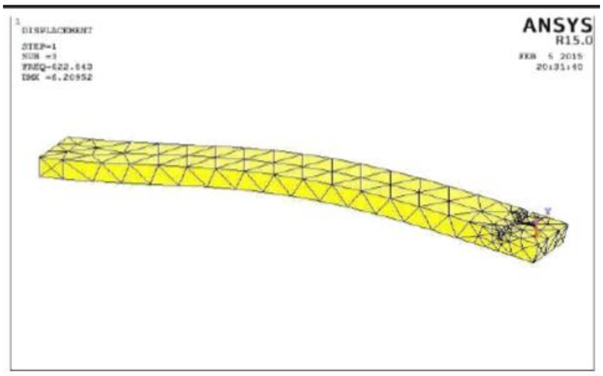

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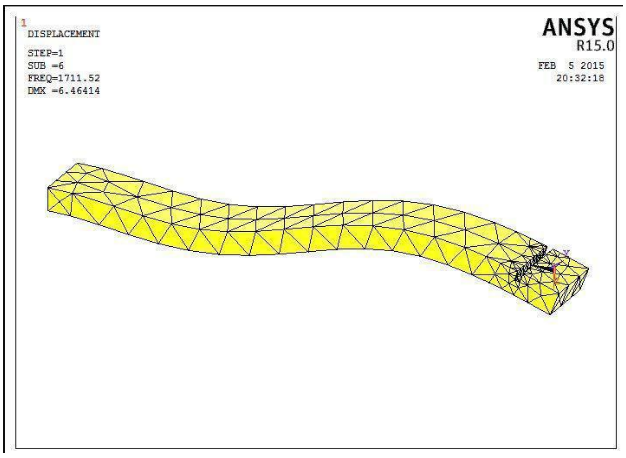

(c)

Fig. 6: (a) First Mode, (b) Second Mode and (c) Third Mode of composite beam with crack away from the fixed end.

3.2.2: Natural frequency using Experimental Setup

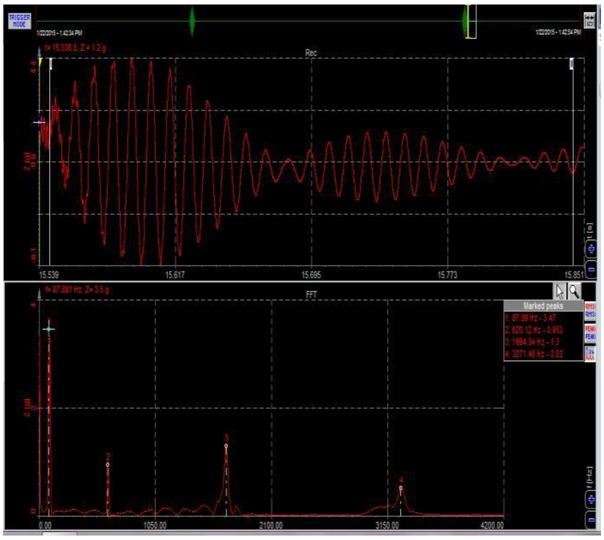

Fig.7 Results from experiment of composite beam with crack away from the fixed end

The experimental results obtained are shown in Fig.7.

Table 3:Comparison of experimental and ANSYS results of composite beam with crack away from fixed end.

Composite Beam	First mode	Second mode	Third mode
Experimental	87.89Hz	620.12Hz	1694.34Hz
ANSYS	100.55Hz	622.64 Hz	1711.52Hz

The comparison of the experimental and ANSYS results is shown in Table 3. The values obtained using both the methods are similar.

IV. RESULTS

While in operation, all structures are subjected to vibrations from different sources, whose effects may cause initiation of structural defects such as cracks which, as time progresses, could ultimately lead to the catastrophic failure or breakdown of the structure. This calls out for the timely inspection of the manufactured products in order to ensure standard quality. Over the past few decades several methods, such as non-destructive testing, have come into the array in order to meet this need which could be used to monitor the condition of a structure. It is clear that new reliable and inexpensive methods to monitor structural defects such as cracks should be explored. [9].

Vibration analysis, which can be used to detect structural defects such as cracks, of any structure offers an effective, inexpensive and fast means of non-destructive testing. What types of changes occur in the vibration characteristics, how these changes can be detected and how the condition of the structure is interpreted based on these data has been the topic of study in this paper. Bi-directional composite beam with epoxy resin as matrix along with glass fibres was manufactured. Compression molding was the method used for the fabrication. The mechanical properties of the composite were determined experimentally. Free vibration analysis of composite beam was done both experimentally and using ANSYS software. Initially the methodology was proven using an aluminium beam. Neglecting minor experimental errors, the values were found to be in good agreement.

A crack was then introduced in the beam with two conditions: crack near to the fixed end and crack away from the fixed end. Vibration analysis of the beam was done experimentally and using ANSYS software and the natural frequencies of the beam corresponding to the first three modes were determined. The frequencies corresponding to the beam without crack and the beam with crack away from the fixed end are almost similar which indicates that the presence of crack away from the point of consideration has got almost no effect on the dynamics of the structure.[2][9].

But there is a large variation in the frequency of the beam when the crack comes closer to the fixed end. The variation in the frequency increases as the crack comes closer to the fixed end. The change in natural frequency of the beam without crack to the beam with crack is greater when the crack is closer to the fixed end. By measuring the natural frequency and finding the variation, the position or location of the crack can be determined. It can also be said that if the change in natural frequency is greater, the structure would be in greater danger. If the variation is low, then the structure would be safe. This illustrates that the structure becomes weak due to the presence of crack closer to the fixed end. The frequency variation could be used to determine the position of the crack and with further analysis even its dimensions could be determined. The application of these results lies in predicting the failure of a

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structure which is subjected to internal defects by just measuring its frequencies.

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