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A Review Paper on Laminated Composite Plates

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Abstract – In the present paper, essential terminology of laminated composite plates are examined. Laminated composite plate structures discover various applications in aviation, military and automotive industries. The part of transverse shear is vital in composites, as the material is frail in shear because of its low shear modulus contrasted with extensional unbending nature. Subsequently, a precise comprehension of their auxiliary conduct is required, for example, deflections and stresses. From the present Literature Review the effect of bending, buckling, thermal and hygrothermal on composite plates examined and diverse speculations like Classical Plate Theory, First Order Shear Deformation Theory and Higher order Shear Deformation Theory and so on for examination of composite plate are specified.

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1. HISTORY

In days of yore we were utilizing bricks made of clay and reinforced with straw are an early case of utilization of composites. The individual constituents, clay and straw, couldn't serve the capacity independent from anyone else yet did when assemble. Some believe that the straw was utilized to shield the clay from cracking, yet others recommend that it blunted the sharp cracks in the dry clay.

Historical examples of composites are abundant. For cases utilization of reinforcing mud walls in houses with bamboo shoots, glued laminated wood by Egyptians (1500 B.C.), and laminated metals in producing swords (A.D. 1800). In the twentieth century, current composites were utilized as a part of the 1930s when glass fibers reinforced resins. Boats and aircrafts were worked out of these glass composites, ordinarily called fiberglass. Since the 1970s, use of composites has generally expanded because of improvement of new fibers, for example, carbon, boron, and aramids, and new composite frameworks with matrices made of metals and ceramics.

2. INTRODUCTION

Laminated composite materials are progressively being utilized as a part of an expansive variety of structures including aerospace, marine and civil infrastructure attributable to the numerous points of interest they offer: high strength/stiffness for lower weight, superior fatigue response characteristics, facility to vary fibre orientation, material and stacking pattern, protection from electrochemical corrosion, and other superior material properties of composites.

3. GENERAL

Composite materials are those framed by consolidating at least two materials on a naturally visible scale with the end goal that they have preferable building properties over the conventional materials, for example, metals. A portion of the properties that can be enhanced by framing a composite material are stiffness, strength, weight reduction, corrosion resistance, thermal properties, fatigue life, and wear protection. Most synthetic composite materials are produced using two materials: a reinforced material called fibre and a base material, called matrix material. The matrix material keeps the fibres together, goes about as a load transfer medium amongst fibres, and shields fibres from being exposed to the environment. Matrix materials have their typical bulk-form properties though fibres have directionally dependent properties.

Composite materials are generally framed in three different types: (1) fibrous composites, which comprise of fibres of one material in a matrix material of another; (2) particulate composites, which are made out of macro size particles of one material in a matrix of another; and (3) laminated composites, which are made of layers of various materials, including composites of the initial two composes. The particles and grid in particulate composites can be either metallic or non-metallic. In this way, there exist four possible combinations: metallic in nonmetallic, nonmetallic in metallic, nonmetallic in nonmetallic, and metallic in metallic. A lamina or ply is a regular sheet of composite material. A laminate is an accumulation of laminae stacked to accomplish the desired stiffness and thickness. The sequence of different orientations of a fiber-reinforced composite layer in a laminate is named the lamination scheme or stacking sequence. The layers are generally bonded together with an same matrix material from that in a lamina. If a laminates has layers with fibres arranged at 30 or 45, it can take shear loads. The lamination scheme and material properties of individual lamina give an additional flexibility to designer to tailor the stiffness and strength of the laminate to coordinate the structural stiffness and strength requirements. Fibre reinforced composite materials comprises of fibres of significant strength and stiffness embedded in a matrix with distinct boundaries between them. The two fibres and matrix keep up their physical and compound characters, yet their combination performs a function which is impossible by each constituent acting separately. Fibres of fiber reinforced plastics (FRP) might be short or continuous. It seems clear that FRP having continuous fibres is to be sure more effective. Characterization of FRP composite materials into four general classifications 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 fibres, for example, glass, carbon or boron. A metal matrix composite comprises of a matrix of metals or combinations reinforced with metal fibres, for example, boron or carbon. Ceramic matrix composites comprise of ceramic matrix reinforced with ceramic fibres, for example, silicon carbide, alumina or silicon nitride. They are principally powerful for high temperature applications. This undertaking is manage fiber reinforced polymer matrix composite materials.

4. REVIEW OF LITERATURE

A point by point investigation of the available literature was conducted to know the current situation with knowledge available in the open literature, which can help with accomplishing the present goals effectively.

Akavci [1] presented the first order shear deformation theory for symmetrically laminated composite plates on elastic foundation. In the classical theory of plates (CPT), it is assumed that plane sections initially normal to the mid surface before deformation remain plane and normal to that surface after deformation. 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 Reissner and Mindlin model which is a first order shear deformation theory (FSDT) and takes the displacement field as linear variations of mid plane displacements.

Pandya and Kant [2] presented finite element analysis of laminated composite plates using a higher-order displacement model. A C0 continuous displacement finite element formulation of a higher-order theory for flexure of thick arbitrary laminated composite plates under transverse loads is presented. The displacement model accounts for non-linear and constant variation of in-plane and transverse displacement respectively through the plate thickness.

Setoodeh [3] presented a closed form solution for bending and free vibration analyses of simply supported rectangular laminated composite plates is presented. The static and free vibration behavior of symmetric and antisymmetric laminates is investigated using a refined first-order shear deformation theory. The Winkler–Pasternak two-parameter model is employed to express the interaction between the laminated plates and the elastic foundation. The Hamilton's principle is used to derive the governing equations of motion. The accuracy and efficiency of the theory are verified by comparing the developed results with those obtained using different laminate theories. The effects of the elastic foundation parameters, orthotropy ratio and width-to-thickness ratio on the bending deflection and fundamental frequency of laminates are investigated.

Ghughal [4] used trigonometric shear deformation theory (TSDT) taking into account transverse shear deformation effect as well as transverse normal strain effect is presented. The in plane displacement field uses sinusoidal function in terms of thickness coordinate to include the shear deformation effect. The cosine function in thickness coordinates is used in transverse displacement to include the effect of transverse normal strain. Governing equations and boundary conditions of the theory are obtained using the principle of virtual work. The results of displacements and stresses for static flexure of simply supported symmetric and anti-symmetric cross-ply laminated square plates subjected to parabolic load and line load are obtained. The results obtained by present theory are compared with those of classical, first-order and higher-order plate theories.

Sayyad [5] presented cylindrical bending of orthotropic plates is presented using nth-order plate theory. Classical plate theory and parabolic shear deformation theory of Reddy can be considered as special cases of present theory. The theory accounts for realistic variation of the transverse shear stress through the thickness of plate and satisfy the traction free conditions at top and bottom surfaces of the plate. The number of unknown variables in the present theory is same as that of first order shear deformation theory. The theory is variationally consistent. The use of shear correction factors which are problem dependent and are normally associated with first order shear deformation theory is avoided in the present theory. The governing equations and associated boundary conditions are derived by the principle of virtual work. Navier solution technique is employed for the simply supported plates. The program has been developed in FORTRAN. The displacement and stresses of a simply supported plate infinitely long in y-direction under sinusoidally distributed load are calculated to demonstrate the accuracy and efficiency of the present theory.

Ghumare et.al [6] presented cylindrical bending of laminated composite plates using refined shear deformation theory. The theory includes transverse shear effect for laminated plates. Appropriate reviews of the recent developments in the analysis of plates with an emphasis placed on shear deformation effects are considered. A refined shear deformation theory for flexural analysis of thick laminated composite plates under cylindrical bending, taking into account transverse shear deformation effects, is developed. The parabolic functions are used in displacement field in terms of thickness coordinate to represent the shear deformation effects. The theory obviates the need of shear correction factor. Governing differential equations and boundary conditions are obtained by using the principle of virtual work.

Reddy et.al [7] presented bending analysis of laminated composite plates using finite element method. A number of finite element analyses have been carried out for various side-to-thickness ratios, aspect ratios and modulus ratios to study the effect of transverse shear deformation on deflection and stresses of laminated composite plates subjected to uniformly distributed load.

Akavci [8] presented two new hyperbolic shear displacement models for orthotropic laminated composite plates. Two hyperbolic displacement models, HPSDT1 and HPSDT2, are developed for the bending analysis of orthotropic laminated composite plates. These models take into account the parabolic distribution of transverse shear stresses and satisfy the condition of zero shear stresses on the top and bottom surfaces of the plates. It is established that the HPSDT1 model is more accurate than some theories of laminates developed previously, and therefore the analysis can be expanded to laminated composite shells.

Akavci [9] presented buckling and free vibration analysis of symmetric and antisymmetric laminated composite plates on an elastic foundation. Inplane displacements vary as a hyperbolic function across the plate thickness, so account for parabolic distributions of transverse shear stresses and satisfy zero shear stress conditions at the top and bottom surfaces of the plate. The foundation is modelled as two parameter Pasternak type foundation and Winkler type if the second foundation parameter is zero. The equation of motion for thick laminated rectangular plates resting on elastic foundation and subjected to in plane loads is obtained through Hamilton’s principle. The closed form solutions are obtained by using Navier’s technique, and then buckling loads and fundamental frequencies are found by solving the results of Eigen value problems.

Khateeb and Zenkour [10] presented the bending analysis of advanced plates resting on elastic foundations. The influence of temperature and moisture on the bending response of such plates is investigated using a refined plate theory. This theory includes the effects of transverse shear strain as well as the transverse normal strain. The number of unknown functions involved in the present theory is only four as against six or more in case of other shear and normal deformation theories. The governing equations are derived based on the present theory, including the hydrothermal effects and elastic foundation parameters. The effects of Winkler’s and Pasternak’s foundation parameters, temperature, moisture concentration, transverse and normal shear deformations, plate aspect ratio, side-to-thickness ratio, as well as the volume fraction distribution on displacement and stresses are investigated.

Ying et.al [11] presented exact solutions for bending and free vibration of functionally graded beams resting on a Winkler–Pasternak elastic foundation are presented based on the two-dimensional theory of elasticity. The beam is assumed orthotropic at any point, while material properties varying exponentially along the thickness direction. The system of governing partial differential equations is reduced to an ordinary one about the thickness coordinate by expanding the state variables into an infinite trigonometric series. The problem is finally solved using the state space method, which is validated by comparing the present results to those available in the literature. Effects of several parameters, such as gradient index, aspect ratios, and foundation parameters on mechanical behaviour of FGM beams are investigated. Numerical results are presented to serve as benchmarks for future analyses of such beams.

From the Literature Review we can utilize higher order shear deformation Theory for investigation of composite Laminate Plate. We can analyse bending, shear, thermal, hygrothermal, bending effects for composite plate. Finite element method is likewise fundamentally utilized for the examination of vibration and dynamics, buckling and failure damage analysis.

5. TECHNIQUES FOR EXAMINATION OF COMPOSITE LAMINATED PLATE

Following Methods are utilized for analysis of composite laminated plate.

5.1 Analytical methods

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

5.2 Computational Techniques

A brief summary of Analytical methods is given as follows,

5.1.1 Classical Plate Theory

Classical Plate Theory (CPT), which is otherwise called Love-Kirchhoff plate. Hypothesis, in which it is expected that Normal to the mid-plane before deformation remain straight and normal to the mid-plane during and after deformation. CPT has been utilized for variety of issues. In this hypothesis, impacts of transverse stress are not represented. Thick plate analysis, transverse stresses assume a critical part, Since CPT does exclude transverse stress effects, and it neglects to precisely analysis thick plates. This inadequacy is more articulated in composite plates, which have moderately low shear modulus contrasted with in-plane modulus. In spite of its constraint to consider shear misshapenings; CPT was stretched out for composite plate investigation as a result of its straightforwardness.

Assumptions:

Subjective number of layer of orthotropic laminae

Overlays are flawlessly reinforced, no slip with respect 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
- Typical to the mid-plane before misshapenings stay straight and ordinary to the mid-plane amid and after distortion.

5.1.2 First Order Shear Deformation Theory (FSDT)

Another hypothesis was proposed known as Reissner-Mindlin plate hypothesis and furthermore known as first request shear Deformation Theory [FSDT]. In this hypothesis the in-plane dislodging directly through the cross area and the typical to the mid-plane before disfigurement require not be ordinary to mid-plane after twisting. It implies that the normal are permitted to turn. This hypothesis utilizes a shear rectification factor in the investigation. FSDT contains five questions. This hypothesis is broadly utilized for the plate investigation. This hypothesis has been connected to static, free vibration, transient and low speed affect examination. Limited component display have been created and used to take care of the plate issues with different limit conditions. This hypothesis is easy to utilize and predicts great worldwide conduct. It predicts consistent shear worry over the cross segment. It might be noticed that the shear rectification factor is issue subordinate.

5.1.3 Higher Order Shear Deformation Theories

Another class of plate speculations was created utilizing polynomials to express the relocations. These hypotheses are likewise called as Higher Order shear Deformation. The part of transverse shear is essential in composites, as the material is frail in shear because of its low shear modulus contrasted with extensional unbending nature. Thus, a precise comprehension of their auxiliary conduct is required, for example, redirections and stresses.

Analysis of laminated composite plate can be done with the help of PHORTRON, MATLAB and ANSYS software.

6. CONCLUSION

From the investigation of examination of composite plates, we can reason that for bowing, clasping examination and impact of warm and hydrothermal examination higher request shear disfigurement hypothesis is more viable when contrasted with different strategies for investigation of composite shafts. By utilizing limited component model of the plate for the different side to thickness proportion, angle proportion and particular proportion can give more precise outcomes.

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