FORMATION OF LAMINATED COMPOSITE PLATE BY USING HIGHER SHEAR DEFORMATION THEORY.

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Abstract: In the present paper, basic terminologies of laminated composite plates are discussed. In this project author discuss on to find the 'u' displacement in x direction for isotropic square and rectangle plate for simply supported and sinusoidal load and to find the warping effect in transverse direction for rectangular plate also the displacement in x, y, z direction for plate with loading condition. Laminated composite plate structures find numerous applications in aerospace, military and automotive industries. The role of transverse shear is very important in composites, as the material is weak in shear due to its low shear modulus compared to extensional rigidity. Hence, an accurate understanding of their structural behavior is required, such as deflections and stresses. From the present Literature Review the effect of bending, buckling, thermal & hydrothermal on composite plates discussed and different theories like Classical Plate Theory, First Order Shear Deformation Theory, and Higher order Shear Deformation Theory etc. for analysis of composite plate are mentioned.
Keyword- U displacement in X direction, Higher Shear Deformation Theory.

1. INTRODUCTION

Laminated composite materials are increasingly being used in a large variety of structures including aerospace, marine and civil infrastructure owing to the many advantages they offer: high strength/stiffness for lower weight, superior fatigue response characteristics, facility to vary fiber orientation, material and stacking pattern, resistance to electrochemical corrosion, and other superior material properties of composites.

1.1 General:

Composite materials are those formed by combining two or more materials on a macroscopic scale such that they have better engineering properties than the conventional materials, for example, metals. Some of the properties that can be improved by forming a composite material are stiffness, strength, weight reduction, and corrosion resistance, thermal properties, fatigue life, and wear resistance. Most manmade composite materials are made from two materials: a reinforcement material called fiber and a base material, called matrix material. The matrix material keeps the fibers together, acts as a load-transfer medium between fibers, and protects fibers from being exposed to the environment [1].
Matrix materials have their usual bulk-form properties whereas fibers have directionally dependent properties.
Composite materials are commonly formed in three different types: (1) fibrous composites, which consist of fibers of one material in a matrix material of another; (2) particulate composites, which are composed of macro size particles of one material in a matrix of another; and (3) laminated composites, which are made of layers of different materials, including composites of the first two types. The particles and matrix in particulate composites can be either metallic or nonmetallic. Thus, there exist four possible combinations: metallic in nonmetallic, nonmetallic in metallic, nonmetallic in nonmetallic, and metallic in metallic [2].
A lamina or ply is a typical sheet of composite material. A laminate is a collection of laminate stacked to achieve the desired stiffness and thickness. The sequence of various orientations of a fiber-reinforced composite layer in a laminate is termed the lamination scheme or stacking sequence.
The layers are usually bonded together with the same matrix material as that in a lamina. If a laminate has layers with fibers oriented at 30 or 45, it can take shear loads [3]. The lancination scheme and material properties of individual lamina provide an added flexibility to designers to tailor the stiffness and strength of the laminate to match the structural stiffness and strength requirements. Fiber reinforced composite materials consists of fibers of significant strength and stiffness embedded in a matrix with distinct boundaries between them. Both fibers and matrix maintain their physical and chemical

identities, yet their combination performs a function which cannot be done by each constituent acting singly. Fibers of fiber reinforced plastics (FRP) may be short or continuous [4].

It appears obvious that FRP having continuous fibers is indeed more efficient. Classification of FRP composite materials into four broad categories has been done accordingly to the matrix used. They are polymer matrix composites, metal matrix composites, ceramic matrix composites and carbon/carbon composites. Polymer matrix composites are made of thermoplastic or thermo set resins reinforced with fibers such as glass, carbon or boron. A metal matrix composite consists of a matrix of metals or alloys reinforced with metal fibers such as boron or carbon. Ceramic matrix composites consist of ceramic matrices reinforced with ceramic fibers such as silicon carbide, alumina or silicon nitride. They are mainly effective for high temperature applications. His project is deal with fiber reinforced polymer matrix composite materials [5].

2. REVIEW OF LITERATURE

Hiroyuki Matsunaga et al. The importance of thermal stresses has been recognized in predicting the predominant cause of failure of composite plates subjected to severe thermal loadings. Failures due to delamination of layers and longitudinal cracks in the matrix are serious problems of the laminated composite structures. A two-dimensional global higher-order deformation theory is presented for the evaluation of interlinear stresses and displacements in cross-ply multilayered composite and sandwich plates subjected to thermal loadings. Transverse shear and normal stresses can be calculated by integrating the three-dimensional equations of equilibrium in the thickness direction, and satisfying the continuity conditions at the interface between layers and stress boundary conditions at the external surfaces. Numerical results are compared with those of the published three-dimensional layer wise theory in which both in plane and normal displacements are assumed to be C0 continuous in the continuity conditions at the interface between layers. Effects of the difference of displacement continuity conditions between the three-dimensional layer wise theory and the global higher-order theory are clarified in multilayered composite and sandwich plates subjected to thermal loadings.

Castel et al. The first method considers an exact 3D solution of the problem. The second method uses the solution provided by the model itself: the transverse shear stresses are computed integrating equilibrium equations. Hence, an iterative process is applied; the model is updated with the new warping functions, and so on. Once the sets of warping functions are obtained, the stiffness and mass matrices of the models are computed. These two models are compared to other models and to analytical solutions for the bending of simply supported plates. Four different laminates and a sandwich plate are considered. Their length-to-thickness ratios vary from 2 to 100. An additional analytical solution that simulates the behavior of laminates under the plane stress hypothesis – shared by all the considered models – is computed. Both presented models give results very close to this exact solution, for all laminates and all length-to-thickness ratios. In many human-built structures, plates and shells are present. These particular structures are distinguished from others because a dimension – the transverse dimension – is much smaller than the others. Hence, although it is always possible, their representation through a three-dimensional domain is not the best way to study them. To understand and predict their mechanical behavior, plate models have been developed.

Loredo et al. A multilayered plate theory taking into account transverse shear and normal stretching is presented. The theory is based on a seven-unknown kinematic field with five warping functions. Four warping functions are related to the transverse shear, the fifth to the normal stretching. The warping functions are issued from exact three-dimensional solutions. They are related to the variations of transverse shear and normal stresses computed at specific points for a simply supported bending problem. In this paper, a multilayered equivalent-single-layer plate theory with normal deformation has been presented. This theory, named 3D-5WF, is based on the use of five warping functions (WFs), four of them describing the transverse shear behavior and the fifth describing the normal deformation. The five WFs are issued from 3D exact solutions of the bending (or of the dynamic response) of the simply supported laminate under bi-sine load. Hence the five WFs depend on the lamination sequence, on the length-to-thickness ratio, and on the frequency. This leads to an adaptable theory which is able to give precise results for various laminates including single layer and sandwich plates, regardless of the length-to-thickness ratio which has been lowered up to 2 in this study.

Balakrishna Adhikari et al. In this work, a new simple quasi 3-D theory based on linear variation of transverse displacement along the thickness of plate is proposed for free and forced vibration of laminated composite plates. The theory satisfies both zero transverse shear stress conditions at top and bottom surfaces of the plate and non-linear distribution of transverse shear stresses across the thickness of plate. Therefore, the necessity of shear correction factor can be avoided. The governing equations of motion are obtained by using Lagrange equation. The finite element discretization of the plate is presented by considering an eight nodded serendipity element. The forced vibration of the plate under different time dependent loads is also illustrated. The Newmark's time integration techniques are employed to obtain the forced response of laminated plate.

Yuwaraj Marotrao Ghugal et al. a sinusoidal shear and normal deformation theory taking into account effects of transverse shear as well as transverse normal is used to develop the analytical solution for the bidirectional bending analysis of isotropic, transversely isotropic, laminated composite and sandwich rectangular plates. The theory accounts for adequate distribution of the transverse shear strains through the plate thickness and traction free boundary conditions on the plate boundary surface, thus a shear correction factor is not required. Results obtained for displacements and stresses of simply supported rectangular plates are compared with those of other refined theories and exact elasticity solution wherever applicable.

S. K. Kulkarni et al. The components of such structures are often subjected to combinations of transverse mechanical and thermal loads. To address the correct response of composite laminated plates when subjected to combined loads is of prime interest to structural analysis. The results are compared with classical plate theory, first-order shear deformation theory and higher-order shear deformation theory. The results of the present theory are in good agreement with those of higher-order shear deformation theory under uniformly distributed nonlinear thermo-mechanical load. This paper is to present an equivalent single-layer shear deformation theory for evaluation of displacements and stresses of cross-ply laminated plates subjected to uniformly distribute nonlinear thermo-mechanical load. A trigonometric shear deformation theory is used. The in-plane displacement field uses a sinusoidal function in terms of the thickness coordinate to include the shear deformation effect.

R. Kotlyar et al. developed a novel simulation approach to model electron mobility in the inversion layer which encompasses all the important effects of arbitrary wafer and applied stress orientations, such as carrier re-population, band warping, and scattering, going beyond the separate treatments of band warping and inversion anisotropy that have been demonstrated. Our model predicts an important consequence of electron band warping in retaining the increase of stress gain at high stress levels in the presence of shear stress at strong inversion.

S. Seren Akavci et al. This is the result of neglecting transverse shear strains. However, non-negligible shear deformations occur in thick and moderately thick plates and the theory gives inaccurate results for laminated plates. So, it is obvious that transverse shear deformations have to be taken into account in the analysis. One of the well-known plate theories is the Mandolin model which is a first order shear deformation theory (FSDT) and takes the displacement field as linear variations of midland displacements. In this theory, the relation between the resultant shear forces and the shear strains is affected by the shear correction factors.

T. Kant et al. a few higher order theories and the first order theory developed by other investigators and already available in the literature are also considered for the evaluation. The equations of equilibrium are obtained using principle of minimum potential energy (PMPE). Solutions are obtained in closed form using Navier’s technique by solving the boundary value problem. The comparison of the present results with the available elasticity solutions and the results computed independently using the first order and the other higher order theories available in the literature shows that this refined theory predicts the transverse displacement and the stresses more accurately than all other theories considered in this paper. After establishing the accuracy of present results for composite and sandwich plates, new results for the stretching bending coupling behavior of ant symmetric sandwich laminates using all the theories considered in this paper are presented which will serve as a benchmark for future investigations.

S. Sayyad et al. To prove the credibility of the present theory, we applied it to the bending analysis of beams. A simply supported isotropic, laminated composite and sandwich beams are analyzed using Navier approach. The numerical results of non-dimensional displacements and stresses obtained by using the present theory are presented and compared with those of other refined theories available in the literature along with the elasticity solution. In this paper, the refined beam theory (RBT) is examined for the bending of simply supported isotropic, laminated composite and sandwich beams. The axial displacement field uses parabolic function in terms of thickness ordinate to include the effect of transverse shear deformation.

Metin Aydogdu et al. In the present study, a new higher order shear deformable laminated composite plate theory is proposed. It is constructed from 3-D elasticity bending solutions by using an inverse method. Present theory exactly satisfies stress boundary conditions on the top and the bottom of the plate. It was observed that this theory gives most accurate results with respect to 3-D elasticity solutions for bending and stress analysis when compared with existing five degree of freedom shear deformation theories [Reddy JN. A simple higher-order theory for laminated composite plates. A new shear deformation theory was proposed to analyse laminated composite static and dynamic behavior. Bending and stress analysis under transverse load, free vibration and buckling and cross ply simply supported composites were analyzed and results were compared with previous studies.

Sanjay Kantrao Kulkarni et al. The in-plane displacement field uses sinusoidal function in terms of thickness co-ordinate to include the shear deformation effect. The theory satisfies the shear stress free boundary conditions on the top and bottom surfaces of the plate. The present theory obviates the need of shear correction factor. Governing equations and boundary conditions of the theory are obtained using the principle of virtual work. The validity of present theory is verified by comparing the results with those of classical plate theory and first order shear deformation theory and higher order shear deformation theory.

Sanjib Goswami et al. A new displacement based higher order element has been formulated that is ideally suitable for shear deformable composite and sandwich plates. Suitable functions for displacements and rotations for each node have been selected so that the element shows rapid convergence, an excellent response against transverse shear loading and requires no shear correction factors. It is completely lock-free and behaves extremely well for thin to thick plates. To make the element rap- idly convergent and to capture warping effects for composites, higher order displacement terms in the displacement kinematics have been considered for each node. The element is very simple to formulate and could be coded up in research software. A small Fortran code has been developed to implement the element and various examples of isotropic and composite plates have been analyzed to show the effectiveness of the element.

R. P. Shimpi et al. A review of displacement and stress based refined theories for isotropic and anisotropic laminated beams are presented. Various equivalent single layer and layer wise theories for laminated beams are discussed together with their merits and demerits. Exact elasticity solutions for the beam problems are cited, wherever available. Various critical issues, related with beam theories, based on the literature reviewed are presented. a review of refined shear deformation theories for the structural analysis of shear deformable isotropic and laminated beams is presented. The methods of development of refined theories are presented.

E. Carrera et al. this paper has been devoted to the so called axiomatic theories and related finite element implementations. Most of the theories and finite elements that have been proposed over the last thirty years are in fact based on these types of approaches. has been devoted to the description of possible approaches to plate and shell structures: 3D approaches, continuum based methods, axiomatic and asymptotic two-dimensional theories, classical and mixed formulations, equivalent single layer and layer wise variable descriptions are considered (the number of the unknown variables is considered to be independent of the number of the constitutive layers in the equivalent single layer case).

3. METHODS FOR ANALYSIS OF COMPOSITE LAMINATED PLATE

Following Methods are used for analysis of composite laminated plate which are generally used.

3.1 Analytical methods:

Analysis by using Different theories such as Classical Plate Theory, First Order Shear Deformation Theory, Higher Order Shear Deformation Theories etc.

3.2 Computational Techniques

A brief summary of Analytical methods is given as follows,

3.1.1 Classical Plate Theory:

Classical plate theory (CPT), which is also known as Love- Kirchhoff plate. Theory, in which it is assumed that lines which are normal to neutral surface before deformation remain straight and normal to neutral surface after deformation. CPT has been used for variety of problems. In this theory, effects of transverse stresses are not accounted for. Thick plate analysis, transverse stresses play an important role, Since CPT does not include transverse stresses effects, it fails to accurately analyze thick plates. This deficiency is more pronounced in composite plates, which have relatively low shear modulus compared to in-plane modulus. Despite of its limitation to take into account shear deformations; CPT was extended for composite plate analysis because of its simplicity.

Assumptions:

- Arbitrary number of layer of orthotropic laminae
- Laminates are perfectly bonded, no slip relative to each other
- Bond between the laminae is thin
- No shear deformation
- Plate acts as a single layer
- Plate is thin
- Displacements are small
- Plate has constant thickness
- Normal to the midplane before deformation remain straight and normal to the midplane during and after deformation $y_{xz},\ y_{yz},\ \epsilon_{zz}, = 0$

3.1.1.2 First Order Shear Deformation Theory (FSDT):

A new theory was proposed known as Reissner-Mindlin plate theory and also known as first order shear Deformation Theory [FSDT]. In this theory the in-plane displacement very linearly through the cross section and the normal to the midplane before deformation need not be normal to midplane after deformation. It means that the normal are allowed to rotate. This theory uses a shear correction factor in the analysis. FSDT contains five unknowns. This theory is widely used for the plate analysis. This theory has been applied to static, free vibration, transient and low velocity impact analysis. Finite element model have been developed and used to solve the plate problems with various boundary conditions. This theory is simple to use and predicts good global behavior. It predicts constant shear stress across the cross section. It may be noted that the shear correction factor is problem dependent.

3.1.3 Higher Order Shear Deformation Theories:

A new class of plate theories was developed using polynomials to express the displacements. These theories are also called as Higher Order shear Deformation. The role of transverse shear is very important in composites, as the material is weak in shear due to its low shear modulus compared to extensional rigidity. Hence, an accurate understanding of their structural behavior is required, such as deflections and stresses. Analysis of laminated composite plate can be done with the help of MATLAB and ANSYS software.

CONCLUSION

From the study of analysis of composite beam, we can conclude that for bending, buckling analysis and effect of thermal and hydrothermal analysis higher order shear deformation theory is more effective as compared to other methods of analysis of composite beams. By using finite element model of the plate for the various sides to thickness ratio, aspect ratio and modular ratio can give more accurate results.

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