Quest Journals
Journal of Research in Mechanical Engineering
Volume 3 ~ Issue 5 (2017) pp: 52-57
ISSN(Online):2321-8185
www.questjournals.org

Research Paper

An Examination of the Influence of Various Plate Aspect Ratios on the Buckling Analysis of Laminated Composites in Clamped-Free Conditions

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

Abstract: *This sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated composite plate [0°/+45°/-45°/90°]$_{2s}$, including square and rectangular cuts, has been statistically analyzed to assess the influence of plate aspect ratio on buckling behavior. The plate underwent a series of linearly variable in-plane compressive stresses by the finite element method (FEM). This study examines the buckling behavior of symmetrically laminated rectangular composite plates subjected to linearly increasing in-plane compressive loads, considering the effects of boundary conditions, the plate length/thickness ratio (a/t), and the dimensions of square or rectangular cutouts. The results indicate that, irrespective of the dimensions, configuration, or boundary conditions of the cutout, the buckling loads of rectangular composite plates with rectangular or square cutouts, when subjected to varying linear in-plane loads, can be diminished by augmenting the ratio of the plate's aspect to its thickness and length. The buckling strength of a rectangular composite plate including a square or rectangular cutout is profoundly influenced by boundary conditions, aspect ratio (a/b), length-to-thickness ratio (a/t), and other linearly changing in-plane loads.*
Keywords: *Plate Aspect Ratio, Buckling Analysis, FEM, Clamped-Free Conditions.*

I. Introduction

Buckling occurs in composite laminated plates when they are subjected to compressive stresses from an external source. A composite is a material that is composed of two or more components that, when combined, provide qualities that are difficult to accomplish with a single component used alone. Composites are made up of these materials. An significant portion of the weight of these materials is carried by the fibers. In addition to providing flexible structural performance, matrices that have a low modulus and a high elongation protect fibers from environmental stresses and ensure that they remain aligned and in the proper location. The composition of the parts of composite materials, which are made up of two or more components, may greatly lower the weight of construction while still retaining a high strength-to-weight ratio. This is because composite materials are made up of several components. Laminas, which are thin sheets, are often used in the construction industry. Fiber-reinforced composites are frequently used in this capacity. Laminae are the specific kind of material macrounit that are found in the material the most often. In order to achieve the necessary level of strength and stiffness for a particular application, modifications may be made to the sequence in which the layers are stacked, as well as to the orientation of the fibers that are contained inside each lamina. Characteristics that set a composite material apart from other materials are the consequence of a singular combination of characteristics that are brought about by the composition, distribution, and orientation of the composite's constituent parts. Cutouts are necessary for a variety of reasons, including the decrease of components' weight, the enhancement of air circulation, and the establishment of connections between components that are located in close proximity to one another. Combining a number of different kinds of carbon fibers with thermosetting resins results in the production of a composite material known as carbon-fiber reinforced plastic. Carbon fiber reinforced plastic, often known as CFRP, is a polymer that is nonconductive, lightweight, and strengthened with fibers by using carbon fiber. A substance that has an extremely long-lasting effect. The material's strength and stiffness may be considerably improved by stacking a large number of fiber sheets in a variety of configurations. This can be done in order to get the desired effect. For the purpose of analyzing the buckling behavior of glass fiber reinforced polymer (GFRP) under linearly increasing stresses, Parth Bhavsar and his colleagues used the finite element approach.

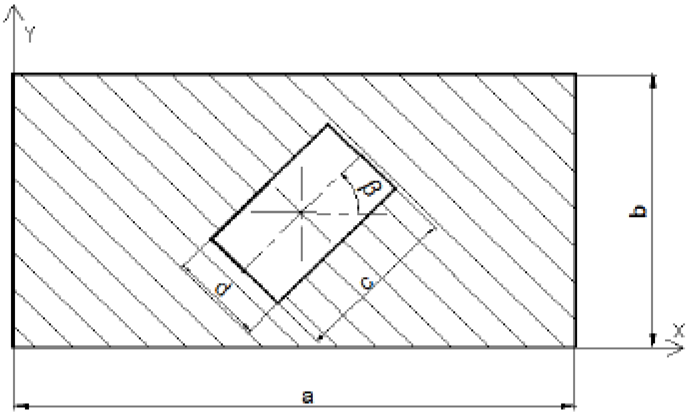

Figure 1: Geometry of the model.

The buckling stress of rectangular plates with an aspect ratio of one has been investigated by researchers who have investigated a wide range of characteristics to see how they influence the stress. In order to determine the buckling stress per unit length of a rectangular plate with circular cuts that was subjected to biaxial compression, Joshi and his colleagues performed two-dimensional finite element analysis. For the purpose of evaluating the buckling factors, there are two methods that may be utilized: adjusting the ratio of length to thickness and positioning the holes. The buckling behavior of laminated rectangular plates was investigated by Nagendra Singh Gaira and his colleagues under conditions when there was no clamp being applied to the border. The presence of cutouts results in a reduction in the buckling load, which is a positive development. An increase in the aspect ratio will lead to a decrease in the buckling load factor, which is the desired objective. The purpose of the buckling research that Hamidreza Allahbakhsh and Ali Dadrasi carried out on a laminated composite cylindrical panel was to investigate the impact that an axial load has on the buckling load of the panel. Throughout the course of the study, an elliptical cutout was present in a number of different sizes and positions. Over the course of his research, Container Okutan Baba investigates the ways in which different cut-out geometries, length-to-thickness ratios, and ply orientations influence the buckling stress that is generated on rectangular plates. Both theoretical and experimental methods were used by the researchers in order to ascertain the influence of these factors on the buckling behavior of E-glass/epoxy composite plates that were exposed to in-plane compression stress. When Hsuan-Teh Hu and his colleagues conducted a finite element buckling research on composite laminate skew plates that were subjected to uniaxial compressive loads, they discovered that the failure criteria and nonlinear in-plane shear had a significant impact on the ultimate loads that were placed on the skew plates. There is a significant difference between this and the linearized buckling loads, which have a smaller impact.

II. Finite Element Model

A straightforward method for satisfying the standards established for the format of the conference paper. Using finite element analysis, the purpose of this investigation is to determine the buckling load factors of carbon fiber composite plates that have either a square or cylindrical form. The version of APDL that is used is ANSYS Version 14.5. There are three separate boundary conditions that are taken into consideration while checking the size of the plate. These circumstances are the fixed, clamped, and unclamped scenarios. The first scenario is comprised of two levels, whilst the second scenario is composed of three levels each scenario. It's possible that this is because of the stacking sequences that were used, which were [0°/+45°/-45°/90°]2s, respectively. In order to carry out the study, the plate has to be perforated with a significant number of center holes that are precisely the same size. Several other configurations, such as square, triangular, circular, and star arrangements, are all possible for the center holes to be positioned. At the moment, an investigation on the properties of the buckling load factor is being carried out.

In this work, finite element method (FEM) is used to investigate the influence of plate aspect ratio (a/b), length/thickness ratio (a/t), and boundary conditions on the buckling response of quasi-isotropic graphite/epoxy composite plates with square/rectangular cuts when subjected to linearly increasing in-plane compressive loads. With graphite fibers serving as reinforcement and epoxy serving as the matrix material, the lamina is constructed. Based on the research conducted by Hsuan Teh Hu and Bor Horng Lin (1995), the material properties of graphite/epoxy are shown in Table 1. Axis 1 of the material is aligned with the global x axis, and axis 2 of the material is aligned with the global y axis throughout the process. There is a congruence between the compressive loads that are applied to the plate and the global x-axis. The direction in which the compressive load is applied coincides with the direction of the 0° fiber.

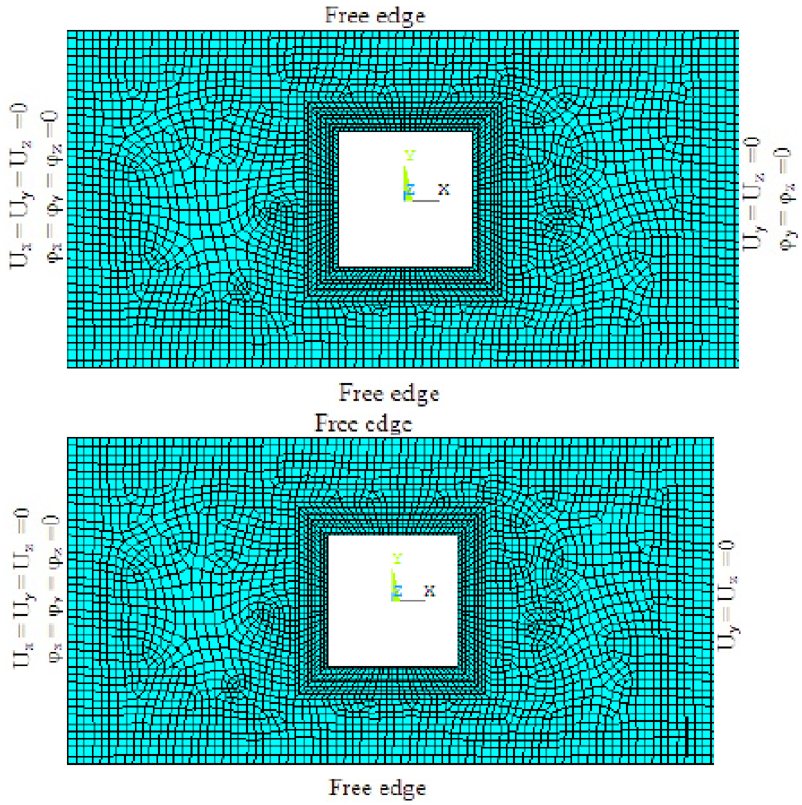

Figure 2: FE model with mesh

III. Description Of Element

The SHELL281 element type is being used for the purpose of this project. The presence of this shell element makes it easier to analyze shells that are either exceedingly thin or fairly thick. Additionally, due to the fact that it can be applied in a wide variety of various ways, it is a perfect material for modeling layered composite coatings and sandwich structures. The effective usage of this material for applications that demonstrate considerable strain nonlinearity, linearity, or rotation are perfect candidates for the successful utilization of this material. In all, there are eight nodes that make up the element, and each of them has six degrees of freedom. As a result of these degrees of freedom, it is possible to rotate around the three axes and to translate along the x, y, and z axes that are included inside the element. The nonlinear element S8R5 is used in projects that include the usage of cylindrical plates for study. There are eight nodes in this element, and each of them has five degrees of freedom. This element may be detected by its existence.

IV. Geometric Modelling And Material Property

As may be seen in Figure 1, the geometry is as described. Plate 'a' is 200 millimeters in length, while plate 'b' measures 100 millimeters in width. In this sixteen-layer laminate, each layer has a thickness of 0.125mm. The letter "t" denotes the thickness of the plate, and the letter "β" specifies the shape of the cutout orientation angle. The cutout orientation angle is assumed to be 0 degrees for the purposes of this study. The piece relies on a rectangular cutout that is positioned in the middle of a rectangular plate. c is the length of the cutout, and d is the breadth. The rectangular hole changes into a square hole when the ratios c and d are equal to one another. Additionally, the influence of square holes is explored using the same conditions as before.In the buckling analysis, both square and rectangular holes are taken into consideration.

Table 1 : Property of composite material

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

V. Results And Discussion

When the plate is exposed to the same boundary condition, the objective of this section is to study the impact that different ply orientations of the plate have on the plate. On the same day, all of these things will take place. At the border, this is an example of a fixed condition, and it is now being taken into consideration. A number of different ply orientations are used in this section. The orientations are as follows: [0°/+45°/-45°/90°]2s to 90°. Please refer to the list that is provided below for any further information. Both of them are investigated, and research is carried out in order to ascertain the consequences that will result from the circumstance. Both are examined, and the implications that will be brought about as a consequence are looked at.

The following figures demonstrate how the buckling loads of a rectangular composite plate with a rectangular/square cutout are affected by the plate aspect ratio (a/b), the length/thickness ratio (a/t), boundary conditions, and linearly rising in-plane compressive stress.

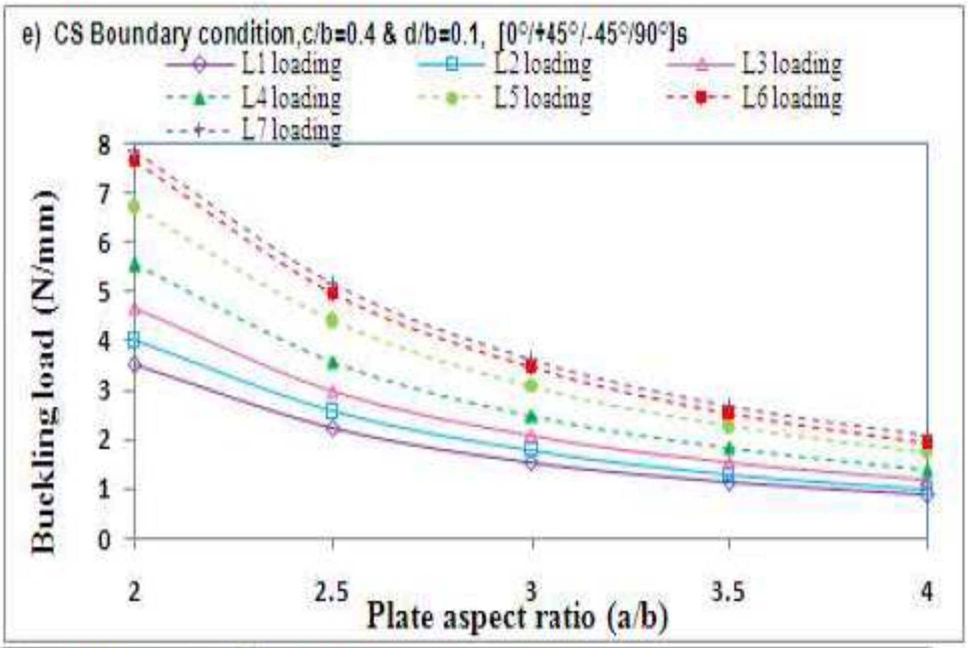

Figure 3 : Effect of plate aspect ratio with holes with unsymmetrical (S) layup under CS condition

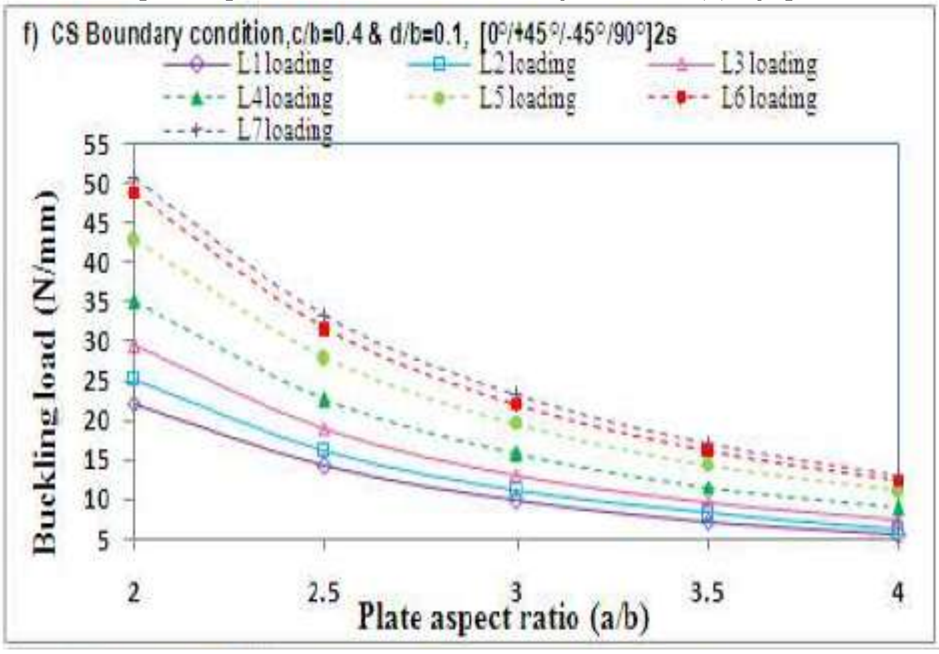

Figure 4 : Effect of plate aspect ratio with holes with unsymmetrical (2S) layup under CS condition

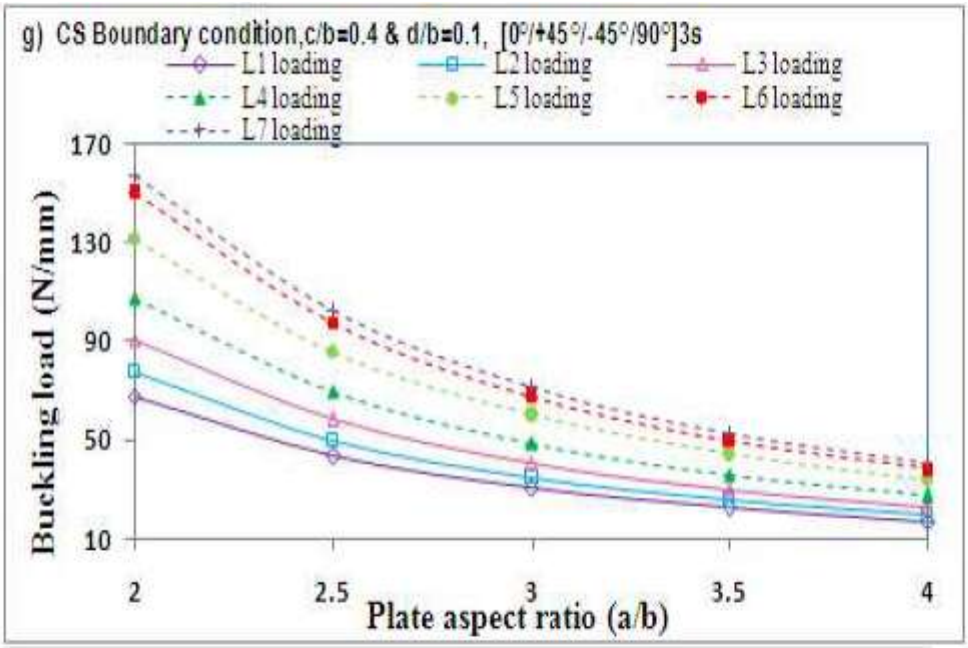

Figure 5 : Effect of plate aspect ratio with holes with unsymmetrical (3S) layup under CS condition

The following figures demonstrate how the buckling loads of a rectangular composite plate with rectangular/square cuts are affected by the plate aspect ratio (a/b), the length/thickness ratio (a/t), boundary conditions, and linearly rising in-plane compressive stress. It is shown in the figures that the buckling loads of a rectangular composite plate with a square/rectangular cutout vary by 35.8%, 30.4%, 26.44%, and 23.4% for a/b=2-2.5, a/b=2.5-3, a/b=3-3.5, and a/b=3.5-4, respectively. This is the case regardless of the length/thickness ratios (a/t), boundary conditions, and linearly varying inplane compressive loading. When compared to a plate with plate aspect ratios of 2.5, 3, 3.5, and 4, respectively, the buckling load of a rectangular composite plate with an aspect ratio of a/b=2 is 1.5 times, 2 times, 3 times, and 4 times more than the buckling load achieved by a plate with a plate aspect ratio of a/b=2. Regardless of the length-to-thickness ratios (a/t), boundary conditions, or linearly increasing inplane compressive force, this is always the case. The buckling load of a rectangular composite plate with a square/rectangular cutout is reduced by 74% when the plate aspect ratio is increased from 2 to 4. This reduction occurs independently of the length/thickness ratios (a/t), boundary conditions, and linearly changing inplane compressive pressures.

VI. Conclusions

This investigation investigates the influence of plate aspect ratio, length/thickness ratio, boundary conditions, and linearly varying in-plane compressive loading conditions on the buckling behavior of a sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated rectangular composite plate $[0°/+45°/-45°/90°]_{2s}$ with square/rectangular cutout.

The buckling load of the rectangular composite plate with a/b=2 is greater than that of plates with a/b=2.5, 2.5, 3.5, and 4, irrespective of boundary conditions, linearly varying inplane compressive loading, or length/thickness ratios (a/t). No matter the plate aspect ratios (a/b), boundary conditions, or linearly varying inplane compressive loading, the buckling load of a rectangular composite plate with square/rectangular cutaway decreases by 97% as the plate length/thickness ratio increases from 50 to 200.

The buckling load of a rectangular composite plate with square/rectangular cutout decreases by 97% as the plate length/thickness ratio increases from 50 to 200, regardless of the plate aspect ratios (a/b), boundary conditions, and linearly varying inplane compressive loading.

References

[1]. 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.
[2]. Jain,P., Ashwin,K.. Post buckling response of square laminates with a central/elliptical cutout. Compos Struct. 75, (2004).
[3]. 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.
[4]. 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.
[5]. 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).

[6]. 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.

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

[8]. 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.

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

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

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

[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.