ORIGINAL RESEARCH PAPER

Engineering

A STUDY ON VIBRATION AND BUCKLING ANALYSIS OF CRACKED COMPOSITE BEAM

KEY WORDS: stiffness, dusttrap , buckling force, fibers, cracks, statics and dynamics.

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ABSTRACT

Cracks in structural members lead to local changes in their stiffness and dusttrap their static and dynamic nature is altered. The influence of cracks on dynamic characteristics value of material like common frequencies, modes of vibration of structures has been the subject of many investigations. However studies related to nature of composite cracked structures subject to in-plane forces 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 damage using the finite element method. The uncracked parts of the beam are modeled by beam finite elements with three nodes and three degrees of freedom at the structure work. An „overall additional flexibility matrix is added to the flexibility matrix of the corresponding non-damage 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 many 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 greater than at about 45% of volume fraction of fibres and the frequency for any depth of crack increases with the increase of angle of filament. The static buckling load of a cracked complex beam is found to be decreasing with the presence of a damage and the decrease is more severe with increase in crack depth for any location of the crack. Furthermore, the buckling force of the beam decreased with increase in angle of the fibres and is highest at 0 degree orientation.

INTRODUCTION

Composites as structural material are being used in aerospace, engineering and civilian applications because of their tailor made properties. The ability of these materials to be designed to suit the specific needs for different structures makes them highly desirable. Improvement in design, materials and production technology enhance the application of composite structures. The suitability of a particular combind material depends on the behavior of applications and needs. The technology has been survey extensively for aerospace and civil engineering applications, which require high strength and stiffness to weight ratio materials Preventing failure of composite material systems has been an important issue in engineering design. Composites are prone to damages like transverse cracking, fiber breakage, delamination, matrix cracking and fiber-matrix depending when subjected to service conditions. The two types of physical failures that occur in composite structures and interact in complex manner are interalaminar and interlaminar failures. Interalaminar failure is manifest in micro-mechanical components of the lamina such as fiber breakage, matrix cracking, and debonding of the fiber-matrix interface. Generally, aircraft structures made of fiber reinforces composite materials are designed such that the fibers carry the bulk of the applied load. Interlaminar failure such as delamination refers to debonding of adjacent lamina. The possibility that interalaminar and interlaminar failure occur in structural components is analyze a design limit, and establishes restrictions on the usage of full potential of composites.

Similar to isotropic materials, composite materials are subjected to various types of damage, mostly cracks and delamination. The crack in a composite structure may reduce the structural stiffness and strength, redistribute the load in a way that the structural failure is delayed, or may lead to structural collapse. Therefore, crack is not necessarily the ultimate structural failure, but rather it is the part of the failure process which may ultimately lead to loss of structural integrity. As one of the failure modes for the fiber-reinforced composites, crack initiation and propagation have long been an important topic in composite and fracture mechanics communities. 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. It is clear that new reliable and inexpensive methods to monitor structural defects such as cracks should be explored. These variations, in turn, affect the static and dynamic behavior of the whole structure considerably. In some cases this can lead to failure, unless cracks are detected early enough. To ensure the safe, reliable and operational life of structures, it is of high importance to know if their members are free of cracks and, should they be present, to assess their extent. The procedures that are often used for detection are called direct procedures such as ultrasonic, X-rays, etc. However, these methods have proven to be inoperative and unsuitable in some particular cases, since they require expensive and minutely detailed inspections. To avoid these disadvantages, researchers have focused on more efficient procedures in crack detection based on the changes of modal parameters likes natural frequencies, mode shapes and modal damping values that the crack introduces.

SCOPE OF THE PRESENT INVESTIGATION

The main goal of this thesis is to work out a complex beam finite element with a non-propagating one-edge open damage. It has been assumed that the crack changes only the stiffness of the element whereas the mass of the structure of the element is unchanged. then theoretical modeling of cracked composite beam dimensions, crack locations, crack depth and material properties is specified. In this work an "overall somision of flexibility matrix", instead of the "local additional flexibility matrix" is added to the flexibility matrix of the corresponding non-cracked composite beam element to achieve the total flexibility matrix, and therefore the stiffness matrix in the line with the other researchers. By using the present model the following effects due to the crack of the cantilever composite beam have been analyzed.

(1) Then authority of the volume fraction of the fibers,absolute magnitude,intensity, location of the crack, angle of fibers upon the bending natural frequencies of the cantilever cracked composite beam.

(2) The effects of above parameters on buckling analysis of cracked composite beam.

The present results are compared with previous studies and the recent results are achieve in the MATLAB environment.

RESULTS AND DISCUSSIONS:

Effect of an open edge transverse crack on various parameters of a composite beam like vibration and buckling are studied and compared with previously studied results. The formulation is then validated and extended for other problems.

COMPARISON WITH PREVIOUS STUDIES

Quantitative results on the effects of various parameters on the vibration and buckling analysis of cracked composite are presented

VIBRATION ANALYSIS STUDIES

The presented method has been applied for the free vibration analysis of a non-cracked and cracked composite cantilever beam. Free vibration analysis of a cantilever cracked composite beam has been examined by Krawczuk & Ostachowicz (1995) using finite element method (FEM). In this study the results obtained with present element are compared with the results of Krawczuk & Ostachowicz. Throughout this investigation, 12 elements are used in modeling the cracked composite beam. In addition, the three lowest eigen-frequencies for various values of the angle of the fiber ( ) and the volume fraction of fibers (V) are determined and given in Table-4.3 and Fig. 4.3, 4.4. In Figure.4.5 and 4.6 the changes of the two first natural frequencies of the beam due to the crack as functions of the angle of fibers ( ) are compared with the results of Krawczuk & Ostachowicz(1995). As seen from the tables agreements are good

Table-4.3: Comparison Of First Three Non-dimensional Natural Frequencies Of The Non-cracked Composite Beam As A Function Of The Angle Of Fibers , Where Value Of V=0.10 And 0.30

Angle of Fibers (degrees)	Volume of Fraction V	Present Analysis			Krawczuk & Ostachowicz (1995)		
		1st Non-dimensional Nat. freq	2nd Non-dimensional Nat. freq	3rd Non-dimensional Nat. freq	1st Non-dimensional Nat. freq	2nd Non-dimensional Nat. freq	3rd Non-dimensional Nat. freq
0	0.10	1.8798	4.6566	7.6681	1.85145	4.52827	7.71888
15		1.8243	4.5300	7.4841	1.81768	4.51477	7.51418
30		1.6655	4.1530	6.9033	1.65453	4.12945	6.89687
45		1.4342	3.5854	5.9833	1.38995	3.53323	5.97735
60		1.2083	3.0230	5.0513	1.15370	3.01580	5.01780
75		1.0998	2.7514	4.5973	1.08133	2.74520	4.57040
90		1.0881	2.7205	4.5410	1.08007	2.71020	4.51710
0	0.30	1.8771	4.6113	7.5073	1.85145	4.52827	7.64894
15		1.8188	4.4873	7.3447	1.81768	4.44477	7.37372
30		1.6484	4.0982	6.7804	1.65453	4.02945	6.92680
45		1.3886	3.4682	5.7818	1.38995	3.43323	5.85710
60		1.1068	2.7684	4.6260	1.15370	2.71580	4.76640
75		0.948	2.3713	3.9632	1.08133	2.27052	4.04030
90		0.9307	2.3263	3.8831	1.08007	2.21720	3.97620

Quantitative results on the effects of various parameters on the vibration and buckling analysis of cracked composite are presented.

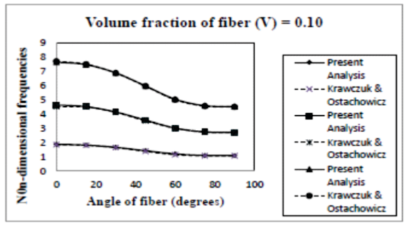

Figure.4.3 First three non-dimensional frequencies of the non-cracked composite beam as a function of the angle of fibers α. Values of V: 0.1

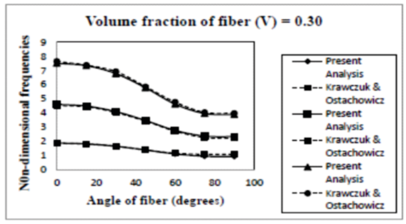

Figure.4.4 First three non-dimensional frequencies of the non-cracked composite beam as a function of the angle of fibers α. Values of V: 0.30

NUMERICAL RESULTS

After achieving the comparison with previous study and validating the formulation with the existing literatures, the results for non-dimensional natural frequencies of the non-damaged composite beam as a function of the angle of fibers (α) are presented. The changes of the two first behavior frequencies of the beam due to the damage as functions of the angle of fibers (α) than volume fraction of fiber are analyzed and buckling analysis is carried out for free vibration of a composite beam with single crack for many crack parallel and damage depths. Similarly, the three first natural frequencies of the composite beam due to the crack as functions of the angle of fibers (α) and volume fraction of fiber are analyzed for free vibration of a composite beam with multiple cracks for many damage condition. The beam assumed to be make of the unidirectional graphite fiber-reinforced polyamide fibre. The geometrical characteristics and the material properties of the graphite fiber-reinforced polyamide composite beam are selected in the same of those used in Ozturk & Sabuncu (2005). The material properties of the graphite flare-reinforced polyamide composite are

CONCLUSIONS:

The following conclusions can be make from the present investigations of the composite beam finite element having transversion non-propagating one-edge open damage. This element is flexible and can be used for static and dynamic analysis of a composite or isotropic beam.

1) From the present investigations it can be concluded that the behavior frequencies of vibration of a cracked composite beam is not only the functions of the crack locations and crack depths but also the functions of the angle of fibers and the volume fraction of the fibers. The presence of a transverse damage reduces the natural frequencies of the combine beam.
2) The rate of decrease in the natural frequency of the cracked composite beam increases as the crack position approaches the fixed end.
3) The intensity of the reduction in the frequency increases with the increase in the crack depth ratio. This reduction in natural frequency along with the mode shapes of vibrations can be used to detect the crack location and its depth.
4) When, the angle of fibers (α) increase the values of the natural frequencies also increase. The most difference in frequency occurs when the angle of fiber (α) is 0 degree. This is due to the fact that the flexibility of the composite beam due to crack is a function of the angle between the crack and the reinforcing fibers.

5) The effect of cracks is more pronounced nearby the fixed end than at far free end. It is conclusiveness that the first, second and third natural frequencies are most concerned when the damage located at the near of the fixed end, the middle of the beam and the free end, respectively.
6) The decrease of the non-dimensional natural frequencies depends on the volume fraction of the fibers. The non-dimensional natural frequency is greater than when the volume fraction of fiber is approximately 45%. This is due to the fact that the flexibility of a composite beam due to crack is a function of the volume fraction of the fibers.
7) Buckling force of a cracked composite beam decrease with increase of crack depth for crack at any particular location due to reduction of stiffness.
8) When, angle of fibers increase the values of the buckling loads decrease. This is due to the fact that for 0 degree orientation of fibers, the buckling plane normal to the fibers is of maximum stiffness and for other
9) orientations stiffness is less hence with buckling load is less.

SCOPE OF FUTURE WORK

1. The vibration and stability results obtained using this formulation 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 damage.
4. The dynamic stability of beam by introductory slant cracks (inclined cracks) in place of transverse crack.

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