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AN OVERVIEW OF BUCKLING ANALYSIS OF SINGLE PLY COMPOSITE PLATE WITH CUTOUTS

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Abstract

The use of Composite material in aircraft industries is booming now-a days to grab the advantage of high strength to weight ratio. These materials are used to build main components of aircraft like fuselage, panels, rudder, and skins. It is unavoidable to provide different size, shaped cutouts in such components for different purpose i.e inspection, maintenance. The buckling behavior on composite plate with different shape, size and location of the cutouts have been explore by many researchers in last 2 decades. The presented review article is an attempt to summarize the issue of critically examine the current status, problems and opportunities to use of single ply composite in aircraft industries.

Keywords:composite material, aircraft, single ply, cutout size, cutout shape, buckling analysis with FEA and Experimental.

INTRODUCTION

The buckling behavior of plates has been studied by many researchers in structural mechanics for aircraft and other structural parts over a Century. Steel, Aluminium, Titanium plates are often used as the main components of aircraft structures such as fuselage, panels, elevator, rudder, skins etc. So for making optimum structural components material must have best characteristics then other conventional materials. So composite materials are widely used for this purpose, like carbon fiber reinforced polymer (CFRP), Glass fiber reinforced polymer (GFRP), Aramide fiber reinforced polymer (AFRP), etc.

There are various holes, vents, cutouts and passage are provided for different purpose, to provide access for inspection, maintenance, or simply to reduce weight. Due to this cutouts in plate elements leads to change in stress distribution within the member and variations in buckling characteristics of the plate element. The effects of the shape, size, location and types of applied load on the performance and buckling behavior of such perforated plates have been investigated by several researchers over the past two decades. Many researcher explore such results for their research work.

REVIEW

These papers have been reviewed for this study. Following researches is based on their methodology, principles and their conclusions.

Donnie G. Brady, Melody A. Hammond explored manufacturing and usage of single ply composite plates, it is a Patent for Single ply reinforced thermoplastic composite. Multiple ply laminates have been used in the aircraft industry for window shades and other applications. A problem with multiple ply laminates is that they are relatively more expensive than single ply composites. However, earlier single ply laminates have a problem to have brittle, and thus not well adapted for being rolled as is required in a window shade application as well as for layering fuselage, fairing and for other components. The invention of a single ply thermoplastic composite is very useful concept for aircraft manufacturer.

Arunkumar R. investigated Buckling Analysis of Woven Glass epoxy Laminated Composite Plate,In this study, the influence of cut-out shape, length/thickness ratio, and ply orientation and aspect ratio on the buckling of woven glass epoxy laminated composite plate

is examined experimentally. From the present analytical and experimental study, the following conclusions can be made. They found following results

- The buckling load decreases as the L/t (length to thickness) ratio of plate increases.
- As the aspect ratio increases, the critical buckling load of the plate decreases.
- When the fiber angle increases, the buckling load decreases.
- The reduction of the buckling load due to the presence of a cutout is found. It is noted that the presence of cutout lowers the buckling load and it varies with the cutout shape. The plate with circular cutout yielded the greatest critical buckling load.

Mahmoud Shariati and Ali Dadrasi has been studied, Numerical and Experimental Investigation of Loading Band on Buckling of Perforated Rectangular Steel Plates. The aim of their paper is to investigate the buckling behavior of the steel rectangular plates with circular and square cut outs under uniaxial in-plane compressive loading in elasto-plastic range with various loading bands using the numerical and the experimental methods.

- They had seen the experimental procedure on UTM (Universal testing machine).
- The results show that, as loading band increases, the ultimate buckling load also increases. The buckling load of the specimen with circle cut out is a little more than the specimens with the square cut out with the equal surface area.

Effect of cutout aspect ratio on buckling and postbuckling strengths of composite panel under shear had been carried away by S. B. Singh, and Dinesh Kumar.This research deals with the effect of circular cutout aspect ratio on the buckling and postbuckling strengths, and failure characteristics of a simply-supported quasi isotropic composite laminate subjected to in-plane shear load (positive and negative).They conclude, it is predicted that buckling and first-ply failure loads decrease monotonically with the increase in aspect ratio (i.e., d/b ratio) of the centrally placed circular cutout.

Dr. Riyah N.K, Mr Ahmed N.E. found Stress Analysis of Composite Plates with Different Types of Cutouts, They have research on an experimental and theoretical investigation of the effect of cutouts on the stress and strain of composite laminate plates subjected to static loads. A numerical investigation has been achieved by using the software package (ANSYS), involving static analysis of symmetric square plates with different types of cutouts which gives

- The value of normal strain at the edge of square hole is greater than the value at the edge of circular hole.
- Increasing the holes dimensions to width of plate ratio increases the maximum value of stress and strain of a symmetric square plate.
- The value of maximum stress increases with the order of type of circular, square, triangular and hexagonal cutout, whereas the value of maximum strain increases with the order of type of circular, square, hexagonal and triangular cutout.

Dr. Hani Aziz Ameen studied Buckling Analysis of Composite Laminated Plate with Cutouts. They found following results,

- The effect of cutout shapes will cause decrease the critical buckling loads
- The critical buckling load is decreased with increased the cutout sizes.
- The critical buckling loads increases with small ratio of 0.65% with the increase the angle of orientation of cutouts (from 0° to 60°)

Buckling analysis of quasi-isotropic symmetrically laminated rectangular composite plates with an elliptical/circular cutout has been analyzed by Lakshminarayana, R. Vijaya Kumar, G. Krishna Mohana Rao in different loading conditions. They have analyzed their work using Finite element analysis(FEA). The results show that the buckling loads of rectangular composite plates subjected to linearly varying in-plane loads are decreased by increasing of cutout positioned angle β and increasing of c/b and d/b ratios .As the plate length/thickness (a/t) ratio increases the buckling load decreases, irrespective of cutout shape, size, and orientation of cutout, boundary conditions and various linearly varying inplane compressive loading conditions.

A closed-form solution for stress concentration around a circular hole in a linearly varying stress field has been generated by raghavendra nilugal1, Dr. M. S. Hebbal. Their paper presents a closed-form solution, based on 'Theory of Elasticity' to determine the stress concentration around a circular hole in an infinite isotropic plate subjected to linearly varying stress. Numerical solutions such as Finite Element Method, Finite Difference Method and Boundary Element Method can be employed to solve this problem. The equation developed in them work can be used to determine the stress field around the circular hole. The results obtained are compared with FEA results.

New equations for stress distribution around circular hole in an isotropic infinite plate in a linearly varying stress field are formulated using closed-form solution and it is extended from the Kirsch's problem for Stress-concentration due to a circular hole in a stressed plate. The maximum stress concentration is found at the edge of the hole at an angle of 90° from the load direction. Localized stress

concentration factor is calculated and it can be observed that the localized SCF is maximum at the hole and it decreases as radius increases. At the end of the plate localized SCF is equal to 1 that means stresses are converged. They validate both results, FEA with closed form solution of newly generated equation.

Payal Jain, Ashwini Kumar has been found Postbuckling response of square laminates with a central circular/elliptical cutout.The finite element method is used to analyse the postbuckling response of symmetric square laminates with a central cutout under uniaxial compression. The formulation is related toMindlin's plate theory and von Karman's assumptions to incorporate geometric nonlinearity. The governing finite element equations are solved using the Newton–Raphson method. For the purpose of analysis, laminates with circular and elliptical cutouts are considered with a view to examine the effect of cutout shape, size and the alignment of the elliptical cutout on the buckling and the first-ply failure loads of laminates. It is observed that these parameters have a substantial influence on the reserve strength which laminates may possess beyond buckling.
They analyse following results.
• For the geometries studied here, there is decrease in the buckling and the first-ply failure loads due to increase in the diameter of circular cutout placed centrally. A laminate with an elliptical cutout aligned along the loading direction has lower buckling load than that with a corresponding circular cutout. A laminate with an elliptical cutout aligned perpendicular to the loading direction has higher buckling load compared to the case when the cutout is aligned along the loading direction. The actual postbuckling strength of a laminate can be ascertained if the allowable transverse deflection is prescribed.A simple laminate without anycutout fails near the diagonal corner, but while circular cutout is present, it failed towards the cutoutedge. However with an elliptical cutout the failure takes place near the vertex of the cutout.

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CONCLUSION

- The buckling behavior of Glass fiber reinforced polymer subjected to linearly varying loading has been studied by the finite element method. Effects of various parameters on the buckling load of rectangular plates with aspect ratios of 1 have been investigated
- There are various parameters which affects the results of this study. Cutout size, Angle of cutout, Specimen geometry (plate), Thickness, Fiber types, Stacking sequences (no. of ply), Ply angles, Loading condition.
- Based on the findings, the following conclusions and recommendations have been made:

  - Single ply composite adapted for being rolled as is required in a window shade application as well as for layering fuselage, fairing and for other components for aircraft manufacturing. It can be layered on to the different structural component to strengthen the structure.
  - Presence of cutout lowers the buckling load and it varies with the cutout shape.
  - The value of maximum stress increases with the order of type of circular, square, triangular and hexagonal cutout, and the value of maximum strain increases with the order of type of circular, square, hexagonal and triangular cutout.
  - The critical buckling load is decreased with increased the cutout sizes.
  - The buckling load of the specimen with circle cut out is a little more than the specimens with the square cut out with the equal surface area.
  - The value of normal strain at the edge of square hole is greater than the value at the edge of circular hole.
  - The critical buckling loads increases with small ratio of 0.65% with the increase the angle of orientation of cutouts. (From 0° to 60°).
  - A laminate plate without a cutout fails near the diagonal corner, but in the presence of a circular cutout the failure location shifts towards the cutout edge. However with an elliptical cutout the failure takes place near the vertex of the cutout.
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