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Behaviour of Laminated Composite Twisted Plates Subjected to In-Plane Loading

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ABSTRACT

The twisted panel has various applications in turbine blades, compressor blades, fan blades and particularly in gas turbines. Many of these plates are subjected to in-plane load due to fluid or aerodynamic pressures. Hence it is necessary to study their behaviour under different types of loads. In these days, composite materials are increasingly used as load bearing structural components in aerospace and naval structures, automobiles, pressure vessels, turbine blades and many other engineering applications because of their high specific strength and stiffness. The analysis is carried out using ANSYS software. An eight-node isoparametric quadratic element is considered in the present analysis with five degrees of freedom per node. In ANSYS, the shell 281 element with five degrees of freedom per node is used. An eight by eight mesh is found to give good accuracy. The vibration and stability behaviour of composit elaminated twisted plate under various types of non-uniform in-plane loading is studied .The effect of number of layers, changing angle of twist, width to thickness ratio, aspect ratio, etc on the vibration and buckling loads are presented. It is observed that for increasing angles of twist of laminated composite plate with different in-plane load conditions, the vibration and buckling both decreases. Also as the number of layers increases, the vibration and buckling parameters of the laminated twisted plate are both observed to increases.

INTRODUCTION

The twisted cantilever panels have significant applications in wide chord turbine blades, compressor blades, fan blades, aircraft or marine propellers, helicopter blades, and particularly in gas turbines. Today twisted plates are key structural units in the research field. Because of the use of twisted plates in turbo-machinery, aeronautical and aerospace industries etc, it is required to understand the deformation and vibration characteristics of the rotating blades. The twisted plates are also subjected to different types of loads due to fluid pressure or transverse loads. The present study is mainly focused on behavior, both vibration and stability, of laminated composite twisted plates under in- plane loading.

Importance of the Present Study

The blades are of ten subjected to axial periodic forces due to axial components of aerodynamic or hydrodynamic forces acting on the blades. Composite materials are being increasingly used in turbo- machinery blades because of their specific strength and stiffness and these can be tailored through the variation of fiber orientation and stacking sequence to obtain an efficient design.

Hence it is required to have an understanding of the behavior of the laminated composite twisted plates under loads.

LITERATURE REVIEW

The vast use of turbo-machinery blades lead to significant amount of research over the years. Due to its wide range of application in the practical field, it is important to understand the nature of deformation, vibration and stability behaviour of cantilever twisted plates.

Crispino and Benson [4] studied the stability of thin, rectangular, orthotropic plates which were in a state of tension and twist. Results were presented, in a compact non-dimensional form, for a range of material, geometric and loading parameters. The effect of thermal gradient and tangency coefficient on the stability of a pre twisted, tapered, rotating cantilever with a tip mass and subjected to a concentrated partial follower force at the free end was investigated by Kar and Neogy [8]. The non-self adjoint boundary value problem was formulated with the aid of a conservation law using

Euler-Bernoulli theory. The associated adjoint boundary value problem was introduced and an opposite variational principle was derived. Approximate values of critical load were calculated on the basis of this variational principle and the influence of different parameters on the stability of the system was studied.

A parametric study was presented by Nemeth [15] of the buckling behavior of infinitely long symmetrically laminated anisotropic plates subjected to combined loads. The loads considered in this report are uniform axial compression, pure in-plane bending, transverse tension and compression, and shear. Results are presented that were obtained by using a special purpose non-dimensional analysis that is well suited for parametric studies of clamped and simply supported plates. An important finding of the present study is that the effects of flexural anisotropy on the buckling resistance of a plate can be significantly more important for plates subjected to combined loads than for plates subjected to single-component loads.

Vibration of cross-ply laminated composite plates subjected to initial in-plane stresses was studied by Matsunaga .Natural frequencies, modal displacements and stresses of cross- ply laminated composite plates subjected to initial in-plane stresses were analyzed for the effects of higher-order deformations and rotatory inertia.

Wang et al [23]studied the plastic buckling of rectangular plates subjected to intermediate and end in-plane loads. The plate had two opposite simply supported edges that were parallel to the load direction while the other remaining edges were any combination of free, simply supported or clamped conditions. Both the incremental theory of plasticity and the deformation theory of plasticity were considered in bounding the plastic behaviour of the plate.

Static, free vibration and buckling analysis of anisotropic thick laminated composite plates on distributed and point elastic supports using a 3-D layer-wise FEM was done by Karami [20]. A three-dimensional elasticity based layer-wise finite element method (FEM) was used to study the static, free vibration and buckling responses of general laminated thick composite plates. Various mixed boundary conditions and free edge conditions were conveniently and accurately implemented. Elastic line and point supports were also successfully incorporated for thick plates.

Shukla et al [21] estimated the critical/ buckling loads of laminated composite rectangular plates under in-plane uniaxial and biaxial loadings. The formulation was based on the first-order shear deformation theory and von-Karman-type non-linearity. An incremental iterative approach was used for estimating the critical load. Various combinations of support conditions were considered. The effects of aspect ratio, lamination scheme, number of layers and material properties on the critical loads were studied.

Free vibration of laminated composite plates subjected to in-plane stresses using trapezoidal p-element was studied by Leung et al [11]. A new trapezoidal p-element was applied to solve the free vibration problem of polygonal laminated composite plates subjected to in-plane stresses with various boundary conditions. The element stiffness and mass matrixes were analytically integrated in closed form.

Buckling of symmetrical cross-ply composite rectangular plates under a linearly varying in-plane load was studied by HongzhiZhong and Chao Gu [21]. It was developed based on the first-order shear deformation theory for moderately thick laminated plates. Buckling loads of cross-ply rectangular plates with various aspect ratio were obtained and the effects of load intensity variation and layup configuration on the buckling load were investigated. The results were verified using the computer code ABAQUS.

Natural frequencies of laminated composite plates using third order shear deformation theory were carried out by Aagaah et al [1]. The natural frequencies of square laminated composite plates for different supports at edges were presented. Laminated plates were supposedto be either angle-ply or cross-ply.

Buckling analysis of symmetrically laminated composite plates by the extended Kantorovich method was conducted by Ungbhakorn and Singhatanadgid [22].They investigated the buckling problem of rectangular laminated composite plates with various edge supports. The principle of minimum total potential energy with a separable displacement function was utilized to derive a set of ordinary differential equations. The buckling load and mode were determined from iterative calculations of the governing equations using the initial trial function which can be selected arbitrarily. The accuracy of this method was confirmed with the available Le´vy and Rayleigh–Ritz solutions.

Failure analysis of laminated structures by FEM based on nonlinear constitutive relationship was found by Huang [6].The influence of different load increments, mesh scales, and stiffness discount schemes on the finite element (FE) analyzed results was studied. Strength envelopes and stress–strain or load–deflection curves of several laminates subjected to in-plane as well as bending loads were obtained.

Three-dimensional dynamic analysis of laminated composite plates subjected to moving load was done by Malekzadeh et al [13]. For accurately determining the dynamic response of cross-ply laminated thick plates subjected to moving load, a solution procedure based on the three- dimensional (3D) elasticity theory was developed. Plates with simply supported edges and subjected to point moving load were considered. The layer wise theory was used to discretize the equations of motion and the related boundary conditions through the thickness of the plates. Then, the modal analysis in conjunction with the differential quadrature method was employed for the in-plane and the temporal discretization of the resulting system of differential equations, respectively.

Spectral element model for axially loaded bending–shear–torsion coupled composite Timoshenko beams was studied by Lee and Jang [10].In this paper, the spectral element model was developed for anaxially loaded bending–shear–torsion coupled composite laminated beam

Which was represented by the Timoshenko beam model based on the first-order shear deformationtheory.
Buckling and vibration analysis of laminated composite plate/shell structures via smoothed quadrilateral flat shell element with in-plane rotations was studied by Nguyen-Vanet al [16].This paper presented the buckling and free vibration analysis of composite plate/shell structures of various shapes, modulus ratios, span-to-thickness ratios, boundary conditions and lay-up sequences via a novel smoothed quadrilateral flat element. The element was developed by incorporating a strain smoothing technique into a flat shell approach.

Bending and vibration responses of laminated composite plates using an edge-based smoothing technique were investigated by Cuietal [3]. The analysis was carried out using a novel triangular composite plate element based on an edge-based smoothing technique. The present formulation was based on the first-order shear deformation theory, and the discrete shear gap (DSG) method was employed to mitigate the shear locking.

In-plane free vibrations of single-layer and symmetrically laminated rectangular composite plates was carried out by Dozio [5]. This work presented accurate upper-bound solutions for free in-plane vibrations of single-layer and symmetrically laminated rectangular composite plates witha combination of clamped and free boundary conditions. In-plane natural frequencies and mode shapes were calculated by the Ritz method with a simple, stable and computationally efficient set of trigonometric functions.

The FEM analysis of laminated composite plates with rectangular hole and various elastic moduli under transverse loads was done by Ozben and Arslan [17].The aim of this work was to predict the expansion of the plastic zone and residual stresses in layers of fiber-reinforced, thermoplastic laminated composite plates with rectangular hole. The effects of the material properties (constant modulus ratio, E1=E2) on residual stresses and expansion of the plastic zone were studied. The elastic and elasto-plastic stresses were analyzed using the finite element method (FEM) by a developed computer program.

Inelastic buckling behavior of stocky plates under interactive shear and in-plane bending was carried out by Alinia et al [2]. Plate girder web panels and infill plates in steel shear wall systems are two typical structural elements that are commonly subjected to interactive shear and
in-plane bending. In general, flat plates may buckle before, concurrent with, or after the material's nonlinearity limit point.

Expansion of plastic zone and residual stresses in the thermoplastic-matrix laminated plates ([0/h]2) with a rectangular hole subjected to transverse uniformly distributed load expansion was carried out by Tamer et al[18]. The work focused on the understanding of elastic stress, residual stress and plastic zone growth in layers of stainless steel woven fiber-reinforced thermoplastic matrix composite laminated plates with rectangular hole by using the finite element method (FEM) and first-order shear deformation theory for small deformations.

The deformation of in-plane loaded unsymmetrically laminated composite plates wasstudied by Majeed[12]. This study focused on the response of flat unsymmetric laminates to an in- plane compressive loading that for symmetric laminates were of sufficient magnitude to cause bifurcation, buckling, post buckling, and secondary buckling behavior. In particular, the purpose of this study was to investigate whether or not the concept of bifurcation buckling is applicable to unsymmetric laminates.

The dynamic failure analysis of laminated composite plates was conducted by Jam and Nia[7]. A developed finite element analysis investigation into the failure behavior of laminated composite plates subjected to impulsive loads was undertaken using ANSYS. The study presented the effects of pulse duration and pulse shapes on the predicted critical static and dynamic failure modes as well as free vibration, for several layer configurations. The effect of parameters like size of plates, boundary conditions and fiber orientation angles was also studied.

Stability of laminated composite pre twisted cantilever panels was studied by Sahuand Asha[19].This study deals with the stability analysis of angle-ply laminated composite twisted panels using the finite element method. Here, an eight-node disoparametric quadratic shell elementis used to develop the finite element procedure. To investigate the vibration and stability behavior of twisted panels, the effect of various geometrical parameters like angle of twist, aspect ratio, lamination parameters, shallowness ratio, etc. are studied.

Composite plates with two concentric layups under compression was analysed by Kassapoglou[9]. A new concept for designing composite panels with improved performance under compression was presented. In this concept, the panel consisted of two different concentric layups. A Rayleigh–Ritz-based approach to model such rectangular panels under compression was presented. The buckling load and the in-plane stresses everywhere in the plate were determined using an energy minimization approach.

METHODOLOGY

This project develops FEA models of a laminated composite twisted plate under an in plane load. The first step is to develop an ANSYS model of a laminated composite plate. The model will be subjected to vibration and buckling with in-plane loads and compared with the previous results with in-plane loading. Then a laminated composite twisted plate is studied for its characteristics with in-plane loads. Vibration characteristics will be analyzed and validated with the calculations using MATLAB**.**

EXPERIMENTAL WORKS

1. **Material Properties**: Laminated composite materials typically consist of layers of different materials stacked together, each with unique mechanical properties such as stiffness, strength, and Poisson's ratio. The behavior of the twisted plate is greatly influenced by the properties of these constituent materials and their arrangement.
2. **Geometry**: The geometry of the twisted plate, including the twist angle, thickness, and boundary conditions, affects its response to in-plane loading. Plates with higher twist angles or non-uniform thickness may exhibit different deformation patterns compared to plates with lower twist angles or uniform thickness.
3. **Boundary Conditions**: How the plate is constrained at its edges or supported affects its deformation behavior. Different boundary conditions, such as simply supported, clamped, or free edges, will lead to different stress distributions and deformation patterns.
4. **Load Type and Magnitude**: The type of in-plane loading applied to the plate, whether it's uniaxial tension, compression, shear, or a combination thereof, will determine the stress distribution and deformation pattern within the plate. The magnitude of the applied load also affects the level of deformation and potential failure modes.
5. **Buckling and Stability**: In-plane loading can induce buckling and stability issues in twisted plates, especially if they are thin or have large twist angles. Buckling can occur suddenly at critical loads, leading to structural instability and potential failure.
6. **Shear Deformation**: Laminated composite plates may undergo significant shear deformation, especially when subjected to in-plane loading. Shear deformation influences the overall stiffness and behavior of the plate, particularly in regions where the shear stresses are high.

Understanding the behavior of laminated composite twisted plates under in-plane loading requires advanced analytical and numerical techniques, such as finite element analysis (FEA) or computational mechanics, to accurately predict their response and optimize their design for specific applications. Experimental testing is also essential for validating analytical predictions and understanding real-world behavior.

CONCLUSION

The behavior of vibration and buckling of laminated composite twisted plate subjected to various types ofin-plane loading was studied. The works are done in ANSYS and MATLAB. Hereeffects of geometrical parameters like angle of twist, aspect ratio, number of layers and change in thickness of laminated composite plate on the vibration and buckling parameters has been analysed.

Based on the study, it is observed that for increasing angles of twist of laminated composite plate with different in-plane load conditions, the vibration and buckling both decreases.

Also as the number of layers increases, the vibration and buckling parameters of the laminated twisted plate are both observed to increase.

Asthe b/h ratio of laminated composite twisted plate increases, the vibration and bucklingparameters are decrease.

REFERENCES

[1]. Aagaah, M. R., Mahinfalah, M., & Jazar, G. N. (2006). Natural frequencies of laminated composite plates using third order shear deformation theory. *Composite structures*, *72*(3), 273-279

[2]. Alinia, M. M., Soltanieh, G., & Amani, M. (2012). Inelastic buckling behavior of stocky plates under interactive shear and in-plane bending. *Thin-Walled Structures*, *55*, 76-84

[3]. Cui, X. Y., Liu, G. R., & Li, G. Y. (2011). Bending and vibration responses of laminated composite plates using an edge-based smoothing technique. *Engineering Analysis with Boundary Elements*, *35*(6), 818-826.

[4]. David J.Crispino, Richard C. Benson(1986). Stability of twisted orthotropic plates. International journal of mechanical science(impact factor 1.23),28(6):371-379,pp371-379

[5]. Dozio, L. (2011). In-plane free vibrations of single-layer and symmetrically laminated rectangular composite plates. *Composite Structures*, *93*(7), 1787-1800.

[6]. Huang, Z. M. (2007). Failure analysis of laminated structures by FEM based on nonlinear constitutive relationship. *Composite structures, 77*(3), 270-279.

[7]. Jam,E.J.,&Nia,G.N.(2007). Dynamic failure analysis of laminated composite plates. *Metalurgija*, *13*(3), 187-196.

[8]. Kar,R. C. and neogy, S,(1989): Stability of a rotating, pretwistednonuni form cantilever beam with tip mass and thermal gradient subjected to a non-conservative forces, computer and Structures, Vol.33(2),pp.499-507.

[9]. Kassapoglou,C.(2008).Composite plates with two concentric layups under compression *Composites Part A: Applied Science and Manufacturing*, *39*(1), 104-112.

[10]. Lee and jang,(2010), spectral element model for axially loaded bending-shear-torsion coupled composite Timoshenko beams, composite structure volume 92(12),pp 2860-2870.

[11]. Leung, A. Y. T., Xiao, C., Zhu, B., & Yuan, S. (2005). Free vibration of laminated composite plates subjected to in-plane stresses using trapezoidal <i>p</i>- element. *Composite structures*, *68*(2), 167-175.

[12]. Majeed, M. A. (2005). *Deformations of In-plane Loaded Unsymmetrically Laminated Composite Plates* (Doctoral dissertation, Virginia Polytechnic Institute and State University.

[13]. Malekzadeh, P., Fiouz, A. R., &Razi, H. (2009). Three-dimensional dynamic analysis of laminated composite plates subjected to moving load. *Composite Structures*, *90*(2), 105- 114.

[14]. Mastsunaga (), vibration of cross-ply laminated composite plates subjected to initial in- plane stresses,department of architecture, setsunan university.

[15]. Nemeth,M.P.(1995). *Buckling behavior of long anisotropic plates subjected to combined load* (Vol. 3568). National Aeronautics and Space Administration, Langley Research Center.

[16]. Nguyen-Van, H., Mai-Duy, N., Karunasena, W., & Tran-Cong, T. (2011). Buckling and vibration analysis of laminated composite plate/shell structures via a smoothed quadrilateral flat shell element with in-plane rotations. *Computers & Structures*, *89*(7),612-625.

[17]. Özben, T., &Arslan, N. (2010). FEM analysis of laminated composite plate with rectangular hole and various elastic modulus under transverse loads.*Applied Mathematical Modelling*, *34*(7), 1746-1762.

[18]. Ozben tamer and arslannurettin, (), expansion of plastic zone and residual stresses in the thermoplastic-matrix laminates plates([]) with a rectangular hole subjected to transverse uniformly distributed load expansion, computational material science 44,pp895-912.

[19]. Sahu, S. K., Asha, A. V., & Mishra, R. N. (2005). Stability of laminated composite pretwisted cantilever panels. *Journal of reinforced plastics and composites*, *24*(12), 1327- 1334.

[20]. Setoodeh, A. R., &Karami, G. (2004). Static, free vibration and buckling analysis of anisotropic thick laminated composite plates on distributed and point elastic supports using a 3-D layer-wise FEM. *Engineering structures*,*26*(2), 211-220.

[21]. Shukla, K. K., Nath, Y., Kreuzer, E., & Kumar, K. V. (2005). Buckling of laminated composite rectangular plates. *Journal of aerospace engineering*,*18*(4), 215-223.

[22]. Ungbhakorn, V., &Singhatanadgid, P. (2006). Buckling analysis of symmetrically laminated composite plates by the extended Kantorovich method. *Composite structures*, *73*(1), 120-128.

[23]. Wang, C. M., Chen, Y., & Xiang, Y. (2004). Plastic buckling of rectangular plates subjected to intermediate and end inplane loads. *International journal of solids and structures*, *41*(16), 4279-4297.

[24]. Zhong, H., &Gu, C. (2007). Buckling of symmetrical cross-ply composite rectangular plates under a linearly varying in-plane load. *Composite structures*,*80*(1), 42-48.