Vibration and Buckling Analysis of Cracked Composite Beam

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Abstract: **Cracks in structural members lead to local changes in their stiffness and consequently their static and dynamic behavior is altered. The influence of cracks on dynamic characteristics like natural frequencies, modes of vibration of structures has been the subject of many investigations. However studies related to behavior of composite cracked structures subject to in-plane loads are scarce in literature. Present work deals with the vibration and buckling analysis of a cantilever beam made from graphite fiber reinforced polyimide with a transverse one-edge non-propagating open crack using the finite element method. The undamaged parts of the beam are modeled by beam finite elements with three nodes and three degrees of freedom at the node. An "overall additional flexibility matrix" is added to the flexibility matrix of the corresponding non-cracked composite beam element to obtain the total flexibility matrix, and therefore the stiffness matrix in line with previous studies. The vibration of cracked composite beam is computed using the present formulation and is compared with the previous results. The effects of various parameters like crack location, crack depth, volume fraction of fibers and fibers orientations upon the changes of the natural frequencies of the beam are studied. It is found that, presence of crack in a beam decreases the natural frequency which is more pronounced when the crack is near the fixed support and the crack depth is more. The natural frequency of the cracked beam is found to be maximum at about 45% of volume fraction of fibers and the frequency for any depth of crack increases with the increase of angle of fibers. The static buckling load of a cracked composite beam is found to be decreasing with the presence of a crack and the decrease is more severe with increase in crack depth for any location of the crack. Furthermore, the buckling load of the beam decreased with increase in angle of the fibers and is maximum at 0 degree orientation.**

I INTRODUCTION

In the recent decades, fiber reinforced composite materials are being used more frequently in many different engineering fields. The automobile, aerospace, naval, and civil industries all use composite materials in some way. Composite materials are gaining popularity because of high strength, low weight, resistance to corrosion, impact resistance, and high fatigue strength. Other advantages include ease of fabrication, flexibility in design, and variable material properties to meet almost any application. In general, any continuous structure has infinite degrees of freedom and, consequently, an infinite number of natural frequencies and the corresponding modal shapes. If a structure vibrates with a frequency equal to a natural one, the vibration amplitude grows rapidly with time, requiring a very low input energy. As a result, the structure either fails by overstressing, or the nonlinear effects limit the amplitude to a large value, leading to high-cycle fatigue damage. Thus, for any structure, its natural frequencies must be determined in order to ensure that the loading frequencies imposed and the natural frequencies differ considerably; in other words, to avoid resonances.

To avoid structural damages caused by undesirable vibrations, it is important to determine:

1 - Natural frequencies of the structure to avoid resonance;
2 - Mode shapes to reinforce the most flexible points or to determine the right positions to reduce weight or to increase damping;
3 - Damping factors.

Structural damage detection has gained increasing attention from the scientific community since unpredicted major hazards, most with human losses, have been reported. Aircraft crashes and the catastrophic bridge failures are some examples. Development of an early damage detection method for structural failure is one of the most important keys in maintaining the integrity and safety of structures. The cracks can be present in structures due to their limited fatigue strengths or due to the manufacturing processes. These cracks open for a part of the cycle and close when the vibration reverses its direction. These cracks will grow over time, as the load reversals continue, and may reach a point where they pose a threat to the integrity of the structure. As a result, all such structures must be carefully maintained and more generally, SHM denotes a reliable system with the ability to detect and interpret adverse "change" in a structure due to damage or normal operation. The greatest challenge in designing a SHM system is to identify the underline changes due to damage or defect. Lots of damage detection techniques have been proposed for structural health monitoring. Some of the nondestructive evaluation approaches that utilize technologies such as X-ray imaging, ultrasonic scans, infrared thermograph, and eddy current can identify damages. However, they are somehow difficult to implement, and some of them are impractical in many cases such as in service aircraft testing and in-site space structures. Almost all of the above techniques require that the vicinity of the damage is known in advance and the portion of the structure being inspected is readily accessible. The drawbacks of current inspection techniques have led engineers to investigate new methods for continuous monitoring and global condition assessment of structures. That is the case for methods based on vibration responses that allow one to obtain meaningful time and/or frequency domain data and calculate changes in the structural and modal properties, such as resonance frequencies, modal damping and mode shapes, and use them with the objective of developing reliable techniques to detect, locate and quantify damage. Hence, the vibration-based damage identification method as a global damage identification technique is developed to overcome these difficulties. Among many SHM techniques, the dynamic response-based damage detection method attracts most attention due to its simplicity for implementation. This technique makes use of the dynamic response of structures which offers unique information on the defects contained with these structures. Changes in the physical properties of the structures due to damage can alter the dynamic response, such as the natural frequency and mode shape. These parameter changes can be extracted to predict damage detection information, such as the presence, location, and severity of damage in a structure. The natural frequency provides the simplest damage detection method since damage tends to reduce the stiffness of the structure. Therefore, a reduction of natural frequency may indicate the existence of damage in the structure. However, the natural frequency is a global feature of the structure, from which the location of the damage is difficult to determine. The modal parameters (e.g., the mode shape and flexibility), which can capture the local perturbation due to damage are used in order to locate damage. The dynamic response of structures can offer unique information on defects that may be contained within the structures. Changes in the physical properties of the structures due to damage will alter the dynamic responses such as natural frequencies, damping and mode shapes. These physical parameter changes can be extracted to estimate damage information. In the past 20 years a lot of work has been published in the area of damage detection, where various methods have been proposed. The modal parameters such as natural frequencies and mode shapes can be used to detect the initiation and development of cracks. The fundamental idea for vibration-based damage identification is that the damage-induced changes in the physical properties (mass, damping, and stiffness) will cause detectable changes in modal properties (natural frequencies, modal damping, and mode shapes).

II MODELING ANALYSIS

ANSYS is commercial finite element software with capability to analyze a wide range of different problems. Like any finite element software, ANSYS solves governing differential equations by breaking the problem into small elements. The FEA software ANSYS includes time-tested, industrial leading applications for structural, thermal, mechanical, computational fluid dynamics and electromagnetic analysis. ANSYS software solves for the combined effects of multiple forces, accurately modeling combined behaviors resulting from “metaphysics interaction”. The ANSYS batch language has many features of the FORTRAN programming language. If statements and do loops can all be included in ANSYS batch files. In addition ANSYS has several built-in functions for further manipulation of ANSYS results or geometry parameters. There two primary ways to use ANSYS interactively through the graphical user interface and through the use of batch files and ANSYS commands. In this project, we have used the GUI. It is easiest to learn ANSYS interactively, especially when compared to the daunting task of learning all of the relevant ANSYS commands. Interactive ANSYS has disadvantages such as it requires the user to save the model geometry, mesh, and results in a *.db file, which can get as large as 50MB or more and the second one is Interactive use is slow if you need to repeat operations. Meanwhile, the advantages of batch processing include an entire model, mesh, and solution description can be contained in a file of 10-100K. Sub Batch processing is highly modular. If you spend time creating batch files, changing dimensions and mesh densities is a snap. The finite element simulation was done by finite element analysis package ANSYS 13. This is used to perform the modeling of the composite beam and calculation of natural frequencies 18 with relevant mode shape.

III MODELING PROCEDURE IN ANSYS 13

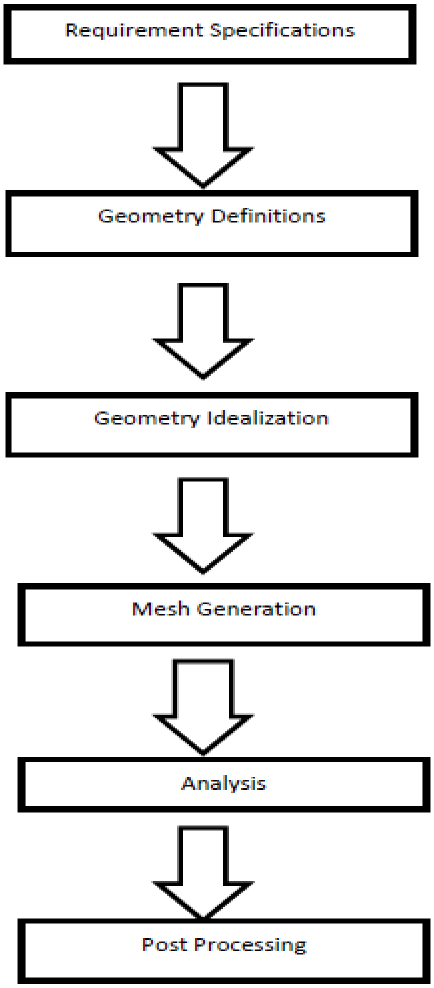
Regardless of the type of problem involved, an ANSYS analysis consists of the same steps as follows:

1. Preprocessing
2. Solution stage
3. Post processing.

After selecting the type of analysis in the preferences, the next step in the preprocessing is to choose an element type. The element type includes a list of general categories such as Structural

Mass, Structural Link, Structural Solid, Beam, Solid Sell etc. A number of different specific elements will appear for each general category. Each element has its own set of DOFs, which are the degrees of freedom for which ANSYS will find a solution. Next material properties, real constants, section etc. need to input. The modeling phase entails geometry definition. This is where you draw a 2D or 3D representation of the problem. ANSYS has a very powerful modeler built into the preprocessor. The modeler allows the user to construct surfaces and solids to model a variety of geometries. For any given geometry, there are often several different ways to create the model. Before the meshing phase you will define material properties and choose a finite element suitable for the problem. In the meshing phase the model discredited i.e. creating the mesh. In the solution phase, boundary conditions and loads need to be defined. The types of loads and boundary conditions you select depend on the simplifications being made. ANSYS will then attempt to solve the system of equations defined by the mesh and boundary conditions.

Finally, when the solution is complete, you will need to review the results using the post processor. The ANSYS post processor provides a powerful tool for viewing results .These results may be color contour plots, line plots, or simply a list of DOF results for each node.



IV CONCLUSION

The following conclusions can be drawn from the present investigations of the composite beam finite element having transverse open crack i.e. v-notch. This element is versatile and can be used for static and dynamic analysis of a composite beam.

1.The in-plane bending frequencies decrease, in general, as the fiber angle increases; the maximum occur at α = 0°and decrease gradually with increasing the fiber angle up to a minimum value obtained for α =90°.

2.In case of composite beam with crack, as the angle of fibers (α) increases the value of the natural frequencies also increases. The most difference in frequency occurs when angle of fibers is zero degree.

3.The non-dimensional natural frequencies is also depends upon the volume fraction of the fibers. The flexibility due to crack is high when the volume fraction of the fiber is between 0.2 and 0.8 and maximum when the fiber fractions is nearly 0.45

4.Decrease in the natural frequencies become more intensive with the growth of the depth of crack.

5.The increase of the beam length results in a decrease in the natural frequencies of the composite beam

6.Boundary conditions have a remarkable influence on the natural frequencies. The natural frequencies for the clamped-clamped support are higher compared to clamped free support condition.

7.The first natural frequency is maximum at crack locations L1/L = 0.1 and L1/L = 0.9 and minimum at L1/L = 0.5. While the second natural frequency is minimum at crack locations L1/L = 0.3 and L1/L = 0.7.

8.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 rear of the fixed end, the middle of the beam and the free end, respectively.

4.1 Scope for future work

1. The vibration results obtained using ANSYS 13 can be verified by conducting experiments.
2. The dynamic stability of the composite beam with cracks
3. Static and dynamic stability of reinforced concrete beam with cracks.
4. The Vibration analysis of composite beam by introducing inclined cracks in place of transverse crack.

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