Analysis of Carbon Fiber Reinforced Composite Laminate under Different Cutouts Using FEM and Reflection Polariscope

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ABSTRACT
Composite materials are widely used in various applications such as automotive industries, aircraft, marine etc. Composites are made of individual materials referred to as constitute materials. The use of fiber reinforced materials has become widespread not only because of their high strength-to-weight ratio but also the possibility of tailoring them to meet specific design requirements by selecting the fiber materials and their orientation. Panels with different cutouts are often used in engineering structures which are generally subjected to compressive loading. The understanding of effect of load bearing capacity and stress concentration of such plates is important. In this paper work is to be carried on unidirectional carbon fiber reinforced composite laminate under different cutouts such as circular, square and rectangular of constant area under compressive loading. For this stress analysis will be carried out using Finite Element Method software ANSYS 14.0 and experimental work will be carried out using Reflection Polariscope.

Keywords — Carbon FRC laminates, Cut-outs, Compressive load, Stress analysis, Reflection Polariscope.

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I. INTRODUCTION
In the last two decades, the use of Carbon fiber reinforced materials has become widespread not only because of their high strength-to-weight ratio but also the possibility of tailoring them to meet specific design requirements by selecting the fiber materials and their orientation. A fiber-reinforced composite (FRC) consists of three components, the fibers as the discontinuous or dispersed phase, the matrix as the continuous phase, and the fine interphase region, also known as the interface. A lamina, also called a ply or layer is a single flat layer of unidirectional fibers or woven fibers arranged in a matrix.

A laminate is a stack of plies of composites. Each layer can be laid at various orientations and can be of different material systems. Considering its light weight, a lamina (ply) of fiber reinforced composite is remarkably strong along the fiber direction. However, the same lamina is considerably weaker in all off-fiber directions. Layer is oriented in a
different direction, it gives different strength and stiffness in various directions as a whole. The largest damage feature in composite laminate is usually de-lamination, which may cause significant reductions in flexural stiffness and buckling loads. The effect of delamination has been a subject of extensive research and fairly reliable methods are now available for prediction of growth of artificial single de-lamination.

Cut-outs commonly appear in the structures due to the requirement of stability, low weight optimization and accessibility of other systems. Many industries using composite structures as compared to metal structures, many of the structures have cut outs or opening to serve as doors, windows, or access ports. The different cut-outs like circular, square, elliptical are used for many structures. During operation, these structural elements may experience compressive loads and thus lead to incorporate stress and strains in the composite laminate, buckling and post buckling. Their buckling and post buckling behaviours play an important role in determining safe operating conditions and effective designs for these structures.

II. OBJECTIVES
The purpose of this paper is to extend the knowledge of Unidirectional GSM 200 Carbon FRC laminate under different cutouts based on following objectives-
1. Analyze the Carbon FRC laminate without cutout and with different cutouts in FEM software ANSYS.
2. Manufacturing of Composite laminate.
3. Testing of Composite laminate under compressive loading using Reflection Polariscope.
4. Verifying FEM and Experimental results for optimum stress value of cutout obtained.

III. PROPERTIES OF MATERIAL
The laminate material used is Unidirectional GSM 200 Carbon Fiber and Matrix material used is Araldite CY 205 and Hardener HY 951. The Properties of Carbon FRC laminate are as follows-

<table>
<thead>
<tr>
<th>Property</th>
<th>Symbol</th>
<th>Value (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s Modulus 0°</td>
<td>E₁</td>
<td>134</td>
</tr>
<tr>
<td>Young’s Modulus 90°</td>
<td>E₂</td>
<td>10</td>
</tr>
<tr>
<td>In Plane shear Modulus</td>
<td>G₁₂</td>
<td>3.703</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>γ₁₂</td>
<td>0.3</td>
</tr>
</tbody>
</table>

IV. MANUFACTURING COMPOSITE LAMINATE
Manufacturing of the composite laminate by using Hand Layup Technique is as explained below-

A. Hand Layup Technique
1. First of all Clean the Carbon fiber with cloth then cut the pieces of 300x300mm of Carbon Fiber from the roll of 5500mm².

2. Place the Mylar sheet on that Carbon fiber sheet.
3. Take 100ml Epoxy resin CY 205 and mix 10ml HY 951 hardener. (Mixing ratio 10:1).
4. Mix these two elements properly with help of Mixing rod so that proper mixture will obtained.
5. Apply this mixture on the Mylar sheet gently with the help of brush.
6. Place the first carbon fiber layer 0° and apply the mixture at top of this sheet as shown in figure 4.
7. Apply the pressure on this First layer with help of Roller or Aluminum rod which will remove an excess resin and will remove air gap.
8. Now, Place the second layer of Carbon fiber sheet with 90° orientation.
9. Repeat the procedure up to 6 layers of Carbon fiber. The orientations for the 6 Layers are as taken as 0/90/0/0/90/0.
10. Place the second Mylar sheet on top layer.
11. Remove the Carbon laminate after 30 hours as curing process takes much time.
12. Also remove two Mylar sheet from composite plate. Advantage of using Mylar sheets is that they gives good surface finish to composite plate and also release the composite plate easily.
13. The composite laminate is ready for further machining and Experimentation.
V. EXPERIMENTATION

The above mentioned objectives can be obtained with the help of following procedure-

A. Test Specimen

The experimentation will be carried out on a Carbon FRC laminate plate of dimensions 140x130mm of 3mm thickness without and with different cut-outs by keeping cut-out area constant of 962 mm² at the centre. These test specimens are as shown in below figure no.6.

![Test Specimens](image)

C. Casting of the Photo stress sheet

For the analysis using Reflection Polariscope the photo stress sheet need to prepare on which stress will be observed. The Procedure for preparing the sheet can be divided into following steps-

1. Determining the amount of resin and hardener

Preparing and pouring the plastic resin and hardener as per the formula-

\[
W = dxAxt
\]

Where,

- \(W\) = Total amount needed (in gm)
- \(d\) = Plastic density \([1.13 \times 10^{-3} \text{ gm/m}^3]\)
- \(A\) = Area of Sheet to be cast (width x length)
- \(t\) = Desired thickness of sheet (in mm)

For the above test specimen-

\[
W = 6.1698 \text{gm}
\]

The amount of hardener indicated in “Parts per hundred” by weight which means that for 100 gm of Type PL-1 Resin the amount of PLH-1 hardener needed as 20gm. For the 60.698gm of total mixture the resin and hardener calculations are as follows-

- PL-1 Resin: \(60.698 \times \frac{120}{100} = 51.415\text{gms.}\)
- PLH-1 Hardener: \(60.698 \times \frac{20}{100} = 10.283\text{gms.}\)

2. Weighing the Calculated amount of Resin and hardener

As per the calculated values of Resin and hardener the exact amount is taken as shown in figure 7.

3. Mixing Hardener and Resin

This is one of the crucial step in obtaining the quality casting sheet. When the resin and hardener reach the temperature indicated in the coating material table, pour the hardener in to the resin being careful to avoid introduction of air bubbles. Stem thermometer should be brought into line contact. Continuous stirring until desired temperature obtained. Now this mixture is ready to pour on the casting table.

4. Pouring the Mixture on the Casting table

The mixed plastic is now ready to pour on the casting table on which Teflon carrier and rubber frame of set dimensions are mountain which restricts the mixture to flow away. Pour the mixture as shown in figure 7 in “S” Pattern.

![Pouring the mixture](image)

Place the cover over the poured sheet to protect it from dust and dirt. Allow to cure it for 2-3 hours. Then carefully try to separate one section of rubber frame at one corner .Lift until Teflon carrier separates from sheet.

5. Bonding of casting Plate on Test Specimen

The casting Plates prepared are as shown in figure 8. These casting plates should be carefully machined to obtain the cutouts of different shapes like circular, square rectangular as per the specimen size.

![Casting Plates](image)

After cutouts on casting sheets, Pour the mixed adhesive PC-1 on the cleaned test part surface and spread it over the entire surface with brush as shown in figure 9.

![Application of Adhesive](image)

Adhesive layer must be thick now carefully position the casting sheet on the adhesive and allow one edge to contact the spread adhesive. Press down on the containing edge with moderate figure pressure this technique will allow excess air
to flow out. Allow the adhesive to polymerize until it thickens and tend to allow shape.

C. Experimental Setup

In Experimental investigation, The Test specimen will be subjected to compressive loading with boundary condition as fixing at the one end. Stress strain behavior of fiber reinforced composite laminate specimen under compressive load will be investigated. Stress analysis will be done by using photo elasticity on reflection Polariscope. The Experimental Setup is as shown in figure 10.

Place the Reflection Polariscope about 2 meters and adjust it so that height of the light source and height of Test specimen will be same. Ensure that initial loading is zero on UTM. Turn on the light source. Lock the screw after alignment is done. Boot the computer and turn on video camera. On clicking the PS cal software icon. Now, apply the load on the Universal Testing machine and observe the fringe patterns on the computer screen. Mark the point on the specimen and observe the compensator reading which gives the Fringe order value directly as shown in the figure 11.

Note down the values of Fringe order (N) by gradually increasing load applied on UTM.

VII. FINITE ELEMENT ANALYSIS

Following are the Finite Element results obtained-

![Stress plot for Plate with circular cutout](image1)

![Stress plot for Plate with circular cutout](image2)

VII. DISCUSSION

The parameters such as the fiber angle orientation, cut-out shapes, size of Cut-out affects the buckling loads. The stress concentration can vary according to the cut-out shape.

The results obtained from the Finite Element method and experimental results can be compared so as to predict the actual behaviour of the composite laminates.

VIII. CONCLUSION

- In this paper Manufacturing of Carbon FRC laminate by using hand layup Technique has been explained.
- Also analysis is carried out using ANYS software.
- It is observed from the FEA that, Plate with Circular cut-out shows optimum stress values.
- Also it is observed that angle ply laminates are better than cross ply laminates.

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