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STUDY ON BUCKLING EFFECT OF CUTOUTS ON THE OPTIMIZED FIBRE ORIENTATED LAMINATED COMPOSITE PLATE

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Abstract- Laminate composite materials are composite materials in which layers of different properties are bonded together to act as an integral part. In structures, cutouts provided in laminated composite plate show reduction in strength, stiffness and inertia. Laminated composite plates have wide application in the aerospace, automotive, marine and civil areas. Cutouts are necessary to serve the purpose of weight reduction, venting and attachments to other units for the cable to pass through are so on. This paper compares the critical buckling load of the laminated composite plate with and without cutout by changing the fibre orientation by experimental and numerical methods. Glass/epoxy laminated composite plate was used here. Laminated composite plate with circular cutout shows a decrease in buckling load than plates without cutout. Also the buckling load decreases with increase in fibre angles. The maximum buckling load combination was obtained with fibre orientation 45/-45/45/-45/45/-45/45/-45 with circular cutout.

Key Words- Buckling Analysis, Circular, Cutouts, Finite Element Method, Glass Fibre, Hardener, Laminated Composite Plate, Resin

1. INTRODUCTION

A lamina is fibre reinforced composite, prepared from fibres and matrix (sometimes woven fabric may also used for making lamina). Laminae having varying fibre orientations are bonded together to form an integral structural component, which is known as laminate. A lamina is considered to be homogenous at macroscopic level. It has three planes of symmetry and hence termed as orthotropic. The laminates may be symmetric or anti-symmetric or unsymmetric. The mechanical performance of laminated composite plates are highly dependent on the degree of orthotrophy of individual layers, the low ratio of transverse shear modulus to in-plane modulus and the stacking sequence of laminates. Lamination is used to bond the best aspects of the adjoining layers and bonding material to develop a more useful material.

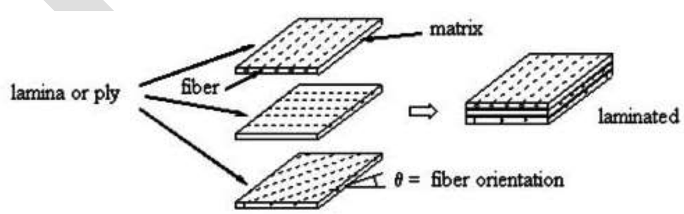

Fig -1: Laminated Composite Plate

Glass-reinforced plastic is a composite material made of epoxy resin matrix reinforced by fine fibers made of E glass. GRP is a lightweight, strong material with very many uses, including boats, automobiles, water tanks, roofing, pipes and cladding. Moreover, by placing multiple fiber layers on top of other, with each fiber layer oriented (stacked) in different preferred directions, the strength and stiffness parameters of the entire material can be enhanced in an efficient manner.

The mechanical behaviour of laminated composite plates are strongly dependent on the degree of orthotrophy of individual layers, the low ratio of transverse modulus of rigidity to the in-plane modulus of elasticity and the stacking sequence of laminates. Lamination helps to combine the better aspects of the combining layers and bonding material in order to achieve a useful composite material. Fiber- reinforced composites are extensively used in the form of relatively thin plate, and they have consequently higher load carrying capability against buckling.

2. SCOPE

Laminated composite plates have wide application in the aerospace, automotive, marine and civil areas. In structures, laminated composite plate consists of cutout which reduces their strength, stiffness and inertia. Cutouts are necessary to serve the purpose of weight reduction, inspection, venting and attachment to other units for the cable to pass through are so on. Cutouts are required for ventilation as well. Hence the effects of cutout in laminated composite plate are to be investigated.

3. OBJECTIVES

- To determine the critical buckling load of laminated composite plate without cutout and with circular cutout by changing the five fibre orientation by experimental and numerical methods.
- To optimize the fibre orientation by performing the buckling analysis using numerical methods.

4. EXPERIMENTAL PROGRAM

4.1 MATERIALS

The materials used for making the laminated composite plate are:

4.1.1 Glass Fibre

The bidirectional glass fibre woven roving of 360 GSM with 0.3 mm thickness was used for the experimental work.

4.1.2 Epoxy Resin

Araldite LY 556 was used as epoxy resin which is medium viscosity, unmodified liquid epoxy resin based on Bisphenol-A.

4.1.3 Hardener

Low viscosity, unmodified, aliphatic polyamine hardener, Aradur HY 951 was used for the experiment which has excellent water resistance property.

4.1.4 Polyvinyl Alcohol

Polyvinyl Alcohol act as a releasing agent applied by means of spray gun.

4.2. MIXING RATIO

Araldite LY 556 and Aradur 951 were mixed well before applying into laminated composite plate. Resin and hardener should be mixed uniformly until a homogenous mixture is formed. It provides a low viscosity, solvent free room temperature curing laminating system. By varying the contents of hardener from 10 to 12 parts, the reactivity of the system can be adapted to suit the processing and curing conditions.

Table -1: Properties of the Mix

Viscosity	at 25^0C	1700 mPa.s
	at 40^0C	650 mPa.s
Useable Life Gel Time	upto 1500 mPa.s	10 minutes
	at 25^0C	120-180 minutes
	at 40^0C	30 minutes

4.3 PREPARATION OF LAMINATED COMPOSITE SPECIMEN

The laminated composite plate specimens used in this research were made from 0/90 woven glass fiber with epoxy matrix. Hand layup technique was used for fabrication of plates. The percentage of glass fiber and mixture of epoxy resin and hardener had taken as 1:1 in weight for fabrication of the plates. A rigid platform made of iron was selected to make a flat surface. A milosh sheet was placed on the rigid platform. Then polyvinyl alcohol i.e releasing agent was applied on the milosh sheet by using the sprayer. After applying that, gel coat (mixture of epoxy resin and hardener) was spread to provide a smooth surface and to avoid the direct exposure of the fibre to environment. Glass fibres from the rovings were placed on the top of the gel coat and again gel coat was applied. The entrapped air was removed by using the steel rollers. The process was continued as above before the gel coat had fully hardened. After the completion of all layers, again a milosh sheet was placed on the top of the gel coat by applying poly vinyl alcohol. A heavy metal rigid platform was placed over it. Then the whole mould was kept at the compression moulding machine for 20 minutes. The temperature was kept at 80^0C. After 20 minutes, switch off the machine and kept the specimen for 4 hours. After 48 hours of curing, cut the specimen in the desired size by water jet cutting with and without cutout for the experimental study.

Fig -2: Pouring of Epoxy Resin

Fig -3: Removal of Entrapped Air by Rollers

Fig -4: Temperature Setting in Machine

Fig -5: Prepared Plate without Cutout

Fig -6: Prepared Plate with Cutout

A total of seven types of laminated composite plate with and without circular cutout of different fibre orientation were prepared for the experimental study.

1. Laminated composite plate 0/90/0/90/0/90/0/90 orientation without cutout (LCPWOC 1)
2. Laminated composite plate 45/-45/45/-45/45/-45/45/-45 orientation without cutout (LCPWOC 2)
3. Laminated composite plate 0/90/0/90/0/90/0/90 orientation with cutout (LCPWC 1)
4. Laminated composite plate 45/-45/45/-45/45/-45/45/-45 orientation with cutout (LCPWC 2)
5. Laminated composite plate 0/90/45/-45/45/-45/0/90 orientation with cutout (LCPWC 3)
6. Laminated composite plate 0/90/60/30/60/30/0/90 orientation with cutout (LCPWC 4)
7. Laminated composite plate 60/30/60/30/0/90/0/90 orientation with cutout (LCPWC 5)

4.4 TEST PROCEDURE

The specimens were tested in an axial compression testing machine having a capacity of 100 kN. The specimen was placed vertically and clamped at top and bottom ends. The other two ends were kept as free. All specimens were loaded slowly until buckling. For axial loading, the plate specimen was placed between the two machine heads, of which the lower head was permanently fixed and the upper head was moving during the test with the help of hydraulic cylinder. The plate was loaded at the rate of 2 mm/min. As the load starts increasing, the dial gauge needle also moves and at a particular point, there was a sudden movement of the needle. The load at this point was the buckling load of the specimen. The testing machine was connected to the computer to obtain the load displacement curve and the critical buckling load. The initial part of the curve was linear, the point where the curve deviates from its linearity was taken as the critical buckling load.

4.5 EXPERIMENTAL RESULTS

The buckling load and load versus displacement curve of the maximum buckling load with circular cutout specimen obtained from the experiment is shown in figure 7.

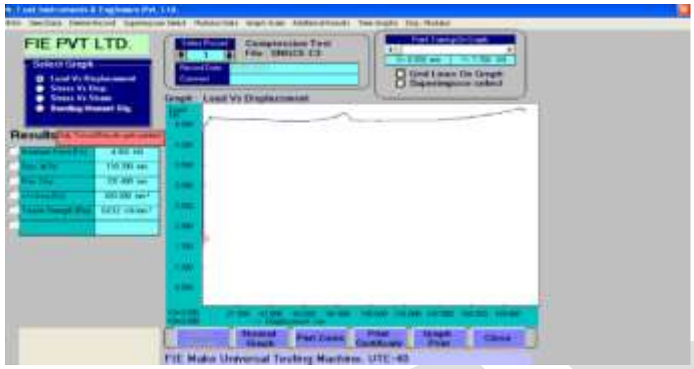

Fig -7: Load Displacement Curve of LCPWC 2

5. FINITE ELEMENT ANALYSIS

Finite element analysis of the above seven different plates were done using the software 'ANSYS 14.5 APDL' also.

Table -2: Element Type and Material Properties

Material No:	Element Type	Material Property
1	Shell 281	Density = 1.2 g/cm^3
		Youngs modulus E = 10 GPa
		Poisons ratio = 0.12

'Shell 281' element was used to model the laminated composite plate. This is an eight- node linear shell element having six degrees of freedom at each node. Those are translation in x, y, z direction and rotation about x, y, z axis. It was used in cases for linear, large rotation, and/or large strain nonlinear applications.

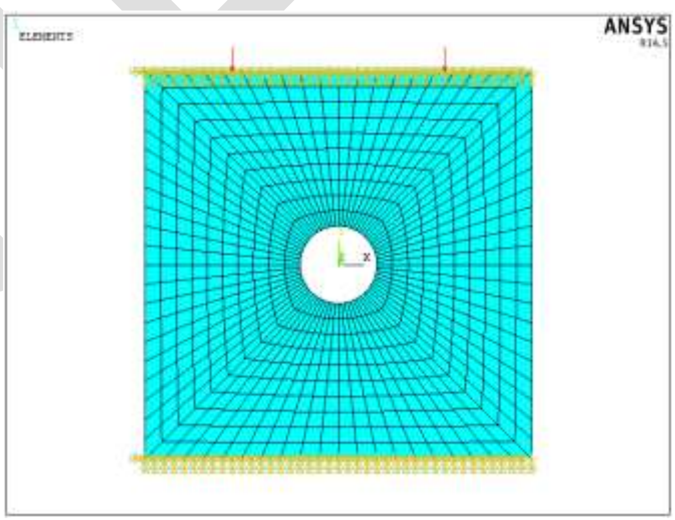

Fig -8: Boundary Condition of Plate with Circular Cutout

5.1 FINITE ELEMENT RESULTS

The plate specimens were modelled in ANSYS software. Analysis of plates was done to obtain critical buckling load.

Table -3: Results obtained from ANSYS 14.5

ID No. of Plate Specimen	Buckling Load (kN)
LCPWOC 1	5.8
LCPWOC 2	6.1
LCPWC 1	4.9
LCPWC 2	4.8
LCPWC 3	4.68
LCPWC 4	4.482
LCPWC 5	4.68

6. RESULTS AND DISCUSSION

Results obtained from software were compared with the experimental results for the seven laminated plate specimens. The results showed satisfactory convergence.

Table -4: Comparison between Experimental Value and Software Value

ID No. of Plates	Buckling Load		Percentage Variation
	Experimental Value	Software Value	
LCPWOC 1	6.4	5.8	9.375
LCPWOC 2	6.6	6.1	9.09
LCPWC 1	4.78	4.9	2.44
LCPWC 2	4.9	4.8	2.04
LCPWC 3	4.62	4.68	1.28
LCPWC 4	4.7	4.482	4.63
LCPWC 5	4.7	4.68	1.5

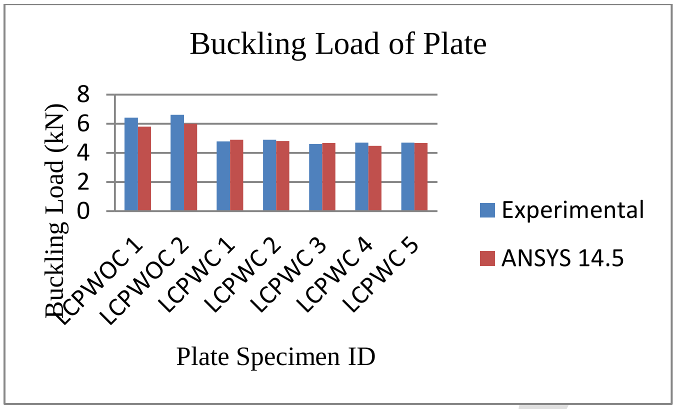

Chart -1: Comparison of Buckling Load

The maximum buckling load capacities was obtained with LCPWC 2 (fibre orientation 45/-45/45/-45/45/-45/45/-45 with circular cutout). The percentage reduction due to the circular cutout at centre was 25 % compared to laminate without cutout.

7. ACKNOWLEDGEMENT

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8. CONCLUSIONS

Experimental results on laminated composite plate of size 250 mm x 250 mm x 1.6 mm with different seven cases were compared with results obtained in the buckling analysis in ANSYS 14.5 software. The results are summarized as below:

- Laminated plates with cutout shows a decrease in buckling load carrying capacity compared to plate without cutout.
- The maximum buckling load depends on fibre orientation of the different layers used. It is observed that the laminated composite plate with fibre orientation 45/-45/45/-45/45/-45/45/-45 shows the maximum buckling load.
- The percentage reduction in buckling load carrying capacity was observed as 25% for LCPWC 2 compared with LCPWOC.

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