Crack Analysis of Composite Beam Using Vibration Analysis Method

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Abstract— This study is an examination of the impacts of crack on the dynamical properties of a cantilever composite bar, made of graphite fiber fortified polyamide. The analysis is done using finite element and the component mode synthesis techniques are utilized to prototype the model. The cantilever composite bar is divided into a few segments from the crack areas. Stiffness diminishes because of cracks as derived from the crack mechanics hypothesis as the inverse of the compliance matrix determined with the legitimate stress intensity factors and strain energy discharge rate expressions. The impacts of the area and depth of the cracks, and the volume fraction and direction of the fiber on the natural frequencies and mode states of the bar with transverse non-spreading open cracks, are investigated. The conclusions of the examination are that the current strategy is sufficient for the vibration investigation of cracked cantilever composite bars, and by utilizing the drop in the natural frequencies and the change in the mode shapes, the presence and nature of cracks in a design can be distinguished.

Keywords: Stiffness, Crack, Mode Shapes, Fiber Orientation, Crack Depth, Graphite Fiber Polyamide

I. Introduction

Recently, fiber fortified composite materials are very commonly in various engineering fields. The automobile, aviation, marine and common civil industries make use of composite materials in various applications. Composite materials are gaining popularity because of high strength, low weight, safeguarding from erosion, impact resistance and better fatigue strength. There are many other benefits like ease of fabrication, design flexibility, and variable material properties to meet practically any application.

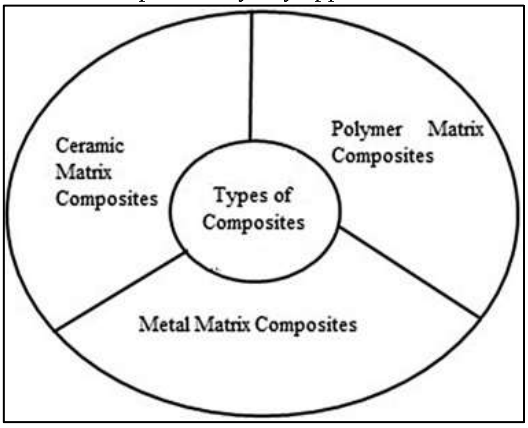


Fig. 1.1: Types of Composites.

Any continuous structure has infinite (DOF) degree of freedom and therefore, an infinite number of natural frequencies and the corresponding modular shapes. Now suppose if vibration frequency of a structure becomes equal to its natural frequency, the vibration amplitude increases quickly with time, requiring an extremely low input energy. Because of which, the structure will either fail due to overstressing or the nonlinear impacts limit the amplitude to a huge value, causing high-cycle fatigue failure. So, for any structure, its natural frequencies should be calculated to make sure that the loading frequencies occurring on the structure differ with the natural frequencies to overcome resonances.

Therefore, using vibrational analysis crack analysis of a composite beam with crack is performed in case of cantilever beam composed of graphite polyamide fortified composite bar. In last thirty years, extensive research has been done in vibration-based damage detection; and therefore critical advancement has been accomplished in this featured region. Therefore, the fundamental target of this study is to contribute for a better apprehension of the dynamic conduct of components created using fiber fortified composite materials, specifically for beams. To examine the impact of the angle of fiber on the dynamic conduct of the members, numerical investigation utilizing the Finite Element Method has been done.

II. Objectives

1) Perform vibration examination of composite bar produced using carbon fiber supported epoxy with a lateral open crack that is V-notch utilizing the FEM (finite element method) programming ANSYS.
2) Compare results of current beam using a standard beam.
3) Performing vibrational analysis to compare results with previous studies.

III. Methodology

Modular investigation of ANSYS has been used for calculating the natural frequencies and mode shapes, which are important parameters for a construction work subjected to dynamic. These parameters are also required for spectrum investigation or for a mode superposition harmonic transient examination. Then the basic equation for a beam is defined as below:

A. Basic Equation:

The differential equation for a beam subjected to bending having a mid-plane symmetry such that there is no bending and no lateral shear deformation ($\varepsilon xz=0$) is given by;

$$IS_{11}\,(d^4\,\omega\,/\,d\,\omega^4) = q\ (x)$$

The above equation is modified according to the need of problem. Generally, basic equation for free vibration of the bar can be expressed as:

$$[K]-\omega^2[M]\{q\} = 0$$

Where,
K = Stiffness matrix
M = mass matrix
q = DOF (degree of freedom).

B. Model:

The model considered for our study is a cantilever composite bar having uniform cross-section A, having an open lateral crack of depth 'a' at position L_1. The width, length and height of the bar are represented by B, L and H. The angle between the strands (fiber of beam) and its axis is α.

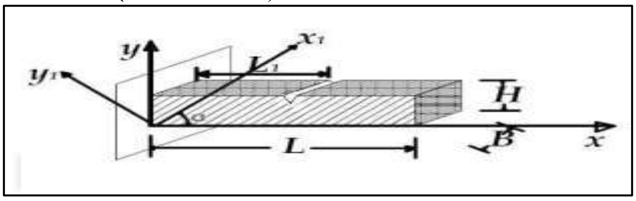


Fig. 3.1 Beam Model

C. Modeling method in ANSYS:

For any type of structural problem considered, an ANSYS investigation procedure have the following three steps given below:

1) Pre-processing stage.
2) Solution stage.
3) Post processing stage.

This could be better understood by Flowchart below:

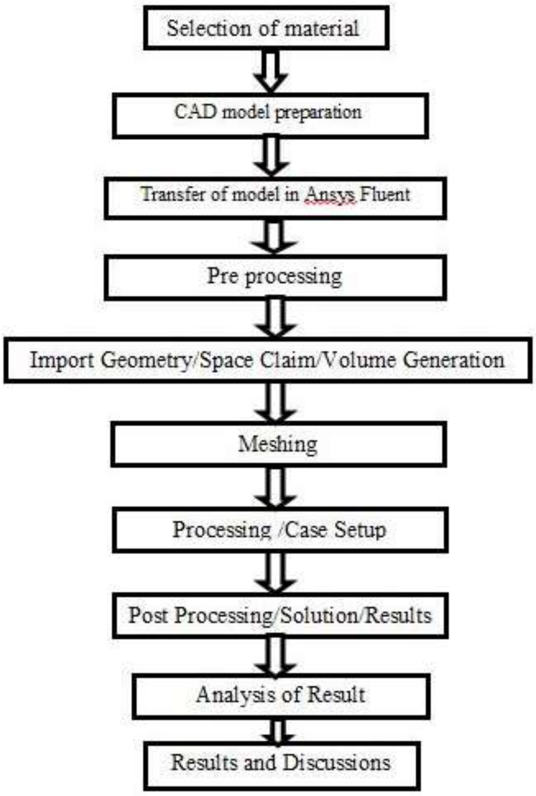
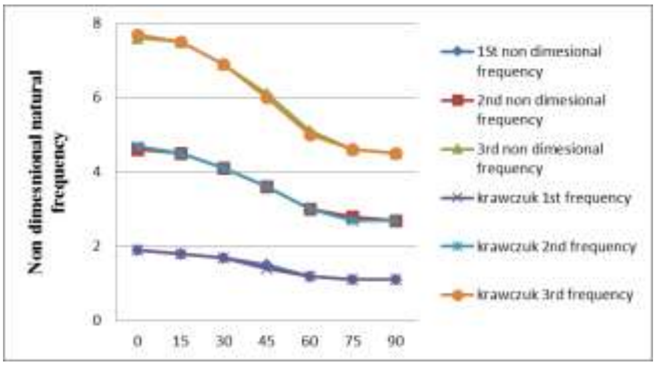


Fig. 3.2: Flowchart diagram.

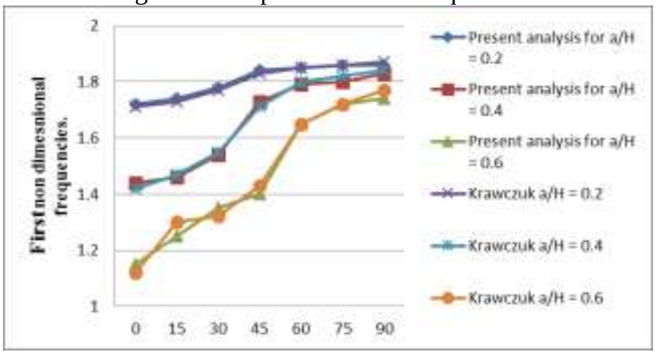
IV. RESULT

The discussed strategy has been applied for the free vibration investigation of an intact and crack composite cantilever bar. Free vibration examination of a cantilever crack composite bar has been inspected by Krawczuk and Ostachowicz (1995) utilizing finite element method (FEM). In this investigation the outcomes got with present component are contrasted with the results of Krawczuk and Ostachowicz. The results obtained are compared with the help of graph shown below:



Angle of fiber

Fig. 4.1: Comparison of the frequencies.



Angle of fiber.

Fig. 4.2: Comparison of the first non-dimensional frequencies.

On a similar basis numerical results can also be calculated.

V. CONCLUSIONS

The following conclusions can be drawn from the current examinations of the composite bar using finite component method having lateral open crack i.e. v-notch.

– The values of in plane bending frequencies decrease as the inclination of fiber (fiber angle) increases, having the largest value at α = 0°and decrease progressively with expanding the fiber inclination up to a least value observed for α =90°.
– For case of composite bar with crack, as the value of fiber angle (α) increases, the value of natural frequencies will also increase. Highest difference in frequency is obtained when fiber angle is zero.
– Decrease in the characteristic (natural) frequencies become more concentrated with the development of the crack depth.
– The expansion of bar length brings about a decrement in the natural frequencies of the composite bar.

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