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ANALYSIS OF WOVEN GLASS EPOXY LAMINATED WITH COMPOSITE PLATE

Panneerdhass R*, Manikandan D, Sivasubramaniyan K, Jayakumar R

Professor* & Assistant Professor, Department of Mechanical Engineering, A.R Engineering College, Villupuram-605601, India.

Email: panneerdhass@gmail.com

ABSTRACT

. In this project the Buckling behavior of laminated composite plates subjected to in-plane loads is an important consideration in the preliminary design of aircraft components. The sizing of many structural subcomponents of the aircraft structures is often determined by stability constraints. The objective of the current study is to understand the influence of the length-to-thickness ratio, the aspect ratio, the fiber orientation and the cut-out shapes on the buckling load for the woven glass epoxy laminated composite plate in clamped-free-clamped-free configuration by finite element analysis using ANSYS software. Initially, buckling analysis was carried out on woven glass epoxy laminated composite plate, both; experimentally and numerically; for the two different geometric configurations to predict the critical buckling load and the test results were compared with the FEA predictions, to check the validity of the analysis methodology. The same methodology was further followed for analyzing the buckling behavior of the composite plates. The results shows the effect of orientation of fiber, aspect ratio, cut-out shape and length-to-thickness ratio on the buckling of the glass epoxy laminated composite plate.

Keywords: - Plate buckling, woven glass epoxy laminate, length-to-thickness ratio, aspect ratio, fiber orientation, cut-out shapes.

1. INTRODUCTION

1.1 INTRODUCTION TO COMPOSITE MATERIALS

There are many types of failures in engineering structures. Some of them include creep, fatigue, alternate stresses, bending, buckling etc. Buckling takes place in columns, plates, shells, and other structures of regular or irregular geometry. In this project only buckling of laminated composite plates has been considered. If the loads applied to a flat plate are low then there is low no observed distortion of the plate however as the load is increased then the equilibrium configuration of the plate changes into no flat configuration. Thus the plate in the case becomes unstable. The minimum load at which the equilibrium is disturbed is called as the critical buckling load. A composite has dual character. It is made up of two or more materials which when combined give different properties than their original characteristics. These materials have important properties like they are light in weight because the combined properties give rise to significant weight loss character. Thus they have high strength and high stiffness compared to their weight.

1.2 LAMINATE

When there is a single ply or a lay-up in which all of the layers or plies are stacked in the same orientation, the layup is called a lamina. When the plies are stacked at various angles, the lay-up is called a laminate.

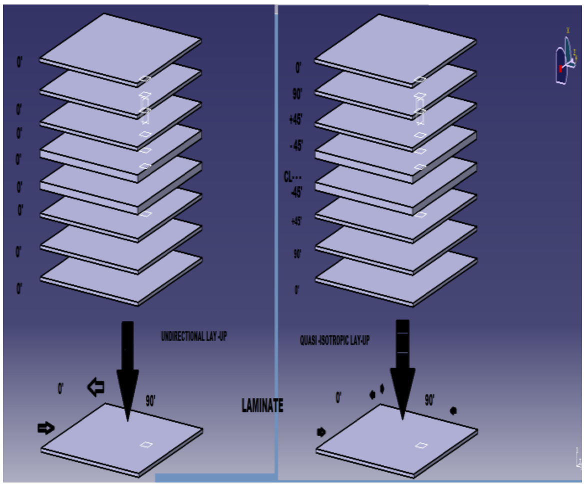

Fig 1.1 Laminate

1.3 LAMINATED COMPOSITE PLATES

Laminated composites are gaining wider use in mechanical and aerospace applications due to their high specific stiffness and high specific strength. Fiber-reinforced composites are used extensively in the form of relatively thin plate, and consequently the load carrying capability of composite plate against buckling has been intensively considered by researchers under various loading and boundary conditions. Due to the excellent stiffness and weight characteristics, composites have been receiving more attention from engineers, scientists, and designers. During operation, the composite laminate plates are commonly subjected to compression loads that may cause buckling if overloaded. Hence their buckling behaviors are important factors in safe and reliable design of these structures

Composites are used in almost all disciplines of engineering. As such there are many processes to prepare composites. Research is also going on in industries to prepare composites much faster and the most economical way. The two most popular methods which are there for the preparation of composites are hand layup technique and the spray up technique. Fabricating a composite part is generally concerned with placing and retaining fibres in the direction and form that is required to provide specified characteristics while the part performs its design function.

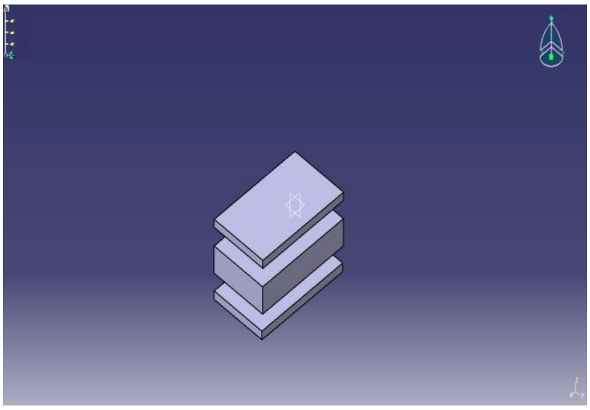

Fig 1.2 laminated composite plate

1.4 WOVEN GLASS FIBER

Woven glass fiber is a type of fiber reinforced plastic where the reinforcement fiber is specifically glass fiber. The glass fiber may be randomly arranged but is commonly woven into a mat. The plastic matrix may be a thermosetting plastic- most often epoxy, polyester resin- or vinylester, or a thermoplastic.

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Fig 1.3 Woven Glass

1.5 BUCKLING ANALYSIS

A mode of failure characterized generally by an unstable lateral deflection due to compressive action on the structural element involved. This mode often occurs in glass reinforced thermosets due to resin shrinkage during cure. In advanced composites, buckling may take the form not only of conventional, general instability and local instability but also a micro-instability of individual fibers.

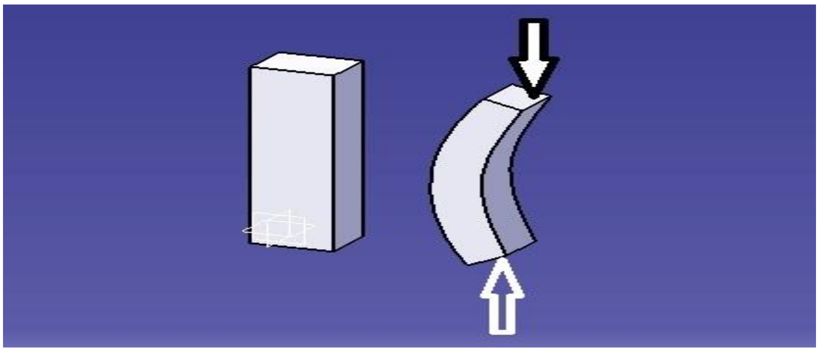

Fig 1.4 Buckling Analysis

There are two major categories leading to the sudden failure of a mechanical component: material failure and structural instability, which is often called buckling. For material failures you need to consider the yield stress for ductile materials and the ultimate stress for brittle materials.

2. PROBLEM IDENTIFICATON

Form the literature review its clear that the bending analysis is the main problem associated with the E-Glass fiber plate and in woven glass fiber plate material. As discussed earlier, the thin laminated composite plates are capable to carry extra amount of load under compressive loading. It is well known that the structures under compressive loading may lose their stability and a geometric instability induced in the structure which in turn says, buckling of the structure.

To achieve the same majority of work has been carried out in modeling and numerical investigation of the buckling behavior of the laminated composite plates time to time. It is also true that the experimental methods however are not too easy to implement. It is because of the fact that fabrication of composite plate by maintaining the required properties for which they have been the quest of design engineers as well as available INSTRON machine which are very costly. Hence, the present project aims at develop an lab scale buckling test rig using hydraulic pressure to calculate the critical buckling load of various laminated plate. It is worthy to mention that the required specimens have been prepared using hand lay-up technique. Finally, the results are also obtained numerically using commercial finite element software

3. METHODOLOGY

The methodology includes the process sequentially which carried out, this project includes the process of analysis and experiment for the characterization of materials. The manufacturing process can be classified into two broad categories:

- Hand methods
- Mould methods

Hand methods can be further classified into hand layup and spray up techniques. Molding methods include Matched-die molding and forming methods by employing gas pressure other processes include filament winding and pultrusion process.

4. HAND LAYUP TECHNIQUE

Hand lay-up refers to the manual method of laying or applying the reinforcement material into the mold. In the hand lay-up process, the reinforcing material (usually fiberglass mat) is placed in the mold and then saturated with polyester resin using a brush or a two-component spray system.

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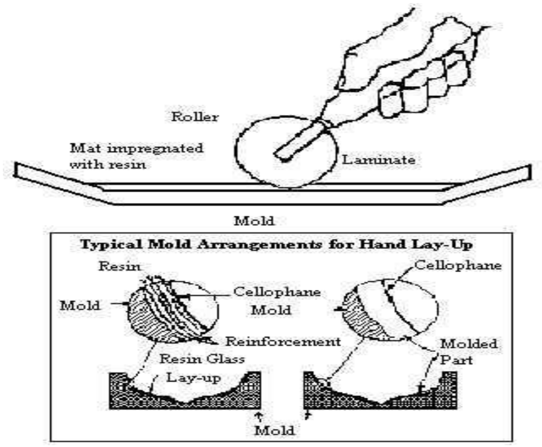

Figure 4.1 Hand Layup Technique

5. ANALYSIS

5.1RECTANGLE AND SQUARE PLATE

RECTANGLE PLATE:

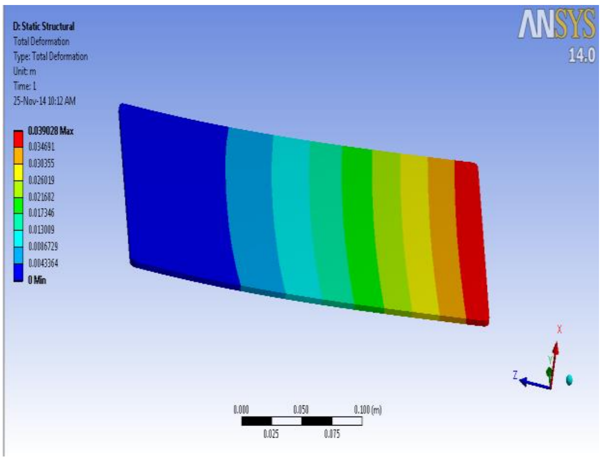

Fig 5.1 Rectangle Plate without Cut-Out

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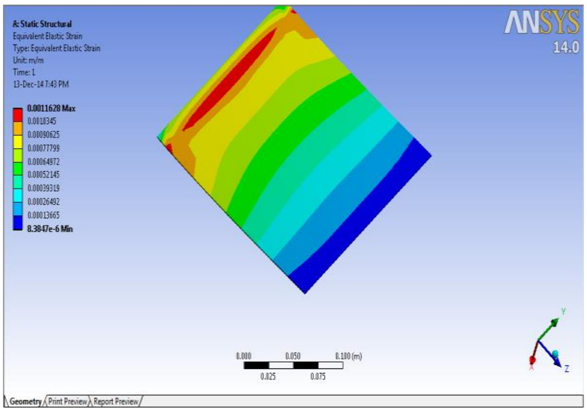

Fig 5.2 Square Plate without Cut-Out

5.2 RECTANGLE AND SQUARE PLATE WITH CIRCULAR CUT-OUT

RECTANGLE PLATE:

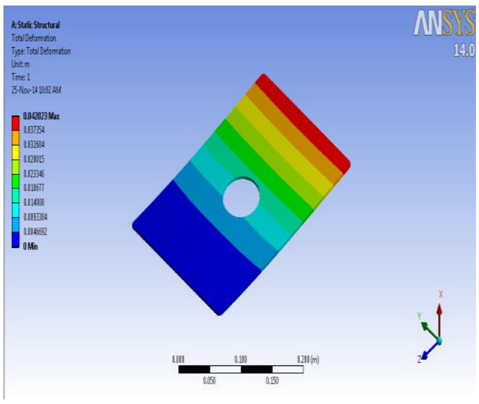

Fig 5.3 Rectangle Plate with Circular Cut-Out

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SQUARE PLATE:

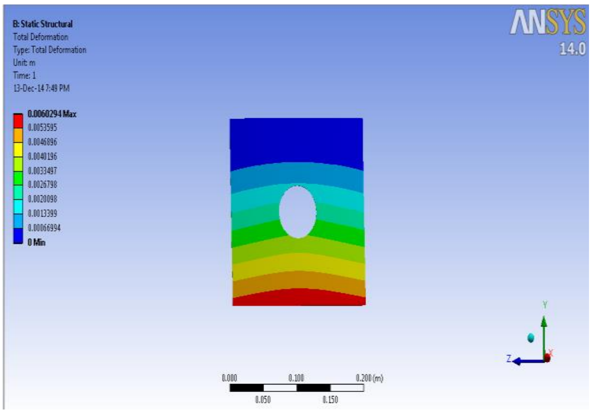

Fig 5.4 Square Plate with Circular Cut-Out

5.3 RECTANGLE AND SQUARE PLATE WITH SQUARE CUT-OUT RECTANGLE PLATE:

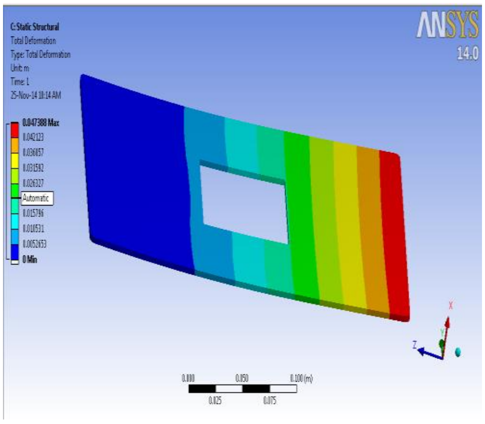

Fig 5.5 Rectangle Plate with Square Cut-Out

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SQUARE PLATE:

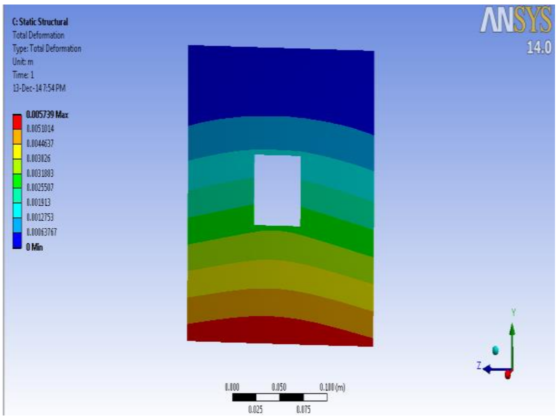

Fig 5.6 Square Plate with Square Cut-Out

5.4 RECTANGLE AND SQUARE PLATE WITH RECTANGLE CUT-OUT

RECTANGLE PLATE:

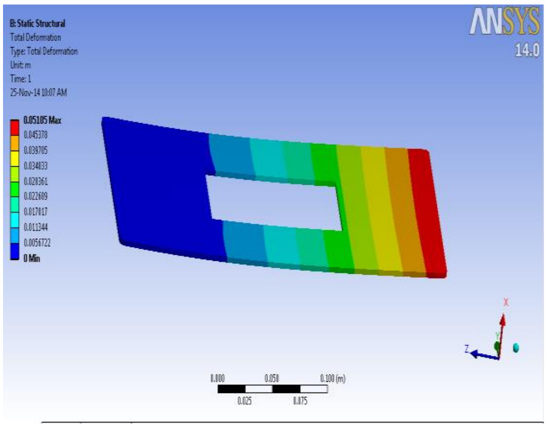

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Fig 5.7 Rectangle Plate with Rectangle Cut-Out

SQUARE PLATE:

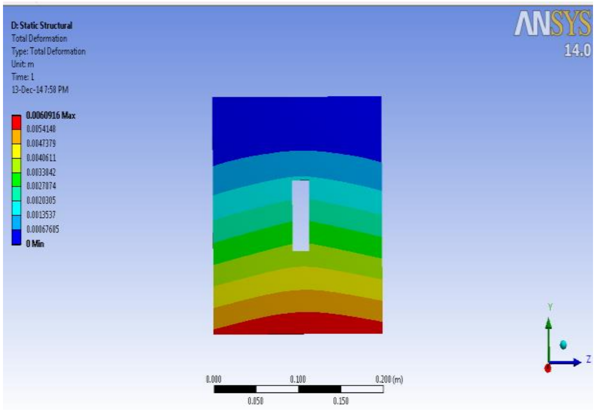

Fig 6.8 Square Plate with Rectangle Cut-Out

6. EXPERIMENTAL STUDY

Experimental studies were carried on the following two woven glass plate configurations to find out the critical buckling load

- Rectangular woven glass plate (400×200×3.2 mm)
- Square woven glass plate (200×200×3.2 mm)

This experimental study was carried out to validate the buckling results obtained from FEA, so that the same analysis methodology can be followed for the buckling analysis of woven fabric composite plates. The experiment comprises of an woven glass plate clamped on two longitudinal ends on an INSTRON 1341 testing machine of 50KN capacity and kept free at the other two. Then it was loaded in axial compression. Clamped boundary conditions were simulated along the top and bottom edges, restraining 50mm length and the test specimens were mounted on the testing machine through the mechanical fixtures. The top fixture was held fixed during the test whereas the bottom fixture was moved by servo hydraulic cylinder.

As the load was increased the dial gauge needle started moving and at a particular value of the load applied, there was a sudden large movement of the needle and thus the 1st mode buckling was observed. The load corresponding to this point is the critical buckling load of the plate. The same test procedure was repeated, similarly, for the square aluminum plate and under the similar loading conditions, the dial gauge showed sudden large movement of the needle due to the large out-of-plane deformation of the plate and thus the 1st mode buckling was observed.

7. RESULT AND DISCUSSION

Buckling Results for woven glass plate

The experimental analysis of the two aluminum plates yielded the load vs. displacement curve with the displacement on the x- axis and the load on the y-axis. That critical buckling load point was determined from the intersection of two tangents drawn from the pre-buckling and post-buckling regions. From the graph shown in the Figure- 5, it can be seen that for the rectangular aluminum plate, the load becomes constant at 2.26 KN. This represents the 1st mode buckling of the specimen after which the plate is considered failed. Since the thickness of the plate is very small, the plate shows a large deflection for small increment in the load. Also, the FE analysis result for the buckled shape of the rectangular aluminum plate is shown in the Figure 6. It is observed that the critical buckling load for the rectangular specimen is determined as 2.52 KN.

S.no	Cut-out shapes	Length, *a* (in mm)	Width, *b* (in mm)	Thickness, *t* (in mm)	Critical buckling

					load, *Pcr* (in kN)
1	No cut-out	400	200	3.8	9.221
2	Circular	400	200	3.8	7.899
3	Square	400	200	3.8	7.804
4	Rectangular	400	200	3.8	7.234

8. CONCLUSION

The composite plate is made with the help of woven glass epoxy laminated resin for two geometric configuration namely square plate and rectangular plate. Modeling is done with the help of catia software for two geometrical configurations for square and rectangle plate with cut-out such as (circular, rectangle, square)

1. It was noted that variations in length-to-thickness ratio affects the critical buckling load. The buckling load decreases as the a/t ratio increases. The rate of decrease of buckling load is not uniform with the rate of increase of a/t ratio.

2. As the aspect ratio increases, the critical buckling load of the plate decreases. When the aspect ratio changed from 1.0 to 1.7. The rate of change of buckling load with a/b ratio is almost uniform.

3. It was seen that the different fiber orientation angles affected the critical buckling load adversely. With the increase in the fiber angle, the buckling load decreased. The plate with [0]8 layup had the highest buckling load and the plate with [45]8 layup had the least.

4. The reduction of the buckling load due to the presence of a cut-out is found to be significant. It is noted that the presence of cut-out lowers the buckling load and it varies with the cut-out shape.

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