Free Vibration Analysis of a Cracked Composite Beam

T.Sunil Kumar¹, K.Durga Rao², M.M.M.Sarcar³, B.S.K.S.Rao⁴

¹&²Vignan University, Vadlamudi, Guntur, Andhra pradesh – 522 213
³&⁴A.U. College of Engineering, Andhra University, Visakhapatnam, A. P.

A R T I C L E   I N F O

Article history:
Received 12 Nov 2012
Accepted 26 Dec 2012

Keywords:
Free vibration, timedomain, frequency domain, crack.

A B S T R A C T

The issue of crack detection and diagnosis has gained widespread industrial interest. Identification of crack depths and their location from reference point are the standard methods in performance monitoring of the composite beam. The present work introduces an attempt to study the variations in the Eigen-nature of cracked composite beam at different crack depths and locations. The composite beam with edge crack is considered in the paper. The presence of crack changes the physical characteristics of a structure which in turn alter its dynamic response characteristics. The frequency, amplitude and acceleration of cracked and uncracked beam response was determined experimentally. Analysis is carried out in both time and frequency domains, which is aimed to identify the dynamic response associated with the existence of crack.

Introduction

Surface cracks and edge crack are the frequently occurring phenomena in the structures of engineering applications. The effect of these cracks on the performance of the structure is more severe and complex when the structure is made of composite material. Identification of various parameters pertaining to cracks like depth, distance from reference point are part of the standard methods in performance monitoring of the structure [1]. Currently available non-destructive testing (NDT) methods, such as acoustic or ultrasonic methods, magnetic field methods, radiographs, eddy-current methods and thermal field methods are time consuming when compared to induced vibration techniques [2]. Many procedures are proposed in this line and developed for isotropic materials. But for composite materials very limited data is available in identification and analysis of cracks. The presence of crack in a structural member introduces a local flexibility that affects its vibration response [3]. In this case the system is non linear moreover the presence of crack introduces new harmonics in the spectrum. The papers [4-6] on this method were published in the recent years. Some information on analytical, numerical and experimental investigations now exits. Finite element analysis techniques [7-10], together with experimental results are used to detect damage. They locate and estimate damage events by comparing dynamic responses between damaged and undamaged structures. According to the dynamic response parameters analyzed, these methods can be subdivided into modal analysis, frequency domain, time domain and impedance domain. Model-dependent methods are able to provide global and local damage information [11]. They are cost-effective and are relatively easy to operate. However, there are still many challenges and obstacles before these methods can be implemented in practice.

Preparation of composite material

A manual fabrication process involves building up layers of chopped glass mat impregnated with catalyzed resin around a suitable mold. The reinforcement is then rolled for better wet-out and removing trapped air. The crack will be made by using a saw cut and the specimen will be mounted for cantilever configuration.

Material Properties and Dimensions

The test specimen is a laminated of composite beam dimensions 200 mm X 24.5 mm and thickness 8.5 mm. The total numbers of layers are 9 and Ply angles are 0/0/0/0/0/0/0/0/0/0. The material properties are as follows: Elastic modulus of fiber = 18.66 GPa, Elastic modulus of matrix = 3 GPa, Density of fiber = 1.7 gm/cm³, Density of matrix = 1.1 gm/cm³, Density of the composite material = 1.4 gm/cm³, Volume...
fraction fiber = 0.50%, Volume fraction matrix=0.50%, Poisson’s ratio of fiber = 0.2, Poisson’s ratio of matrix= 0.3

Experimental Setup

The experimental apparatus is shown in Fig.1 and 2. The specimen was mounted on clamping and excited by 5800b Dynapulse™ impact hammer, with a force transducer built into the tip to register the force input. The vibrations are induced by impulse force hammer will be used to induce impact loads. The beam response is being sensed by SAA-1150-1000 Single axis piezoelectric accelerometer and the captured signal will be processed by an FFT analyzer. A personal computer outfitted with NI 9234 integrated hardware and software (smart office) functions as data acquisition system and multi channel fast Fourier transform signal analyzer. The analog signals from each piezoelectric sensor will be converted from time domain to frequency domain by fast Fourier transform. Different frequency spectra will be obtained from different successive mechanical impulses and will be electronically averaged to form a single spectrum, so that the random variation inherent to the method could be evaluated. The variation in the output signal parameters will be analyzed for different crack locations and depths.

Result and discussion

The time domain and Frequency response function of laminated composite beams have been measured and analyzed for different crack locations and depths. The three crack location and different crack depths for a single edge of the specimen are considered. The experiment is carried crack location at 50mm, 100mm, 150mm from fixed end position, and different crack depths. The data acquisition time is 0.4 sec and band width is 1000 Hz. The experimental natural frequencies are measurements against the different states of crack.

Time Domain

The time domain shows time Vs magnitude (acceleration) graphs. The input force is in the range of 0.2N to 0.3N for all cases. Appreciable variation in sinusoidal wave decay is observed for uncracked and state of crack as shown in Figs from 3 to 12.
**Frequency response function (FRF)**

Frequency response is the quantitative measure of the output spectrum of a system or device in response to a stimulus, and is used to characterize the dynamics of the system. The frequency response shows frequency Vs magnitude graphs as shown in Figs from 14 to 22.
The highest natural frequencies in above graphs are tabulated in table 1.
Table 1: Natural frequency for state of crack

<table>
<thead>
<tr>
<th>Crack location (mm) from fixed end</th>
<th>Crack depth (mm)</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2</td>
<td>465</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>464</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>463</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>450</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>449</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>449</td>
</tr>
<tr>
<td>150</td>
<td>2</td>
<td>448</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>447</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>446</td>
</tr>
</tbody>
</table>

From the Fig. 13, it is observed the natural frequency of uncracked is 450Hz. The various states of cracks in beam changes its Eigen nature of beam as shown in Table 1. The trend follow of results satisfies the literature.

**Conclusion**

In the present work, an investigation into the Eigen-nature of a cracked composite beam is investigated experimentally. The natural frequency for transverse vibration of cracked and uncracked beams are compared. The results obtained from the experiments are presented in graphical form. From the experiments presented in this paper, the following conclusions are obtained.

1. Results show that there is an appreciable variation between natural frequency of uncracked and state of crake in cantilever composite beam.
2. The crack depth increase the natural frequency is decreases.
3. The crack location is increases from fixed end, the natural frequencies are decreased.

The present study provides an efficient nondestructive technique for the detection and prediction of the current state of the crack for any composite structure system.

**References**
