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Impact Of Lamination Scheme For Simply Supported And Clamped Supported Composite Laminates

Yogishkumar S V [1], Sheshagiri A T [2], Biligirinayaka M [3]

[1] Lecturer, Department of Machine Tool Technology, Smt. L.V. (Govt.) Polytechnic Hassan, Karnataka, India.
[2] Lecturer, Department of Mechanical Engineering, Government polytechnic Chamarajanagar, Karnataka, India.
[3] Lecturer, Department of Machine Tool Technology, Government polytechnic Chamarajanagar, Karnataka, India.

ABSTRACT

Using the finite element (FE) approach, thin rectangular laminated composite plates are investigated under biaxial effect of in-plane compressive stresses. Applied in this work, the standard laminated plate theory (CLPT) cannot include shear deformations. According to this theory, each lamina shows linear elasticity and there is a total connection between layers that causes the laminate to be under plane strain. Extending the classical plate theory (CPT), the classical laminated plate theory (CLPT) asserts that the mid-surface normal stays straight before to deformation and maintains its straightliness post-deformation. This hypothesis is thus relevant only for the study of buckling in thin laminates. Fortran programming language has been created for this use. One may determine the convergence and accuracy of the answers given by a comparison of the finite element solutions for the biaxial buckling of thin laminated rectangular plates against different theoretical and experimental results. New numerical findings are obtained for in-plane compressive biaxial buckling to evaluate the impacts of the laminar scheme, aspect ratio, material anisotropy, fiber orientation of layers, reversed laminar scheme, and boundary conditions. Depending on the kind of end support used, the buckling load varies with the mode number at various rates. Moreover, it is shown that when the mode number rises the plate requires greater support.

Keywords: Laminated Scheme, Buckling Load, Laminated Composite, Boundary Conditions.

1. INTRODUCTION

It was a little more than three quarters of a century ago that composites were first under investigation as prospective materials for structural usage. Starting from that point and on into the present, they have been attracting more and more interest in all spheres of material science, manufacturing technology, and theoretical analysis. If one took the term "composite" at face value, it might be understood to signify practically anything. When closely examined, all materials are composites of unique components different from one another. This is the reason this is so. The word is often used in the area of contemporary materials engineering to refer to a matrix material reinforced with fibers, therefore offering a more specific description. For instance, the matrix made of thermosetting polyester that contains glass fibers is sometimes referred to as "FRP," which is an acronym for "Fibre Reinforced Plastic. In the commercial sector, this specific composite now boasts lion's share of market share.

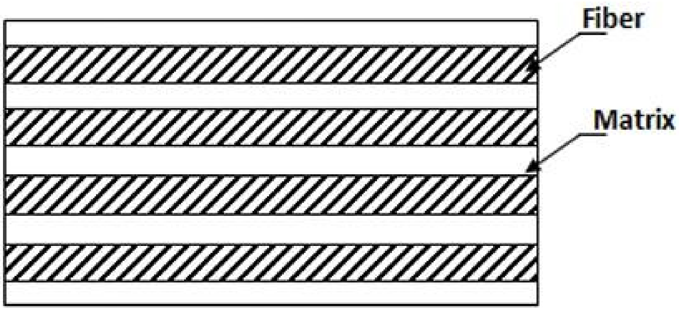

Fig. 1. Structure of a fibrous composite

Many of the composites in use today are the front edge of materials science. For really demanding uses like spacecraft, these materials provide a mix of performance and economy that fits rather well. Conversely, heterogeneous materials—which combine the best favorable features of several elements—have been used by nature for millions of years. In their imitation of the natural world, ancient civilizations used a similar strategy: as the book of Exodus notes, bricks would have little strength without the reinforcing of straw. Without straw, brick structural integrity would not have the strength seen in modern uses. From ancient times, zibala—a mixture of animal feces and mud—has been a powerful building tool used in Sudan, following Meroe civilization. This custom still exists today. Usually lacking the necessary qualities to operate as fibers alone, these materials are coupled with a matrix material that helps load transmission to the fibers and simultaneously offers wear resistance and environmental degradation prevention. These materials nonetheless have exceptionally high specific qualities when weighed, even if the matrix may partially reduce the intrinsic properties. Polymers have great use in many different fields; mostly, unsaturated styrene-hardened polyesters are used in low to medium performance settings, while more advanced thermosetting materials or epoxy resins dominate upper echelons of the market. Although their main drawback may be manufacturing complexity, thermoplastic matrix composites are progressively seen as interesting materials. These materials are usually mixed with a matrix material as they usually lack the necessary characteristics to operate independently as fibers. This matrix protects against environmental damage and wear and helps the fibers to disperse stresses. These materials nonetheless have rather high specific qualities when corrected for weight, even if the matrix may slightly reduce their natural properties. Polymers find great use in many different fields; unsaturated styrene-hardened polyesters predominate in low to medium performance categories; while epoxy and more advanced thermosetting polymers define the highest echelons of the market. Although thermoplastic matrix composites are becoming more and more interesting materials, their main drawback can be processing complexity.

2. LITERATURE REVIEW

In the field of solid mechanics, two main causes produce the deformation of a plate exposed to transverse and/or plane pressure: flexural deformation arising from the rotation of the cross-section and shear deformation resulting from the sliding of sections or layers. Two main determinants of the final deformation are the ratio of thickness to length and the interaction of elastic and shear moduli. Whereas a plate experiences mostly shear deformation when both the thickness to length ratio and the modulus ratios are significant, a thin plate mostly suffers deformation by flexure or bending when the ratio of thickness to length is small. Because of their considerable ratio of in-plane modulus to transverse shear modulus, shear deformation effects are more noticeable in composite laminates under transverse and/or in-plane stresses than in isotropic plates under identical loading circumstances. Reddy argues that the three-dimensional theories of laminates—which see every layer as a homogenous anisotropic medium—are unworkable. The existence of anisotropy often results in complex interrelations among extension, bending, and shear deformation modes in laminated composite structures, hence producing multifarious reactions under different loading circumstances. Especially with regard to composite structures, the complexity, processing needs, and generation of unnecessary data—with certain exceptions—make it difficult to efficiently solve a problem in three dimensions. Many ideas in the literature help to clarify the phenomena of normal stresses and transverse shear, as Mindlin's work shows. The sheer quantity of them makes a thorough debate in this context impossible. We will only analyze a small number of foundational works and those clarifying the contemporary debate. Within the individual layer laminate theories, every layer is seen as an autonomous entity creating a unique plate. Since the displacement fields and equilibrium equations are developed for every individual layer, neighboring layers must align at each contact using suitable interfacial conditions for displacements and stresses. Following ESL laminate theories, the coordinate across the thickness defines the stress or displacement field along with a linear combination of unknown functions. When the in-plane displacements are extended to the nth power respecting the thickness coordinate, the theory is assigned as nth order shear deformation theory. ESL laminated structures are understood from a basic framework provided by the classical laminated plate theory (CLPT). This hypothesis indicates that the ratio of length to thickness ($a/h > 20$) is kept relevant for homogeneous thin plates. The classical laminated plate theory (CLPT), which functions as an extension of the classical plate theory (CPT) especially designed for laminated structures, is the first theoretical framework devised for the analysis of laminated plates. Reissner and Stavsky developed this theory in 1961 using the fundamental ideas put out by Kirchhoff and Love—that lines normal to the mid-surface before to deformation stay straight and normal to the mid-surface subsequent to deformation. Still, it falls short for the flexural study of quite thick laminates. Still, as Srinivas and Rao and Reissner and Stavsky have shown, combined with thin composite plates, it produces results relevant to a range of engineering problems with great degree of precision. This theory treats a laminate as a single equivalent layer, therefore ignoring the components of transverse shear stress. Because transverse shear strain is neglected, Turvey, Osman, and Reddy have shown that the classical laminated plate theory (CLPT) tends to understate deflections. When plates made of advanced filamentary composite materials—including graphite-epoxy and boron-epoxy—have ratios of elastic modulus to shear modulus noticeably higher than the usual value of 2.6 for standard isotropic plates, deflection errors are much more pronounced.

3. CONVERGENCE STUDY

By use of an examination of convergence, the ideal amount of plate components in every given direction—that is, mesh size or discretization—necessary for precisely computing the buckling loads to a satisfactory degree of accuracy may be found. The appropriate number of finite elements is determined by several elements, including material qualities, dimensions of the plate, laminations configurations, boundary conditions, and computer RAM capacity. As the mode order increases, one can clearly see the need of more finite components. It follows that the higher modes would logically call for more components. Design-wise, ANSYS offers complete engineering simulation solutions covering a wide range of technical problems. Many companies in many different fields use this program. ANSYS combines the Finite Element Method (FEM) with many other programming techniques in its attempt to reproduce and improve a varied range of design issues.

Table 1. Convergence study of non – dimensional modes of buckling of simply supported (SS) isotropic square plate with a/h=20.

Mesh Size	Mode Sequence Number						
	1	2	3	4	5	6	7
2 × 2	30.69	76.89	83.18	83.49	94.71	94.95	101.78
3 × 3	32.64	79.12	79.18	117.58	179.04	189.78	191.05
4 × 4	33.60	82.38	82.44	123.22	165.70	166.35	192.53
5 × 5	34.10	84.08	84.14	127.71	168.69	168.92	202.10
6 × 6	34.39	85.10	85.15	130.85	170.41	170.52	208.35
7 × 7	34.58	85.75	85.79	133.03	171.55	171.61	212.50
8 × 8	34.70	86.19	86.23	134.57	172.34	172.39	215.79
9 × 9	34.78	86.50	86.53	135.68	172.92	172.97	218.07
10 × 10	34.84	86.72	86.75	136.52	173.35	173.40	219.78

4. RESULTS AND DISCUSSION

A choice was taken to do particular study situations and provide fresh insights into biaxially loaded laminated composite rectangular plates considering the confidence built in the finite element (FE) software by several verification activities. On each of the four sides, it was hypothesised that the plates displayed either simply supported (SS), clamped (CC), or a mix of clamped and simply supported properties (CS). Using a finite element model, an energy technique is used to examine and solve the critical buckling stresses in laminated composite plates. In connection with such concept, we investigate a rectangular element of a plate with four nodes. Each individual component at every node has three degrees of freedom. Researchers are looking at how many elements affect the non-dimensional critical buckling stresses of laminated composite plates. These elements include the laminar scheme, aspect ratio, material anisotropy, layer fiber orientation, reversed laminar scheme, and boundary conditions.

Table 2. The first five non – dimensional buckling loads

Lamination Scheme	Mode Number	Boundary Conditions		
		SS	CC	CS
0/ 90/ 90/ 0	1	0.6972	2.1994	1.8225
	2	1.2522	2.5842	2.0097
	3	2.4284	4.1609	2.7116
	4	2.6907	4.7431	4.3034
	5	2.7346	5.0168	4.4536
0/ 90/ 0/ 90	1	0.6973	2.2273	1.5591
	2	1.9947	3.9687	2.3391
	3	1.9958	3.9732	3.7581
	4	2.6912	4.7871	3.8290
	5	4.3962	7.0544	4.5402

45/-45/-45/45	1	0.8729	1.9505	1.4756
	2	1.6400	2.8534	2.1162
	3	2.3130	3.8941	3.3039
	4	2.7100	4.3753	3.3068
	5	3.5488	5.2694	4.4166
45/-45/45/-45	1	0.8729	2.2010	1.6554
	2	1.6400	3.7616	2.5672
	3	2.3130	3.7654	3.4642
	4	2.7100	5.6599	4.2174
	5	3.5488	5.9540	4.8091

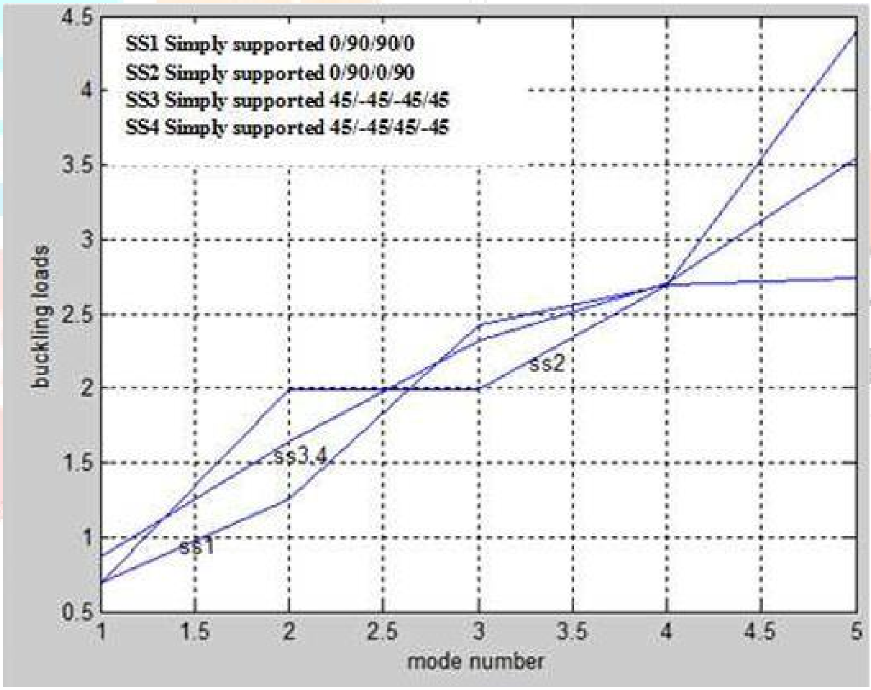

Fig. 2 Effect of lamination scheme for simply supported laminates

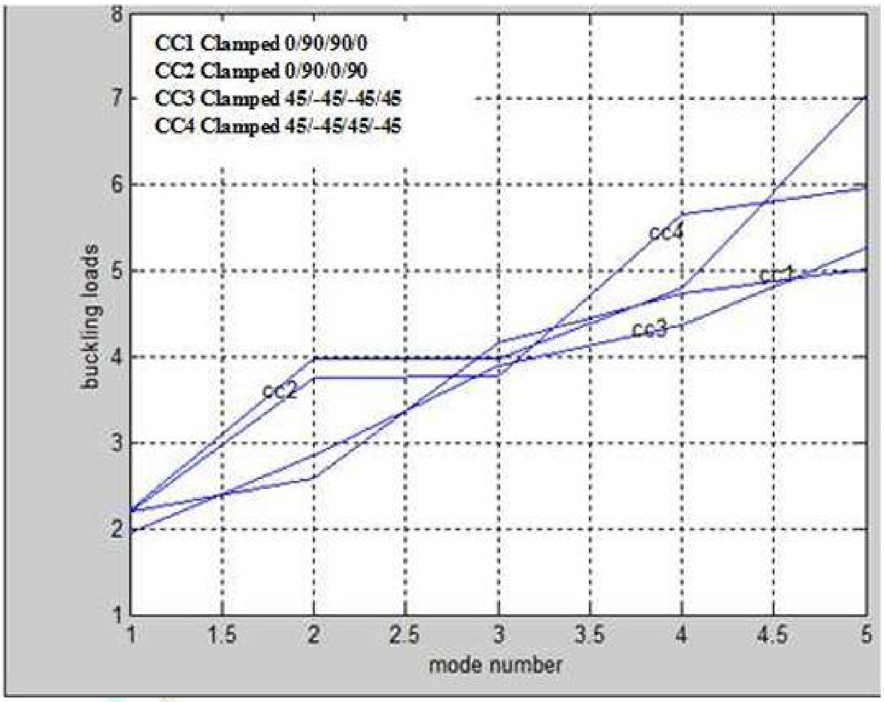

Fig. 3 Effect of lamination scheme for clamped – clamped laminates

According to the current study the laminating pattern of plates should be symmetric, anti-symmetric, and quasi-isotropic.

Four laminates with symmetric and anti-symmetric cross-ply and angle-ply laminates were under consideration. Table (2) compares the non-dimensional buckling stresses across all laminating techniques. Fig. (2) shows the findings visually. Assumed to be equal is the thickness of all layers; the length to thickness ratio (a/h=20); and the modulus ratio (E1/E2=5). Except for symmetric and anti-symmetric angle – ply laminates which are precisely the same, it is seen from table (2) and Figs. (2) and (3) that the values of the non-dimensional buckling loads for both symmetric and anti-symmetric laminates are somewhat different. This means that the remainder of the forthcoming impacts will be covered only in symmetric cases. The findings show that the symmetric laminate has stiffness more than the anti-symmetric one. Coupling between bending and stretching causes this phenomena, which reduces the buckling stresses of symmetric laminate.

5. CONCLUSIONS

To analyze buckling on thin rectangular laminated plates in classical laminated plate theory (CLPT), Fortran software has been created using finite element techniques (FEM). Composite plates in layers may experience buckling pressures, which scholars have studied. The problem is evaluated and handled using a finite element model and energy approach. Quadrilateral components are used in this four-node architecture. Each component has three degrees of freedom at every node. Using the finite element model, buckling stress was computed. The study examined the non-dimensional critical buckling loads of laminated composite plates with rectangular cross-sections and the effects of lamination schemes, aspect ratios, material anisotropy, fiber orientation of layers, reversed lamination schemes, and boundary conditions. New findings were revealed to the audience. The aspect ratio increases the buckling stress, however this increase is not uniform. The critical load may increase owing to bending-extensional twisting stiffness. A plate's buckling resistance depends on its limitations. Constraints reduce structural rigidity, explaining these occurrences. The buckling load grows with mode number, but at different rates depending on whether the plate is simply supported (SS), clamped (CC), or both. Each mode number increases load at different rates. The buckling load is lowest while the plate is supported and highest when clamped. The buckling load is larger under clamped boundary circumstances than in merely supported boundary conditions. This is because the clamped boundary condition is rigider. As the mode number increases, the plate needs greater support.

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