VIBRATION ANALYSIS OF COMPOSITE BEAM

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Abstract : Beams are the basic structural components. When they are made laminated composites their strength to weight ratio increases. They can be used for different application just by changing the stacking sequence in the laminate with the same weight and dimensions. So this requires a complete analysis of laminated composite beams. They are used in a variety of engineering applications such as airplane wings, helicopter blades, sports equipment's, medical instruments and turbine blades. An important element in the dynamic analysis of composite beams is the computation of their natural frequencies and mode shapes. It is important because composite beam structures often operate in complex environmental conditions and are frequently exposed to a variety of dynamic excitations. In this research work first order shear deformation theory is used for vibration analysis of composite beams. A dynamic analysis is carried out which involves finding of natural frequencies and mode shapes for different L/H ratios and different stacking sequences. Finally the non-dimensional natural frequencies of the beam are calculated by using MATLAB and ANSYS model of corresponding composite beam.

I. INTRODUCTION

Since many years ago, the combination of different materials has been used to achieve better performance requirements. As an example of that the Sumerians in 4000 B.C. used to add straw to the mud to increase the resistance of the bricks. Although the benefits brought by the composite materials are known for thousands of years, only a few years ago the right understanding of their behavior as well as the technology for designing composites started to be developed. The airplane F111 was one of the first models to incorporate composite technology. Also airplane Boeing 767 has 2 tons in composite materials. The possibility to combine high strength and stiffness with low weight has also got the attention of the automobile industry: the Ford Motor Company developed in 1979 a car with some components made from composite materials. The prototype was directly 570 kg lighter than the same version in steel, the transmission shaft had a huge reduction of 57% of its original weight. More recently, Chrysler developed a car completely based on composite materials, known as CCV (Composite Concept Vehicle). Besides these examples in the automobile and aeronautical industry, the applications of composite materials have been enlarged, including now areas as the sporting goods, civil and aerospace construction and in medical field. In order to have the right combination of material properties and in service performance, the static and dynamic behavior is one of the main points to be considered. Thus, the main objective of this work is to contribute for a better understanding of vibration analysis of components made from composite materials, specifically for the case of beams. In the present investigation I have used First Order Shear Deformation Theory (FSDT) and Higher Order Shear Deformation Theory (HSDT) to analyze the composite beams. In order to investigate the influence of the stacking sequence, l/h ratio and boundary conditions on natural frequencies and mode-shapes of the composite beam. A MATLAB program is written for both theories used in the investigation and also an ANSYS model is made of composite beam and results are compared with the past author works. Fig. 1 shows comparison of steel, aluminium and composite material (S-Glass) on the basis of weight, thermal expansion, stiffness and strength.

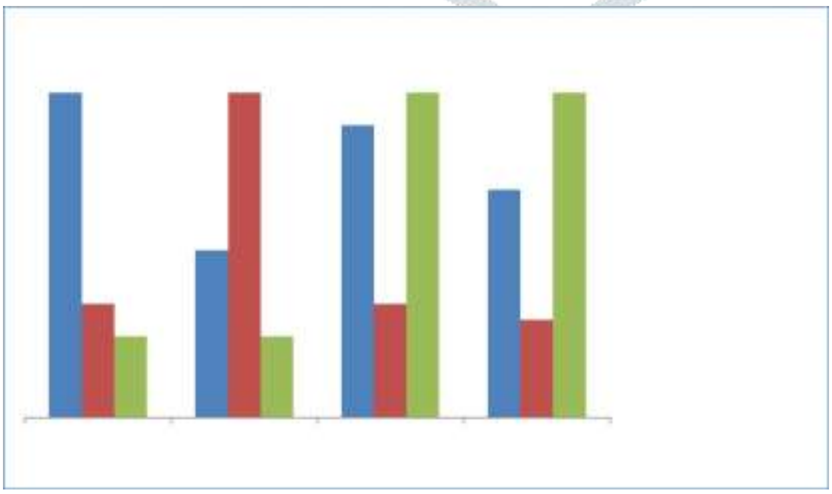

Fig. 1 Comparison of composite material properties with steel and aluminium.

II LITERATURE SURVEY

Composite substances are widely used in structures, specifically in plane and spacecraft, because of their excessive electricity-to-weight and stiffness-to weight ratios. Their behavior is designed consistent with their usage, so that their advantages are fully utilized. Laminated composite beams are normally analyzed through electricity strategies and classical laminate plate theory (CLPT). This literature gives vibration evaluation of laminated composite beams via first and higher order shear deformation theories.

Maiti & Sinha [1] used better order shear deformation theory for the analysis of composite beams. Nine noded isoparametric elements are used inside the evaluation. Natural frequencies of composite beam are in comparison for unique stacking sequences, distinct (l/h) ratios and distinct boundary situations. They had shown that herbal frequency decreases with an boom in ply angle and a lower in (l/h) ratio.

Jafari and Ahmadian [2] had achieved free vibration evaluation of a go-ply laminated composite beam on Pasternak Foundation. The version is designed in this type of way that it could be used for single-stepped move-phase. For the primary time to-date, the equal analysis turned into conducted for a single-stepped LCB on Pasternak basis. Stiffness and mass matrices of a cross-ply LCB on Pasternak basis the use of the electricity approach are computed. Raciti and Kapania [3] collected a document of developments in the vibration evaluation of laminated composite beams. Classical laminate plate idea and first order shear deformation principle are used for analysis. The assumption of displacements as linear capabilities of the coordinate within the thickness direction has proved to be inadequate for predicting the response of thick laminates.

Teboub and Hajela [4] permitted the symbolic computation technique to research the free vibration of normally layered composite beam on the basis of a first-order shear deformation theory. The model used thinking about the effect of poisson impact, coupled extensional, bending and torsional deformations in addition to rotary inertia.

Bassiouni [5] proposed a finite detail model to analyze the natural frequencies and mode shapes of the laminated composite beams. The FE version wanted all lamina had the identical lateral displacement at an ordinary cross-segment, but allowed each lamina to rotate to a different amount from the alternative. The transverse shear deformations have been covered.

Banerjee [6] has investigated the unfastened vibration of axially laminated composite Timoshenko beams the usage of dynamic stiffness matrix method. This is done with the aid of growing an actual dynamic stiffness matrix of a composite beam with the consequences of axial force, shear deformation and rotatory inertia taken into consideration. The outcomes of axial pressure, shear deformation and rotatory inertia on the natural frequencies are verified. The theory advanced has packages to composite wings and helicopter blades.

Yuan and Miller [7] derived a new finite element model for laminated composite beams. The model includes enough levels of freedom to allow the move-sections of each lamina to deform right into a form which includes up thru cubic phrases in thickness co-ordinate. The element consequently admits shear deformation up through quadratic terms for each lamina but not interfacial slip or delamination.

Krishnaswamy [8] have studied the free vibration of LCBs including the effects of transverse shear and rotary inertia. Dynamic equations governing the free vibration of laminated composite beams are developed using Hamilton's principle. Analytical solutions are obtained by the method of Lagrange multipliers. Natural frequencies and mode shapes of clamped-clamped and clamped-supported composite beams are presented to demonstrate the efficiency of the methodology.

Chandrashekhara [9] have presented exact solutions for the vibration of symmetrically LCBs by first order shear deformation theory. Rotary inertia has been included but Poisson effect has been neglected and demonstrated the effect of shear deformation, material anisotropy and boundary conditions on the natural frequencies.

Subramanian [10] has investigated free vibration analysis of LCBs by using two higher order displacement based shear deformation theories and finite element. Both theories assume a variation of in-plane and transverse displacements in the thickness coordinates of the beam respectively. Results indicate application of these theories and finite element model results in natural frequencies with higher accuracy.

A study of literature by Ghugal and Shimpi [11] indicates that the research work dealing with flexural analysis of thick beams using refined hyperbolic, trigonometric and exponential shear deformation theories is very scant and is still in early stage of development.

Pagano NJ [12] investigated the limitation of CLPT by comparing solutions of several specific boundary value problems in this theory to the corresponding theory of elasticity solutions. The general class of problems treated involves the geometric configuration of any number of isotropic or orthotropic layers bonded together and subjected to cylindrical bending. In general it is found that conventional plate theory leads to a very poor description of laminate response at low span-to-depth ratios, but converges to the exact solution as this ratio increases. The analysis presented is also valid in the study of sandwich plates under cylindrical bending.

Yildiz and Sarikanat [13] developed a finite-element analysis program to analyze multi-layer composite beams and plates. The arithmetic average and weighted average method were developed. By considering different loading conditions, one of the averaging methods was used. The effects of both averaging methods on the results were investigated. On comparing the obtained results with the analytical solutions, here we can see that both methods are giving matching results for certain types of loading.

Oral [14] developed a shear flexible finite element for non-uniform laminated composite beams. He tested the performance of the element with isotropic and composite materials, constant and variable cross-sections, and straight and curved geometries.

A method proposed by Hurty [15] enabled the problem to be broken up into separate elements and thus considerably reduced its complexity. His method consisted of considering the structure in terms of substructures and was called as sub structuring. Essentially, the method required the derivation of the dynamic equations for each component and these equations were then connected mathematically by matrices which represent the physical displacements of interface connection points on each component. In this way, one large Eigen value problem is replaced by several smaller ones. There are applications where alternative justifications are valid, for example where the results of independent analysis of individual structural modules are to be used to predict the dynamics of an assembled structure.

Ergatoudis and Zienkiewicz [16] describes the theory of a new family of Isoparametric elements for use in two-dimensional situations. The possibilities of improvement of approximation are thus confined to devising alternative element configurations and developing new shape functions. An obvious improvement is the addition of a number of nodal points along the sides of such elements thus permitting a smaller number of variables to be used for solution of practical problems with a given degree of accuracy. Examples illustrating the accuracy improvement are included.

Bhimaraddi and Chandrashekhara [17] had done modeling of laminated beams considering a systematic reduction of the constitutive relations of the three-dimensional anisotropic body. The basic equations of the beam theory here are those of the parabolic shear deformation theory. Numerical results for natural frequencies and the Euler buckling load have been presented using the modeling of the constitutive relations and those of the conventional type modeling. It has been observed from the numerical results that the two approaches differ little in the case of cross-ply laminates but there exists a considerable difference (by a multiple factor of 3 in some cases) in the case of angle-ply laminates.

Spadea and Zinno [18] analysis shows that the finite element approach requires more computer equipment and engineer expertise but enables a more general and consistent analysis. Nevertheless, if a more realistic assessment of the behavior of this kind of structure is carried out, the cost is reduced and a higher safety factor usually gained.

Banerjee and Williams [19] used the express stiffness expressions, rather than the numerical computation of the dynamic stiffness matrix via inversion, is illustrated by way of comparing elapsed CPU instances. The software of the derived dynamic stiffness matrix to calculate the herbal frequencies and mode shapes of bending-torsion coupled composite beams uses the Wittrick-Williams algorithm.

Yong-Bae and Ronald [20] mentioned a polished beam theory primarily based on sub laminate linear zig - zag kinematics and a brand new two-dimensional finite element based totally theory is advanced. The new CO element consists of four nodes of which every has simplest 3 engineering stages of freedom - translations and one rotation. The element is proven to be correct, easy to apply and well matched with the necessities of business finite-element codes.

Akavci, Yerli and Dogan [21] used classical concept of plates (CPT), it is assumed that aircraft sections to begin with normal to the mid surface earlier than deformation continue to be plane and ordinary to that surface after deformation. As a end result of neglecting transverse shear strains. However, there are non-negligible shear deformations occurring in thick and reasonably thick plates. This principle gives erroneous effects for laminated plates. So the transverse shear deformations ought to be taken into consideration inside the evaluation of composite structures.

Sayyad [22] as compared refined beam theories for the free vibration evaluation of thick beams with the aid of contemplating transverse shear deformation effect. This theory entails exponential, sinusoidal, parabolic and hyperbolic features in phrases of thickness coordinates to include transverse shear deformation impact. In this theory the numbers of unknowns are same as that of FSDT.

III FINITE ELEMENT MODEL FOR FSDT

Reissner and Mindlin [29, 32] is a well-known theory for the analysis of composite structures. This theory is also known as first order shear deformation theory (FSDT) and takes the displacement field as linear variations of mid plane displacements. Here the relation between the resultant shear forces and the shear strains is affected by the shear correction factors. This theory has some advantages as its simplicity and low computational cost. The geometry of a laminated composite beam is shown in fig. 2.

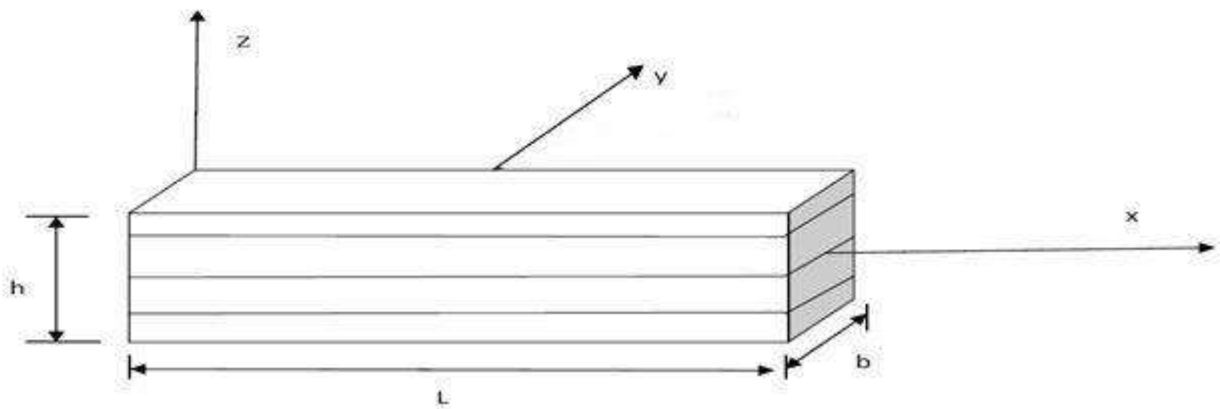

Fig. 2 Geometry of laminated composite beam.

IV. RESULT AND DISCUSSION

5.1 Numerical analysis

For both first and higher order shear deformation theories MATLAB program is written [27]. Eigen value analysis is used to find natural frequencies for the laminated composite beam. Also an ANSYS, APDL program is written for the same laminated beam. The results of all the three programs are compared for different boundary conditions, (l/h) ratios and different stacking sequences. The numerical results are obtained for free vibration of composite beams using FSDT, HSDT and ANSYS. The shear correction factor is assumed to be 5/6 for the first-order theory. The lamina properties used are as follows

E1=129.207 GPa; E2=E3=9.42512 GPa; G12=5.15658 GPa; G13=4.3053 GPa;

G23=2.5414GPa; ν_{12}=0.3; ν_{23}=0.218; ν_{21}=0.021; =1550.0666kg/m3

The beam is assumed to have a length of 0.1905 m and a width of 0.0127 m. The following boundary conditions are used

For simply supported end condition

$$u_0 = v_0 = w_0 = \theta_x = \phi_x = \phi_y = \phi_z = \xi_x = 0.$$

For clamped supported end condition

$$u_0 = v_0 = w_0 = \theta_x = \theta_y = \theta_z = \phi_x = \phi_y = \phi_z = \xi_x = \xi_y = \xi_z = 0.$$

For free edge end condition

$$u_0, v_0, w_0, \theta_x, \theta_y, \theta_z, \phi_x, \phi_y, \phi_z, \xi_x, \xi_y, \xi_z$$

have not been specified.

The non-dimensional natural frequencies λ for different boundary conditions of unidirectional composite beam varies for various (l/h) ratios. The present results are found to be in good agreement with those of Maity [1] and there is no appreciable discrepancy between the first order and higher order theory in the case of clamped-free uniaxial beams varying from thin (l/h=60) to thick (l/h=5) laminates. The results reveal the usual trends. The frequency decreases when the fiber is oriented from 00 to 900. Table 1 provides the value λ for uniaxial composite beams having clamped free end condition. In addition, there do not exist wide discrepancies between the first-order theory and the higher-order theory. Furthermore, the frequencies are found to reduce with the increase in fiber orientation. Tables 2 illustrate the non-dimensional fundamental frequencies for laminated composite beams with different support conditions and different stacking sequences for (1/h=60). Practically no appreciable difference is observed employing the first-order theory, higher-order theory and ANSYS for the thin (1/h=60) laminated composite beams. For large (l/h) ratios there are low transverse shear stresses. So this reduces the effect of shear correction factor in first order shear deformation theory. So this results in approximately equal values of natural frequencies from each theory.

Table 3 shows variation of non-dimensional natural frequency with different stacking sequences for (l/h=5). The results of HSDT, FSDT and ANSYS are compared in the table provided for all the three boundary conditions. The results of both theories are found in good agreement with each other and ANSYS results too for clamped free end condition.

First four mode shape obtained for (l/h=60), stacking sequence (0-90-0) and clamped-clamped or simply-supported boundary condition from ANSYS are

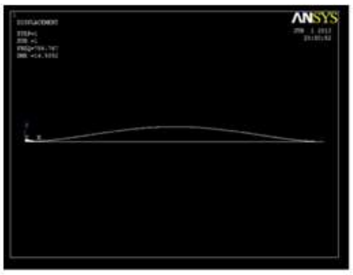

Fig. 9 1st mode shape for clamped-clamped BC.

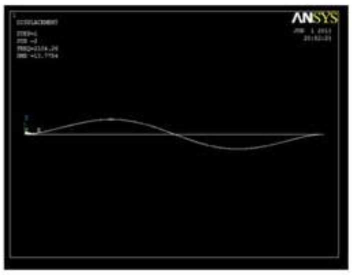

Fig. 10 2nd mode shape for clamped-clamped BC.

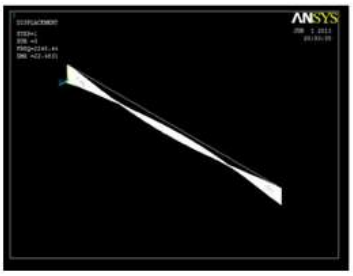

Fig. 11 3rd mode shape for clamped-clamped BC.

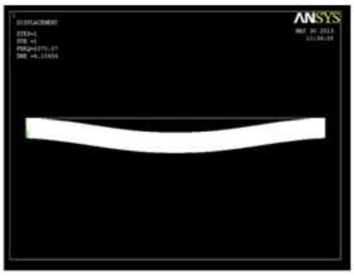

Fig. 12 4th mode shape for clamped-clamped BC.

Here 1st and 2nd mode are vertical bending mode, 3rd mode is torsional mode and 4th mode is

Here 1st and 2nd mode are vertical bending mode, 3rd mode is torsional mode and 4th mode is lateral bending mode of vibration.

First four mode shape obtained for (l/h=60), stacking sequence (0-90-0) and clamped-free boundary condition from ANSYS are

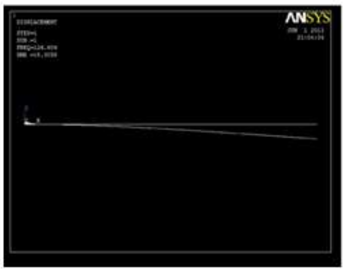

Fig. 13 1st mode shape for clamped-free BC.

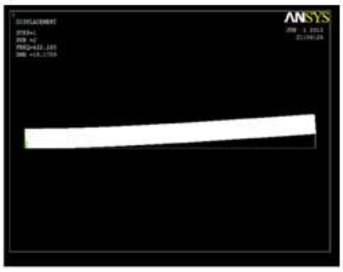

Fig. 14 2nd mode shape for clamped-free BC.

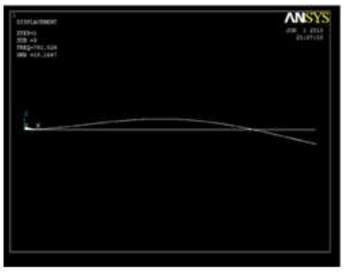

Fig. 15 3rd mode shape for clamped-free BC.

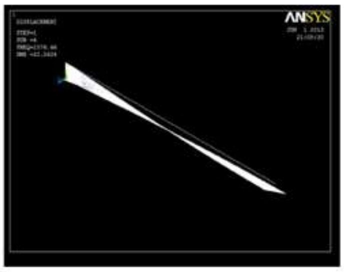

Fig. 16 4th mode shape for clamped-free BC.

Here 1st and 3rd mode are vertical bending mode, 2nd mode is lateral bending mode and 4th mode is torsional mode of vibration.

V.CONCLUSION

A finite detail evaluation approach used to have a look at the loose vibration characteristics of laminated composite beams has been advanced using a higher-order shear deformation theory and the traditional first-order shear deformation theory. Nine-noded isoparametric factors are used to discretize the evaluation domain. The present outcomes also evaluate well with the ones of Maiti [1] and with the ANSYS application written for the hassle described. Therefore, the prevailing higher-order idea is predicted to yield correct estimation of frequencies. It is found that there isn't always a good deal difference in frequencies the usage of the higher-order and first-order shear deformation theories. As ply perspective of the lamina increases from zero to ninety, herbal frequency decreases. As (l/h) ratio of the beam will increase from 5 to 60, the non-dimensional fundamental frequency increases.

Boundary conditions have a massive impact on herbal frequency of the beam. Small (l/h) ratio reasons discrepancy in computation of non-dimensional fundamental frequencies for clamped-clamped and simply supported situations, so a 3D finite detail model can also be derived for this hassle. Bending analysis can be accomplished in future for the equal laminated composite beam.

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