International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

Buckling Analysis of Laminated Carbon Fiber Composite Beam using Ansys

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***Abstract*: — Many carbon fiber-reinforced composite materials offer a combination of higher strength and high modulus that are either comparable to or better than many traditional metallic materials which are using now days. Significant developments of these composites have occurred in the last few years. The physical understanding and numerical simulation of the buckling of laminated anisotropic beams have been the focus of intense efforts because of the extended use of fibrous composites in aerospace, automotive shipbuilding and other industries. Ansys is used as the tool for modeling and analysis of the composites .Experiments will be conducted for validating the analytical results. The beams were stiffened to prevent crippling and warping at the supports, and local tensile failure at the load points. This model will reveal many details and properties of carbon fiber reinforced composite materials.**

Keywords: Carbon fiber composite, Hand layup fabrication, Buckling analysis.

I. INTRODUCTION

In many engineering structures likes columns, beams, or plates etc, their failure developing not only from higher stresses but also from buckling of the material. Only rectangular thin plates are considered in the study. When a flat plate is subjected to low in-plane compressive loads or stress, it remains flat and is in equilibrium condition. As the magnitudes of the in plane compressive loads or other loads increases, then equilibrium configuration of the plate is eventually deformed to a non flat configuration and the plate becomes unstable and may be deformed. The magnitude of the compressive loads at which the plate becomes unstable or deformed is called the “critical buckling load.”A composite material having of two or more materials and offering weight saving in structures in view of its high strength, weight and high stiffness ratios. Further, in a fibrous composite, the mechanical properties may be varied as required by suitably orienting the fibres. In this kind of material the fibres carries major load carrying members, and the matrix, which has low modulus and high elongation, provides the high flexibility and also keeps the fibres in position and protect them from the environment. Development of newly introduced applications and new composites materials is accelerating due to the requirement of materials with a combination of properties that cannot be met by ordinary monolithic materials. Actually, composite materials are capable of fulfilling this requirement in all means because of their heterogeneous nature. Properties of composite material introduced as a function of its components materials, their distribution and the interaction among them and results an unusual combination of composite material properties can be obtained.

Laminated composites materials are having wider use in mechanical and aerospace applications because of their high specific stiffness, high specific strength and less weights. Fiber-reinforced composites materials are using widely in the form of relatively thin plate, beams and consequently the weight carrying capability of composite materials plate or beam against the buckling load has been considered by scientists and researchers under various loading and boundary conditions. They have excellent stiffness and weight characteristics, so composites material have been receives more priority from engineers, scientists, and designers. In many applications the composite laminate plates are commonly subjected to loads likes compression loads, which may causes buckling failure if overloaded. So that their buckling loads behaviors are very important factors in safe and reliable design of these structures.

II. PROBLEM STATEMENT

Created composite material poses new problems, like as damages due to Delamination and transverse shear effects due to the various ratio of in plane to transverse shear modulus. So that real understanding of composites materials structural behavior is must, like as the deflections, deformations, buckling loads and the modal characteristics, inside thickness distributions of stresses, strains loads, and the large deflection behavior and, of extreme importance for getting stable, and reliable multilayered structures design. Transverse shear is very important in composites materials, as the composite material is weak in shear because of its low shear modulus compared to the extensional rigidity.

III. OBJECTIVE

Thus far there have been numerous studies on the carbon fiber composite laminated structures which find widespread applications in a lot of engineering areas such as aerospace, biomedical, civil, and marine and mechanical engineering because they are easy of handling, good mechanical properties and low making cost. They also have excellent damage tolerance and impact resistance. It is clear that most of the studies and investigations are based mainly

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

on the numerical approaches. Very less attention has been paid on the buckling of composite plates.

Most of the studies and researchers were focused on unidirectional types fiber. Industrial driven woven type fibers are being increasingly using in many applications. So that we have to give more importance on its structural behavior also. It also indicating the interaction between stacking sequence, and length/thickness ratio on the buckling loads behavior of woven type fiber laminated composites are needed to understand in more detail. The main aim of undergoing this research is to understanding of the structural behavior of woven type fabric composites subject to compressive load. The major objective of this study is to find out the experiment of buckling load analysis of laminated carbon fiber composite beam using Ansys.

IV. MATERIALS AND METHODS

Materials used for making carbon fiber composites are carbon fiber cloth and Resin. Carbon fibers or carbon fibers materials (alternatively called as CF, Graphite fiber or graphite fibre) are fibers contents about 5–10 micro meters in its diameter and composed tightly with the carbon atoms. To make a carbon fiber, the carbon atoms are bonding together in crystals that are higher or lesser aligned in parallel to the long axis of the fiber as the crystal alignment gives the fiber high strength-to-volume ratio (making it very strong for small size). Many hundreds of carbon fibers are bundled to form a tow, which may be used to make woven into a fabric cloths. The main properties of carbon fibers are,

- High stiffness,
- High tensile strength,
- Low weight,
- High chemical resistance,
- High temperature tolerance and
- Low thermal expansion,

These properties make them very famous in aerospace, civil engineering, military, and motorsports, along with other sports materials. And, they are relatively bit expensive as comparing with similar fibers, likes glass fibers or plastic fibers. Carbon fibers are usually produced by combined with other materials to form a composite material.

When combined with a plastic resin- hardener mixer wound or molded it forms carbon-fiber-reinforced polymer otherwise called as cfrp (often referred to as carbon fiber). They have very high strength, less weight, and extremely rigid, somewhat brittle. Carbon fibers are also fabricated with other materials, such as with graphite to form carbon-carbon composites, which have a very high heat tolerance and used in furnaces.

Fig 1: Woven carbon fibre

Table 1 Physical properties of carbon fiber used

Density (g/cm3)	1.8
Filament Diameter (µm)	7
Tensile Strength (MPa)	4000
Tensile Modulus (GPa)	240
Elongation (%)	1.7

Table 2 Physical epoxy resin and hardener

Name of Epoxy resin	BONDINSUL 52 (A)
Physical State	Viscous liquid
Appearance	Transparent
Colour	Pale yellow/colourless
Viscosity @25°C	2500-3500 cps
% hydrolysable chlorine	0.5 max
Epoxy eq wt.	225-250 eq/gm
Pot Life @25°C	45-60 min
Name of Hardener used	BONDINSUL 71 (B)
Ratio (Resin: Hard.)	: 100:10

*A. Fabrication of Carbon Fiber Composite (*Hand Lay Up Process)

The carbon fibres are first put in place in the mould of required size. The fibres may be in the different forms likes woven, knitted, stitched and bonded fabrics. Then the suitable resin and hardener mixer is applied. The application of resin and hardener mixer is done by using rollers, brushes or a roller type impregnator.

This application helps in forcing the resin hardener mixer inside the fabric. The laminates created by this process are then allowed to cure within the standard atmospheric conditions, no requirement of autoclave. The wet/hand lay-up process is shown in Figure 2. One can use different combination likes resins epoxy, polyester, vinyl ester, phenolic and any other fibre material.

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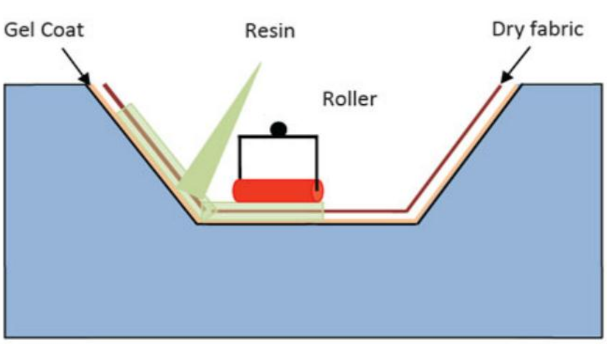

Fig 2: Hand layup process

In hand layup process liquid stage resin is used along with reinforcement (woven carbon fiber) on the finished clean surface of an open mould cavity. The Chemical reactions taking in the resin harden the fiber to very strong, light weight products. The resin acts as the matrix for the reinforcing carbon fibers, much act as concrete in the matrix for steel reinforcing. The percentage of carbon fiber and matrix was 50:50 in weight.

Fig 3. Cut the woven fabric of carbon fiber into 10 pieces of dimension 250mm*200mm

Contact molding in an open mould cavity by hand layup process was used to combine plies in a specific sequence. A flat plywood rigid platform was selected as open mould. A plastic sheet was kept on the plywood mold and a thin film of polyvinyl alcohol is applied as a releasing agents. Laminating starts with the application of the matrix (epoxy and hardener) deposited on the open mould by using brush, the main purpose was to make a smooth external surface finishing and to protect the composites from direct attacks to the environment. Plies were cut out from roll of woven type roving. Some layers of reinforcement were placed on the open mould at top of the gel coat (epoxy hardener mixer) and gel coat was again applied by using brush. If any air bubbles which may be entrapped inside was removed by using steel rollers. The process is continues before the gel coat had fully hardened.

After that, a thick plastic sheet was covered on the top of plate by applying releasing agent (polyvinyl alcohol) inside the sheet. Then, a wooden rigid platform was kept top of the composite for compressing test purpose. The plates were left for a minimum of 2 weeks before being transported and cut to exact shape for testing. The following materials are used for fabricating the carbon fiber composite plate

- Carbon fiber woven roving as reinforcement
- epoxy as resin
- Hardener as catalyst
- Polyvinyl alcohol as a releasing agent

Fig 4.By using hand layup process fabricating the composite

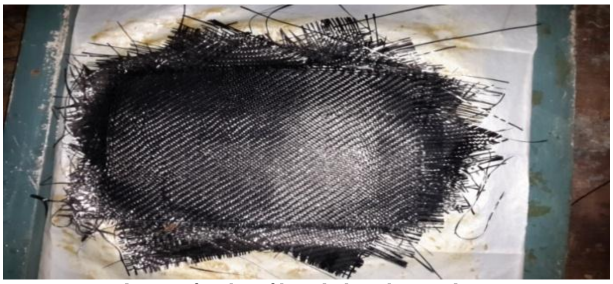

Fig 5. 10 layers of carbon fiber cloth with +30 ply orientation

Fig 6. After 2 weeks of curing Process

V. EXPERIMENTAL STUDY

In the view of difficulty of theoretical and numerical analysis for laminated structure behaviors, experimental methods are important to solve the buckling problem of laminated carbon fiber composite plates. To find out that fabricated composite plate's compression buckling test conducted. The test specimen was clamped on two sides and specimens were loaded in axial compression by using a compression testing machine of 100 tonne load capacity.

In this buckling compression tests buckling load of carbon fiber composite plate is determined.

A. Test Procedure

The fabricated carbon fiber plate was loaded in axial compression using an Instron testing machine of 100 KN capacities. The plate was clamped at two ends and kept free at the other two ends. A dial gauge was placed at the centre of the specimen to find out the lateral deflection. All plates of different dimensions were loaded slowly until buckling. For axial compression loading, the test plates were placed

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between the two extremely ends of the machine heads; the lower side was fixed in the test, whereas the upper head was moved downwards by servo hydraulic cylinder. As the compression load was increases the centrally placed dial gauge needle started moving, and due to buckling there was a sudden movement of the needle. The compression load at this point will be the buckling load of the specimens.

Fig .7 Instron testing machine

Table 3 Test Specimen Dimensions

Plate No	Length(mm)	Thickness(mm)	Width(mm)
1	100	2	20
2	150	2	20
3	150	2	30

Fig .8 Test specimens

Table 4 Experimental Results

Plate No	Length (mm)	Thickness(mm)	Width(mm)	Experimental Buckling Load(KN)
1	100	2	20	0.810
2	150	2	20	0.265
3	150	2	30	0.250

VI .MODELLING AND FEM ANALYSIS

ANSYS was used to carry out the finite element analysis in the work. ANSYS is used to analyze the buckling load Of Carbon fiber composite plates of different sizes. The dimension of the specimen were 100*20*2mm, 150*30*2mm and 150*20*2 in length, width and thickness. Eigen value buckling analysis in ANSYS has four steps:

1. Build the required model: It includes defining element type, size, real constants, material properties and modeling.
2. Solution (Static Analysis): It includes applying boundary conditions, applying loads and solving the static analysis. The applied boundary condition and load is shown below

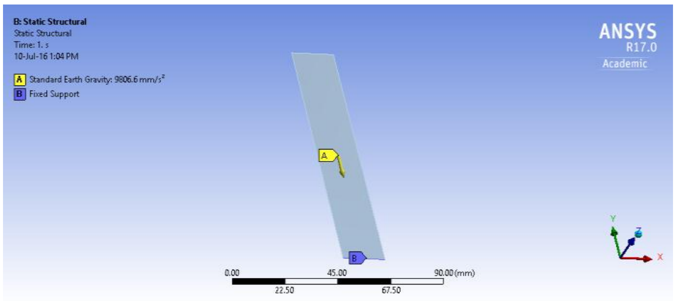

Fig .9 Static structural

3. Eigen buckling analysis: Eigen value buckling analysis predicts the theoretical buckling strength of an ideal linear elastic structure.
4. Postprocessor: This step includes listing different buckling loads and viewing in different buckled shapes. We can plot the deformed and un deformed shape of the plate.

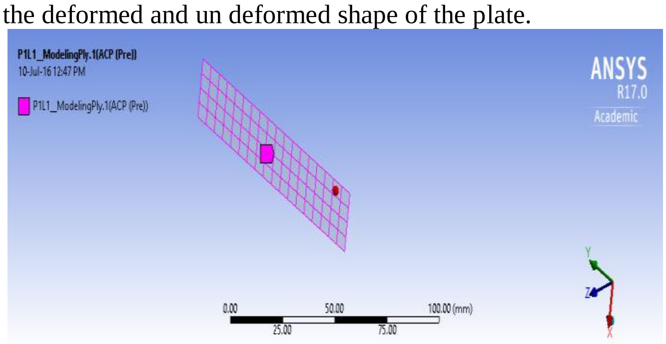

Fig.10 Model Ply 1

The model created by using 10 ply of carbon fiber sheets. Each plies carries a thickness of 2mm and ply orientation 0,+30,+60,+90,+120,+150,+180,+210,+240,+270.

VII .ANLYSIS RESULTS

A. *Model Analysis of Specimen 1*

Specimen Dimensions: 20mm*100mm*2mm in length width and thickness

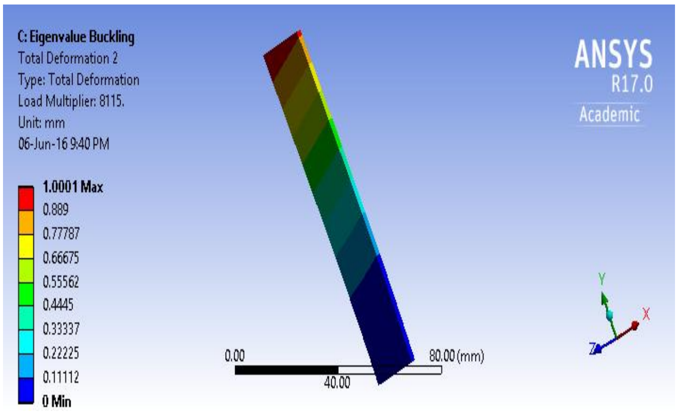

Fig 11 Eigen value buckling deformation 1

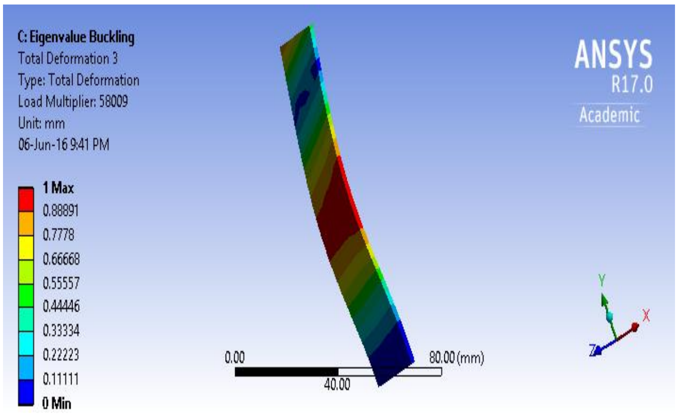

Fig .12 Eigen value buckling deformation 2

Table 5 Eigen value buckling of specimen 2

Eigen value Buckling Deformation No	Maximum Deformation (mm)	Load Multiplier	Load(KN)
1	1.0001	8115	0.8272
2	1	58009	5.91325
3	1.0011	$1.5402*10^5$	15.700
4	1.033	$2.9517*10^5$	30.088
5	1.0147	$4.3425*10^5$	44.266
6	1.0076	$4.829*10^5$	49.2313

B. *Model Analysis Of Specimen 2*

Specimen Dimensions: 30mm*150mm*2mm in length width and thickness

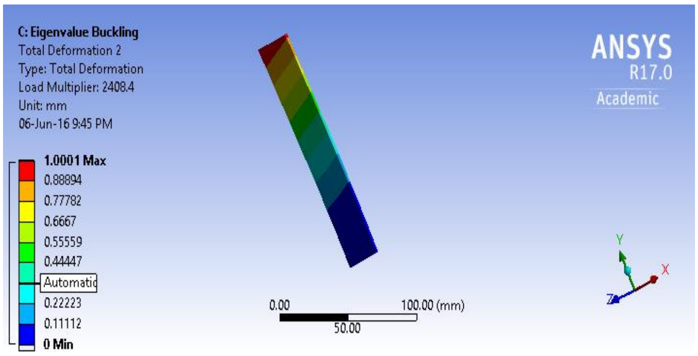

Fig .13 Eigen value buckling deformation 1

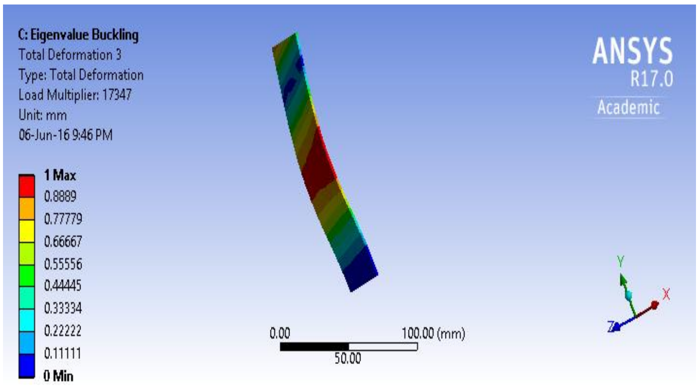

Fig .14 Eigen value buckling deformation 2

Table 5 Eigen value buckling of specimen 2

Eigen value Buckling Deformation No	Maximum Deformation (mm)	Load Multiplier	Load(KN)
2	1.001	2408.4	0.245
3	1	17347	1.7682
4	1.005	46763	4.7668
5	1.0013	91704	9.3480
6	1.0025	$1.352*10^5$	13.78
7	1.0013	$1.549*10^5$	15.79

C. *Model Analysis Of Specimen 3*

Specimen Dimensions: 20mm*150mm*2mm in length width and thickness

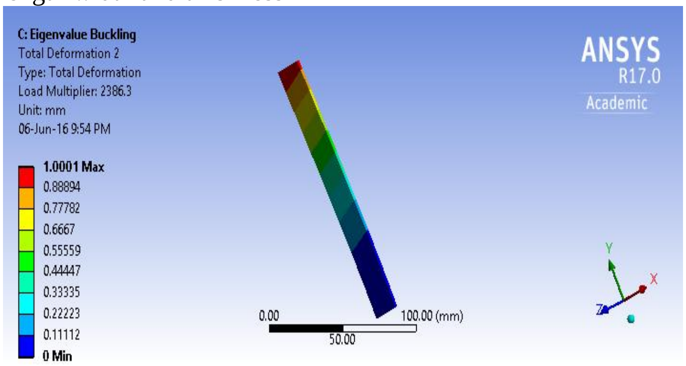

Fig.15 Eigen value buckling deformation 1

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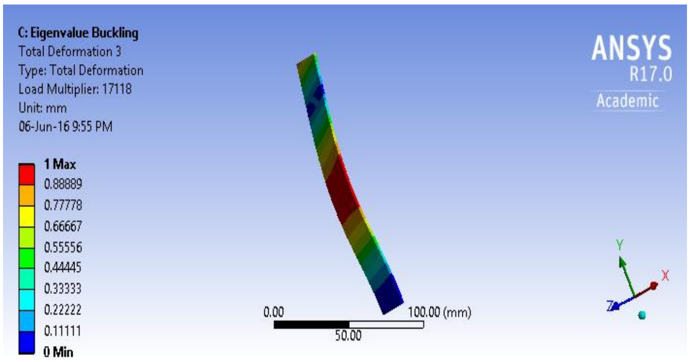

Fig .16 Eigen value buckling deformation 2

Table 6 Eigen value buckling of specimen 3

Eigen value Buckling Deformation No	Maximum Deformation (mm)	Load Multiplier	Load(KN)
2	1.0001	2386.3	0.24325
3	1	17118	1.7449
4	1.0005	45798	4.668
5	1.0019	89050	8.9050
6	1.0013	$1.476*10^5$	14.76
7	1.0259	$2.2176*10^5$	22.176

VIII. RESULTS COMPARISON

Table 7. Results comparison

Plate No	Length(mm)	Thickness (mm)	Width(mm)	Experimental Buckling Load(KN)	Ansys Buckling Load(KN)
1	100	2	20	0.810	0.8272
2	150	2	20	0.265	0.245
3	150	2	30	0.250	0.2432

From the above table it is understandable that both experimental buckling load and Ansys analyzed buckling load are almost equal. Plates with different types of dimensions are used extensively due to different design requirements. Thus, the buckling load response of plates with different dimensions must be fully understood in the structural design. In this section, the effects of length and width with same thickness are taken in to account. The experiments indicate that the variation of the buckling loads is very sensitive to the length. It can be seen that buckling load generally decreases with increase in length.

IX. CONCLUSION

This study understanding the buckling response of laminated rectangular plates with clamped-free boundary conditions. The laminated composite plates have varying L/W ratio, aspect ratio. From the present analytical and experimental study, the following conclusions can be made. Buckling load of carbon fiber composite plates of different dimensions obtained in both experimentally and analytical method. The experiments indicate that the variation of the buckling loads is very sensitive to the length. It can be seen that buckling load generally decreases with increase in length.

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