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Research Paper

Buckling Mode Shape of the Rectangular Composite Plate with Square Cutout Subjected to Various In-plane Compressive Loading Conditions

Made Gowda B [1], Honna Prabhu Lingegowda B M [2]
[1, 2] Senior Scale Lecturer, Department of Automobile Engineering, Government Polytechnic Channapatna, Karnataka, India.

Abstract: *The impact of the plate aspect ratio on buckling behavior was examined statistically using this sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated composite plate* $[0°/+45°/-45°/90°]_{2s}$*, which includes square and rectangular slices. The plate was subjected to a sequence of finite element method (FEM) in-plane compressive loads that were linearly variable. With boundary conditions, the plate length/thickness ratio (a/t), and the dimensions of square or rectangular cuts taken into account, this research investigates the buckling behavior of symmetrically laminated rectangular composite plates that are exposed to linearly increasing in-plane compressive stresses. The findings show that the buckling loads of rectangular composite plates with square or rectangular cutouts can be reduced by increasing the aspect to thickness and length ratio, regardless of the dimensions, configuration, or boundary conditions of the cutout, when these plates are subjected to different linear in-plane loads. A rectangular composite plate with a square or rectangular cutout will have its buckling strength significantly affected by in-plane loads that change linearly with respect to boundary conditions, aspect ratio (a/b), and length-to-thickness ratio (a/t).*
Keywords: *Mode Shape, Rectangular Composite Plate, FEM, Square Cutout, Compressive Load.*

I. Introduction

The external application of compressive pressures causes composite laminated plates to buckle. Combining the properties of two or more materials into a single composite makes it possible to achieve results that would be impossible with just one of the individual components. These materials are the building blocks of composites. The fibers in these materials bear a disproportionate share of their total weight. A low-modulus, high-elongation matrix not only provides flexible structural performance, but it also shields fibers from outside pressures and keeps them in the right place. Composites, which consist of two or more materials, have the potential to significantly reduce building weight without sacrificing strength-to-weight ratio due to their part composition. This is due to the fact that composites consist of several elements. The building sector often makes use of laminas, which are thin sheets. This is a common use for fiber-reinforced composites. One kind of material macrounit that is prevalent in the material is laminae. The stacking order of the layers and the orientation of the fibers inside each lamina may be adjusted to give the material the strength and stiffness required for a specific application. The unique mix of properties caused by the composition, distribution, and orientation of a composite material's component elements is what gives it its distinctive properties. Cutouts are essential for several purposes, such as reducing component weight, improving air circulation, and connecting nearby components. As a composite material, carbon-fiber reinforced plastic is made by combining thermosetting resins with various types of carbon fibers. A polymer that is nonconductive, lightweight, and reinforced with fibers made of carbon fiber is carbon fiber reinforced plastic, or CFRP for short. An ingredient with a very long-lasting impact. Multiple designs including stacking many fiber sheets have the potential to significantly enhance the material's strength and stiffness. It is possible to get the intended result by doing this. Parth Bhavsar and colleagues used the finite element method to examine the buckling behavior of glass fiber reinforced polymer (GFRP) subjected to linearly increasing loads.

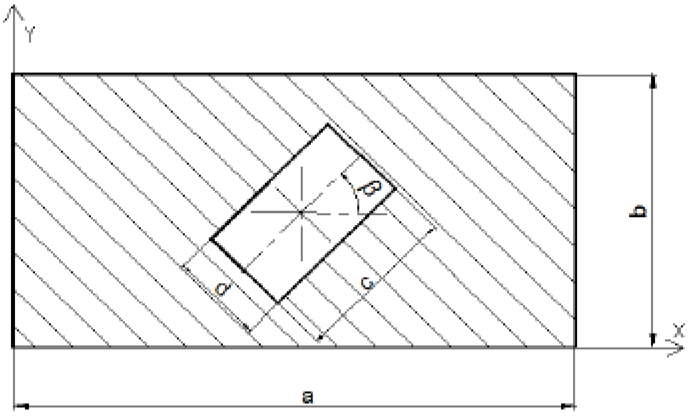

Figure 1: Geometry of the model.

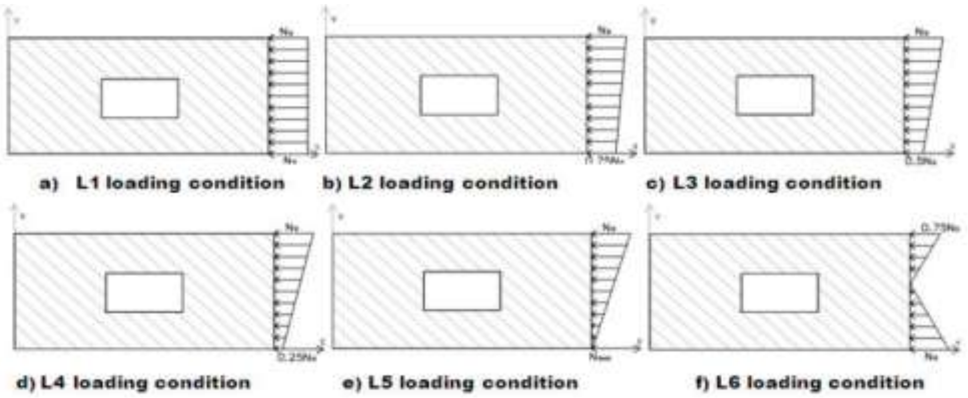

Figure 2: Details various loading conditions

Researchers have looked at the buckling stress of one-dimensional rectangular plates by examining a variety of properties to determine the effect of each on the stress. After subjecting a rectangular plate with circular incisions to biaxial compression, Joshi and colleagues used two-dimensional finite element analysis to find the buckling stress per unit length. Changing the length-to-thickness ratio and situating the holes are two options for assessing the buckling variables. In the absence of a border clamp, Nagendra Singh Gaira and colleagues studied the buckling behavior of laminated rectangular plates. A favorable development is the decrease in the buckling load caused by the presence of cuts. The goal is to reduce the buckling load factor, which may be achieved by increasing the aspect ratio. The influence of an axial load on the buckling load of a laminated composite cylindrical panel was the focus of the buckling study conducted by Hamidreza Allahbakhsh and Ali Dadrasi. An elliptical cutout appeared in a variety of sizes and placements throughout the research. Container Okutan Baba spends his time studying how various cut-out shapes, length-to-thickness ratios, and ply orientations affect the buckling stress that rectangular plates experience. After subjecting E-glass/epoxy composite plates to in-plane compression stress, the researchers used both theoretical and experimental approaches to determine the impact of these parameters on the buckling behavior of the plates. In their study of composite laminate skew plates subjected to uniaxial compressive loads, Hsuan-Teh Hu and colleagues found that the failure criteria and nonlinear in-plane shear greatly affected the ultimate loads applied to the plates. Compared to the less consequential linearized buckling loads, this is a huge deal.

II. Finite Element Model

An easy way to conform to the guidelines for the conference paper's structure. This study aims to find the buckling load factors of square and cylindrical carbon fiber composite plates using finite element analysis. We are using ANSYS Version 14.5 with the APDL version. The size of the plate is checked by considering three distinct border criteria. In these cases, we have the clamped and unclamped situations. Each scenario in the second case has three levels, while the first one only has two. Given that the stacking sequences employed were [0°/+45°/-45°/90°]2s, it's plausible that this is the reason. The plate has to have many center holes of the same size punched for the research to be conducted. The center holes may be arranged in a variety of different ways, including square, triangle, circular, and star configurations. Research on the characteristics of the buckling load factor is under underway. Applying finite element method (FEM) to quasi-isotropic graphite/epoxy composite plates with square/rectangular cuts and linearly increasing in-plane compressive loads, this study examines the buckling response as a function of plate aspect ratio (a/b), length/thickness ratio (a/t), and boundary conditions. The lamina is built using epoxy as the matrix material and graphite fibers as the reinforcing. These material characteristics of graphite/epoxy are provided in Table 1, which is based on the study of Hsuan Teh Hu and Bor Horng Lin (1995). All the while, the material's x-axis and y-axis are in perfect alignment with the global x and y axes, respectively. Pressural stresses acting on the plate are orthogonal to the international x-axis. It just so happens that the 0° fiber runs in the same direction as the compressive load.

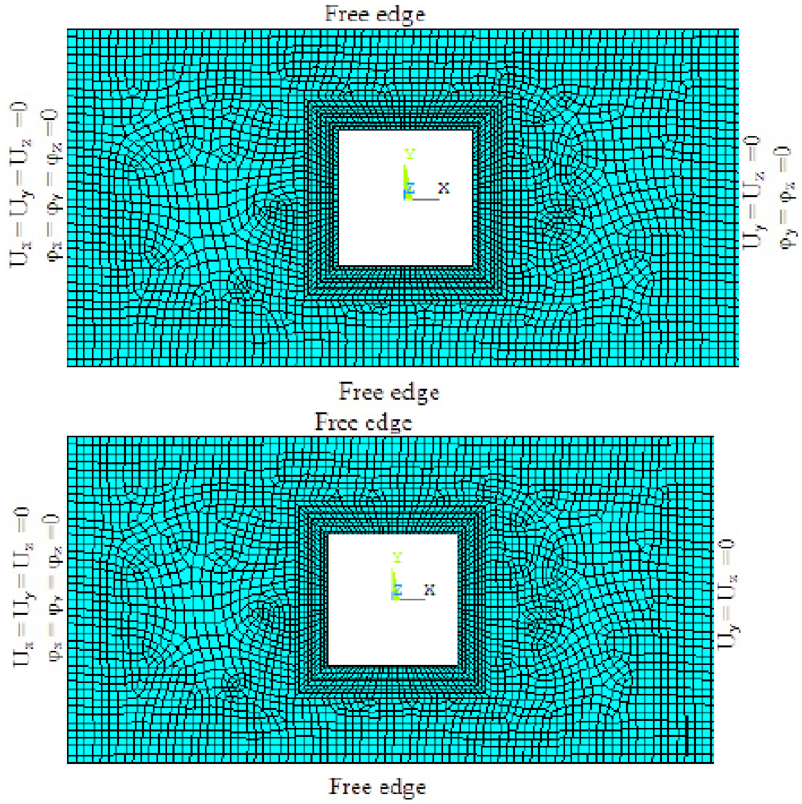

Figure 3: FE model with mesh

III. Description Of Element

Regarding this research work, the SHELL281 element type is being used. With this shell element present, very thin or somewhat thick shells may be more easily analyzed. As an added bonus, its versatility makes it an ideal material for simulating sandwich structures and layered composite coverings. Applications exhibiting significant strain nonlinearity, linearity, or rotation are ideal candidates for the efficient exploitation of this material. Eleven nodes comprise the element, and every one of those nodes has six degrees of freedom. Equipped with these degrees of freedom, the element may be rotated about its three axes and translated along its internal x, y, and z axes. In projects where cylindrical plates are utilized for investigation, the nonlinear element S8R5 is used. Every one of the eight nodes that make up this element may be freely moved in five different ways. The presence of this element may be used to identify it.

IV. Geometric Modelling And Material Property

Figure 1 clearly shows that the geometry matches the description. The length of plate 'a' is 200 mm and the width of plate 'b' is 100 mm. Each of the sixteen layers of this laminate measures 0.125 mm in thickness. The initial "t" stands for the plate's thickness, while the form of the cutout orientation angle is indicated by the letter "β". In this analysis, the cutout orientation angle is taken to be zero degrees. A rectangular plate with a cutout in the center serves as the foundation for the item. The dimensions of the cutout are its length (c) and its width (d). If the ratios of c and d are equal, the square hole will be formed out of the rectangle one. Furthermore, under the identical circumstances as before, the impact of square holes is investigated. The buckling analysis considers both square and rectangular holes.

Table 1 : Property of composite material

E_{11} (GPa)	E_{22} (GPa)	v_{12}	$G_{12} = G_{13}$ (GPa)	G_{23} (GPa)
128	11	0.25	4.48	1.53

V. Results And Discussion

The goal of this section is to examine the effects of various ply orientations on the plate when subjected to the same boundary condition. All of these events will transpire simultaneously. This is a case of a fixed condition at the border, and it is currently being considered. This part makes use of a variety of ply orientations. This is the order of the orientations: from 0 degrees to 90 degrees in [0°/+45°/-45°/90°]2s. Should you need any more information, please consult the list that has been supplied below. In order to determine the outcomes that will be brought about by the situation, study is conducted on both of them. We take a look at both of them and consider the consequences that will follow. Figures below show the effects of boundary conditions, linearly increasing in-plane compressive stress, rectangular/square cutout, plate aspect ratio (a/b), and length/thickness ratio (a/t) on buckling loads of a rectangular composite plate.

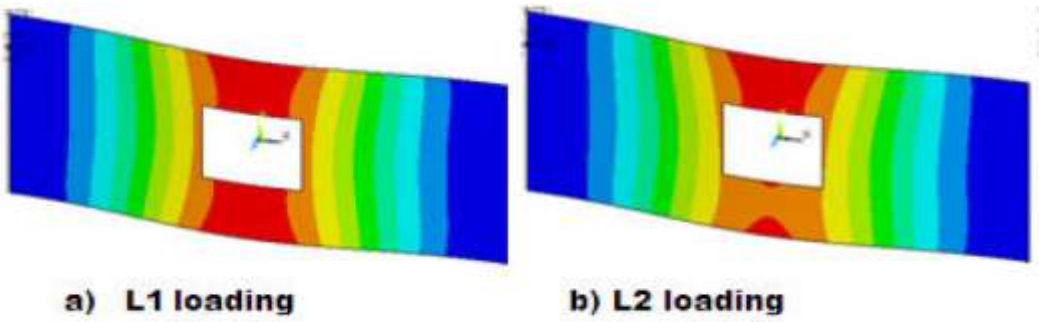

Figure 4 : First Mode shape under L1 and L2 loading conditions

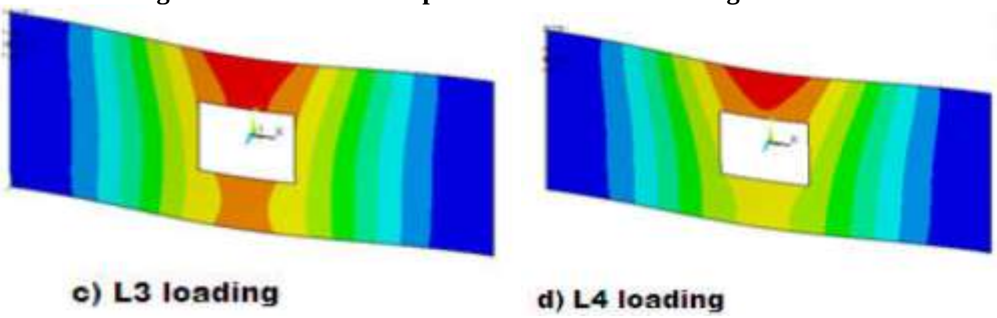

Figure 5 : First Mode shape under L3 and L4 loading conditions

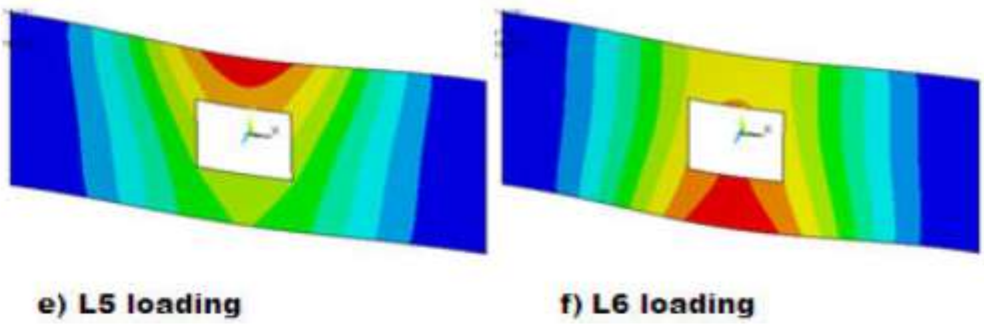

Figure 6 : First Mode shape under L6 and L7 loading conditions

When a structure experiences buckling or vibration at a particular mode, its distinctive deformation pattern is known as the mode shape. Mode shapes are used in structural analysis to explain how a structure deforms under various buckling loads or natural frequencies. A structure (such a composite plate) may bend and become unstable when exposed to rising in-plane compressive stresses. The deformation pattern at the lowest critical buckling load is represented by the first buckling mode shape. The first mode shape often has the simplest deformation pattern and correlates to the lowest buckling load. Greater mode forms exhibit more complicated deformations (with more waves or curvatures) and arise under greater loads.

A square cutout alters the mode shape and weakens the plate, often focusing deformation around the cutout. The buckling behavior is greatly influenced by the cutout's size and location.

There are a number of important criteria that determine the form of the initial buckling mode of a rectangular composite plate that has a square cutout when subjected to a variety of in-plane compressive stress situations. "Aspect ratio" refers to the ratio of the plate's length to its breadth.

The dimensions of the square cutout as well as its position. In the composite layers, the fiber orientation and stacking sequence are both important.

Material qualities that are orthotropic include the elastic modulus, the shear modulus, and Poisson's ratio. The buckling reaction is substantially impacted by whether the edges are simply supported, clamped, or free or free.

It is possible for asymmetric mode forms to be introduced by mixed boundary conditions. Depending on the size of the cutout and the boundary circumstances, the first mode shape will often display either symmetric or asymmetric deformation characteristics.

In the vicinity of its edges, the cutout functions as a stress concentrator, which results in localized buckling from the tension. The critical buckling load is decreased as the size of the cutout is increased, which also results in a change in the mode shape due to the shifting of the deformation zones. In composites that are reinforced with fibers, the orientation of the fibers has a considerable impact on the deformation pattern.

VI. Conclusions

The unique deformation pattern of a structure undergoing buckling or vibration at a certain mode is referred to as the mode shape. Mode shapes are used in structural analysis to elucidate the deformation of a structure under different buckling loads or natural frequencies. A structure, such as a composite plate, may deform and become unstable when subjected to increasing in-plane compressive pressures. The deformation pattern at the minimum critical buckling load is characterized by the first buckling mode shape. The initial mode shape often exhibits the most straightforward deformation pattern and corresponds to the minimum buckling load.

Higher mode forms demonstrate more complex deformations (including more waves or curvatures) and occur under increased stresses.A square cutout modifies the mode shape and compromises the integrity of the plate, often concentrating deformation in the vicinity of the cutout. The buckling behavior is significantly affected by the dimensions and position of the cutout.

References

[1]. Khdeir AA. Free vibration and buckling of symmetric cross-ply laminated plates by an exact method. J Sound Vib 1988; 126:447–61.

[2]. F. Millar, D. Mora, A finite element method for the buckling problem of simply supported Kirchhoff plates, Journal of Computational and Applied Mathematics 286 (2015) 68-78.

[3]. Jain,P., Ashwin,K.. Post buckling response of square laminates with a central/elliptical cutout. Compos Struct. 75, (2004).

[4]. Aydin Komur.M et al. (2010) Buckling analysis of laminated composite plates with an elliptical/circular cutout using FEM. Advances in Engineering Software 41: 161-164.

[5]. B.O. Baba, A. Baltaci, Buckling characteristics of symmetrically and antisymmetrically laminated composite plates with central cutout, Applied Composite Materials 14(4) (2007) 265-276.

[6]. Ghannadpour, S.A.M., Najafi,A., Mohammadi,B.: Buckling of Cross-ply laminate composite plates due to circular/elliptical cutouts. Compos.Struct.27 pp. 3-6 (2006).

[7]. Afsharmanesh, B., Ghaheri, A. and Taheri-Behrooz, F. (2014), "Buckling and vibration of laminated composite circular plate on winkler-type foundation", Steel and Composite Structures, 17(1), 1-19.

[8]. Y. Zhang, C. Yang, Recent developments in finite element analysis for laminated composite plates, Composite Structures 88(1) (2009) 147-157.

[9]. M. Dehghan, G.H. Baradaran, Buckling and free vibration analysis of thick rectangular plates resting on elastic foundation using mixed finite element and differential quadrature method, Applied Mathematics and Computation 218(6) (2011) 2772-2784.

[10]. R. Mania, Buckling analysis of trapezoidal composite sandwich plate subjected to in-plane compression, Composite Structures 69(4) (2005) 482-490.

[11]. B.O. Baba, Buckling behavior of laminated composite plates, Journal of Reinforced Plastics and Composites (2007).

[12]. Ganesh Soni, Ramesh Singh and Mira Mitra, Buckling behavior of composite laminates subjected to nonuniform In-plane loads, International Journal of Structural Stability and Dynamics 2013.

[13]. Topal U, Uzman U (2008) Maximization of buckling load of laminated composite plates with central circular holes using MFD method. Struct Multidisc optim35:131-139.