International Journal of Mechanical
Engineering (IJME)
ISSN(P): 2319-2240; ISSN(E): 2319-2259
Vol. 4, Issue 5, Aug - Sep 2015, 9-16
© IASET

International Academy of Science,
Engineering and Technology
Connecting Researchers; Nurturing Innovations

STRESS ANALYSIS OF LAMINATED GRAPHITE/EPOXY COMPOSITE PLATE USING FEM

YENDA KESAVARAO[1], CH. SIVA RAMAKRISHNA[2] & SAINEELKAMAL ARJI[3]

[1]PG Student, Vignan's Institute of Information Technology, Visakhapatnam, A.P, India

[2]Associate Professor, Vignan's Institute of Information Technology, Visakhapatnam, A. P, India

[3]Assistant Professor, Vignan's Institute of Information Technology, Visakhapatnam, A. P, India

ABSTRACT

This work presents a stress analysis of Graphite/Epoxy laminated composite plate. In the present work the stress behaviour of laminated composite plates under Tensile loading using a four-node element with six degrees of freedom at each node and translations in the x and y directions. The static stress analysis includes the all type of stress behaviour in diagrammatic form and results are plotted for investigation. In the present study the modelling is done in ANSYS 14.5 .In this study investigations were carried on square plates starting with Three layers of top location of 0^0 angle ply laminated composite plates at clamped boundary condition and 0^0 angle ply oriented with 15,30, 45,60,and 75 degree then analyze the stresses for optimizing the structure.

KEYWORDS: Laminated Composite Square Plate, Ply Orientation, Tensile Loading, ANSYS and Analysis

1. INTRODUCTION

Composite materials are extensively used in aerospace, automobile, nuclear, marine, biomedical and civil Engineering. As composite materials having high strength to weight ratio and high stiffness to weight ratio. The material has superior fatigue characteristics and also ability to change fibre orientations to meet design requirements. Now a day's laminated composite materials are the primary need of high rise buildings. In practical the use of laminated composite as slabs, beams, panels, deck etc. The matrix, compared with fibre direction, limits the strength of laminated composites. However composite structures subjected to low-velocity impacts or the drop of minor objects, such as tools during assembly or maintenance operation, exhibit a brittle behaviour and can sustain significant damage.

These impacts are particularly significant in design of laminated plies. The structural components like beam made of composite materials are being increasingly used in engineering applications. Because of their complex behaviour in the analysis of such structures some technical aspects must be taken into consideration. Finite element method is versatile and efficient tool for the analysis of complex structural behaviour of the laminated composite structures. The analysis of vibration and dynamics, buckling and post buckling, failure and damage analysis based on the various laminated plate theories is mainly carried out using ANSYS software.

2. LITERATURE REVIEW

Wimmer and Pettermann [1] numerically simulated separation in composite plates. In his study, he used combination of critical and failure loadings. Yang et al. [2] defined exact numerical method for mechanical behaviour of composite plates with elastic joints. They assumed isotropic joints and also considered friction in contact surface between joints and plates. In their analysis, plates were assumed symmetric. L. Jun, H.Hongxing and S. Rongying [3], introduced a dynamic finite element method for free vibration analysis of generally laminated composite beams on the basis of first-order shear deformation theory. The influences of Poisson effect, couplings among extensional, bending and tensional deformations, shear deformation and rotary inertia are incorporated in the formulation. The dynamic stiffness matrix is formulated based on the exact solutions of the differential equations of motion governing the free vibration of generally laminated composite beam. Hyer and Liu [4], investigated effect of pin elasticity, clearance and friction on radial and tangential stress distribution around hole in mechanical joints of orthotropic plates by numerical method. Their model was 2D and constituted of two symmetric layers to investigate aforementioned parameters. Yegao et al [5] presented a general formulation for free and transient vibration analysis of composite laminated beams with arbitrary lay- ups and any boundary conditions. A modified variational principle combined with a multi-segment partitioning technique is employed to derive the formulation based on a general higher order shear deformation theory. The material coupling for bending-stretching, bending-twist, and stretching twist as well as the poison's effect are taken into account. K. Mosalam, L Glascoe, J Bernier [6] stated as different varieties of bricks such as hollow bricks, fly ash bricks, clay bricks, wire cut bricks, etc. and varied mortar mixes containing fly ash, lime, or only cement and sand. Other factors affecting the properties of masonry are anisotropy of the brick units, mortar joint thickness, mortar strength and workmanship. Therefore, the masonry properties are not similar and vary with the properties of its constituent materials like brick unit and mortar. To understand the behaviour of masonry, the material properties of brick units and mortar has to be determined. Shahid Nazir, Manicka Dhanasekar, [7] has modelled the masonry for thin layered mortar joints. The reviews helped in carryout the present work.

3. METHODOLOGY

3.1 Finite Element Method (FEM)

The physical structure that was used in this work is a fibre reinforced composite plate; the length (a) of 1.0 metre width (b) of 0.5metre and thickness (h) of the plate is 0.015m. A number of analyses are performed in this design study, using a finite element model of the plate. The model was developed using linear layered structural shell elements in ANSYS 14.5. The global x-coordinate is taken along the length of the plate; the global y-coordinate is taken along the width of the plate while the global z-direction is taken out the plate surface. There are 40 elements in the axial direction and 40 along the width one. The boundary conditions, all sides are constrained in all directions. The pressure applied on the plate is 1000 N. In this study, three ply [$0^0/30^0/-45^0$] symmetric laminated composite plate is considered in the analysis. The plate is analyzed for deflections and stresses under a fully constrained boundary condition when the plate is subjected to tensile loading along the X and Y - directions for various ply locations.

3.2 Geometry of the Shell Element

In ANSYS software, there are many element types available to model layered composite materials. In our FE analysis, the linear layered structural shell element is used. It is designed to model thin to moderately thick plate. An accurate representation of irregular domains (i.e. domains with curved boundaries) can be accomplished by the use of refined meshes and/or irregularly shaped elements. For example, a non-rectangular region cannot be represented using only rectangular elements; however, it can be represented by triangular and quadrilateral elements. Since, it is easy to derive the interpolation functions for a rectangular element and it is much easier to evaluate the integrals over rectangular geometries than over irregular geometries, it is practical to use quadrilateral elements with straight or curved side assuming a means to generate interpolation functions and evaluate their integrals over the quadrilateral elements. The linear layered structural shell element is shown in Figure 3.1 Nodes are represented by I, J, K, L, M, N, O, and P.

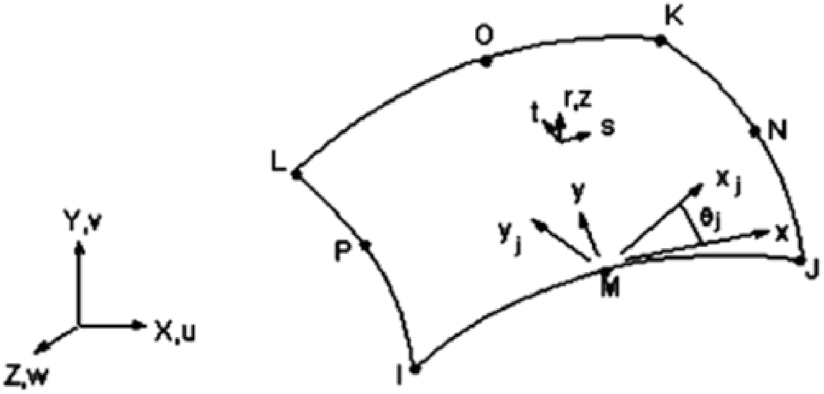


Figure 1: Geometry of 8-Node Element with Six Degrees of Freedom

In the present context of table (3.1&3.2), modelling the stresses in a Symmetric Cross-Ply Laminar Composite in tension load. in ANSYS Mechanical APDL. This composite consists of three layers. The model will use two dimensional layered shell elements. By comparing the results with the analytical solution based on the Generalized Hooke's Law, the module will emphasize techniques on modelling orthotropic materials and layered materials.

3.3 Problem Description

An orthotropic plate with three numbers of layers is subject to transverse loading condition for clamped boundary condition and the best ply location oriented with different angles has been considered for the present study, and the results were given in diagrammatic form.

Table 3.1: Geometric Properties of Orthotropic Material Plates

Dimensions	No. of Layers	Stacking Sequence	Fiber Orientation
Length=1.0m	3	$0^0/30^0/-45^0$	Symmetric ply
Width=1.0m			
Thickness=0.015m			

Table 3.2: Material Properties of Graphite/Epoxy Composite Material

Elastic Constants	Values
E_1	181GPa
E_2	10.3 GPa
E_3	10.3 GPa
$V_{12}=V_{13}$	0.28
V_{23}	0.01593
$G_{12}=G_{13}$	7.17 GPa
G_{23}	7.17 GPa

RESULTS & DISCUSSIONS

The problem was anlyzed using FEM based software ANSYS. Figures detail the different stresses of laminated composite plate. The stress in X direction, stress in Y direction, Shear stress in XY direction for 0^0 layer located at bottom, middle and top location of the lamina are shown in Figure 4.1 to 4.9. The orientation of layers are changed and change values are plotted in Figure 4.10 to 4.24. The optimized ply location and ply orientation are identified with the results.

(a) When Layer is Located at Bottom (0^0)	**(b.) When Layer is Located at Middle(0^0)**

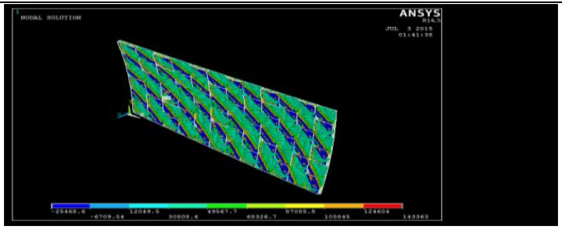
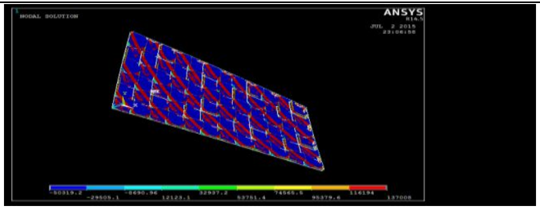

	

Figure 4.1: Stress in X Direction	**Figure 4.4: Stress in X Direction**

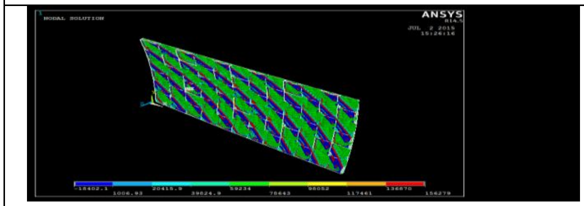
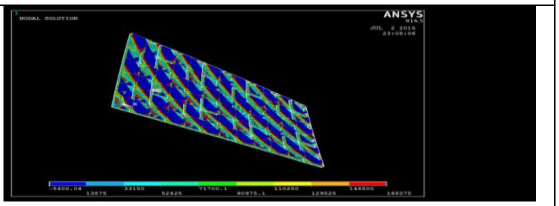

	

Figure 4.2: Stress in Y Direction	**Figure 4.5: Stress in Y Direction**

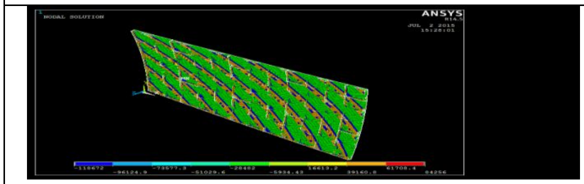
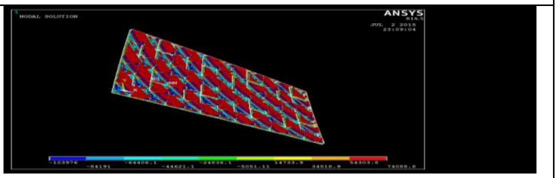

	

Figure 4.3: Shear Stress in XY Direction	**Figure 4.6: Shear Stress in XY Direction**
(c) When Layer is Located at Top (0^0)	**(d) When 0^0 Layer is Oriented with 15^0**

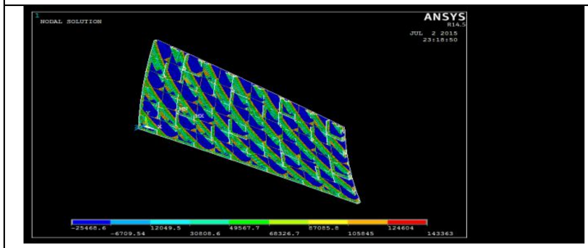
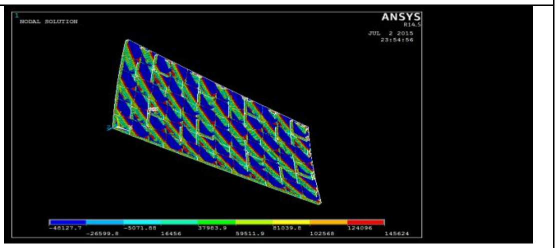

	

Figure 4.7: Stress in X Direction	**Figure 4.10: Stress in X Direction**

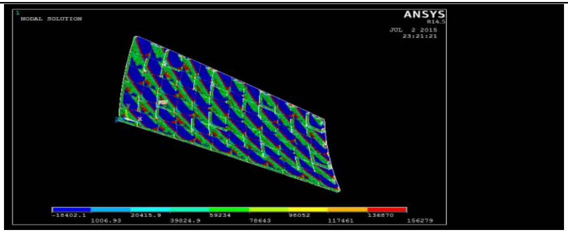
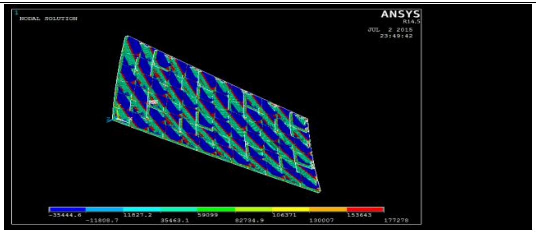
	

Figure 4.8: Stress in Y Direction	**Figure 4.11: Stress in Y Direction**

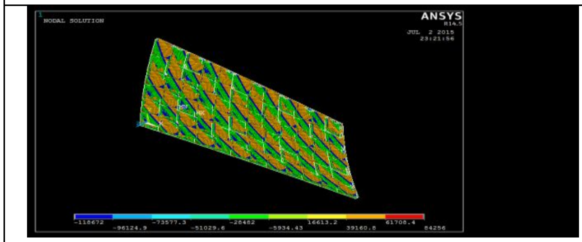
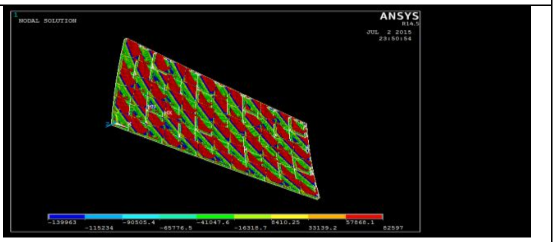

	

Figure 4.9: Shear Stress in XY Direction	**Figure 4.12: Shear Stress in XY Direction**
(e) When 0^0 Layer is Oriented with 30^0	**(f) When 0^0 Layer is Oriented with 45^0**

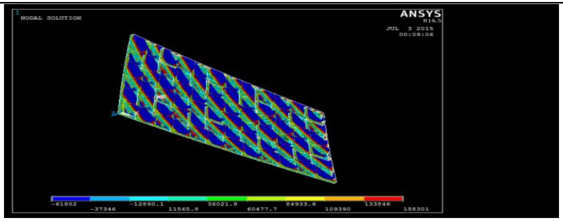
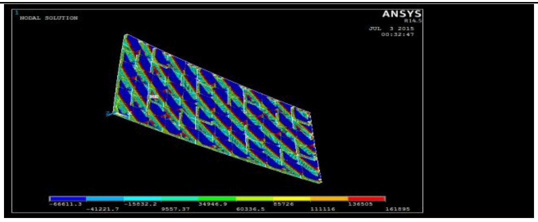

	

Figure 4.13: Stress in X Direction	**Figure 4.16: Stress in X Direction**

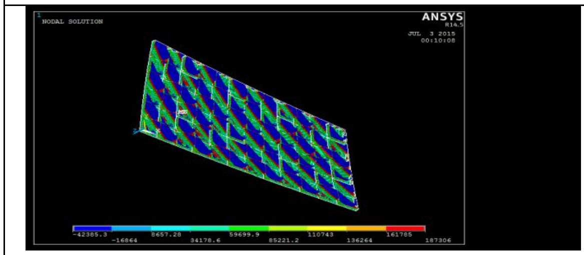
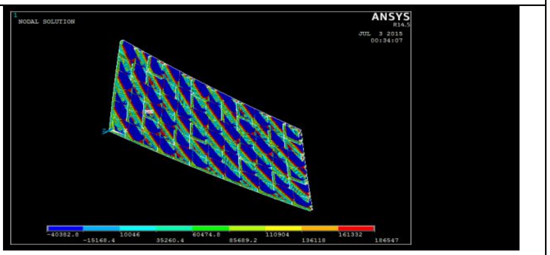

	

Figure 4.14: Stress in Y Direction	**Figure 4.17: Stress in Y Direction**

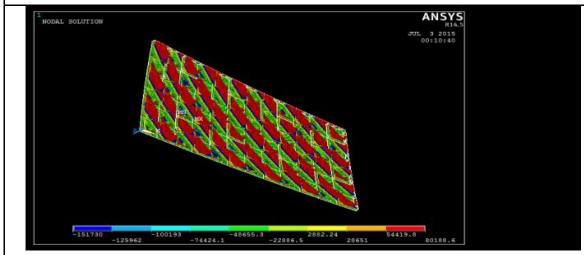
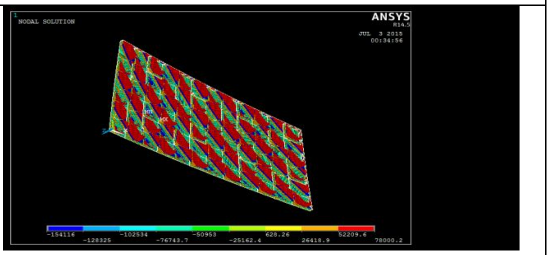

	

Figure 4.15: Shear Stress in XY Direction	**Figure 4.18: Shear Stress in XY Direction**

(g) When 0^0 Layer is Oriented with 60^0

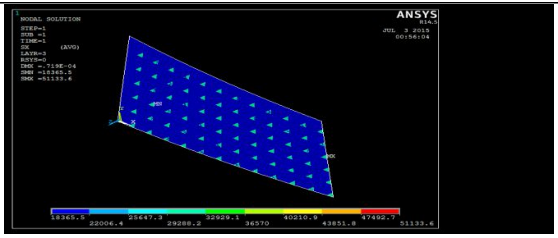


Figure 4.19: Stress in X Direction

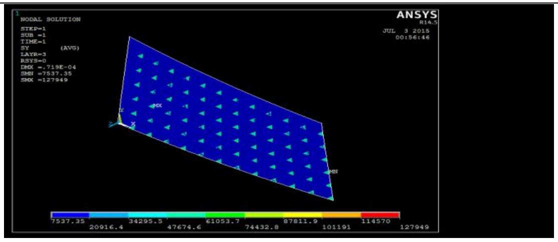


Figure 4.20: Stress in Y Direction

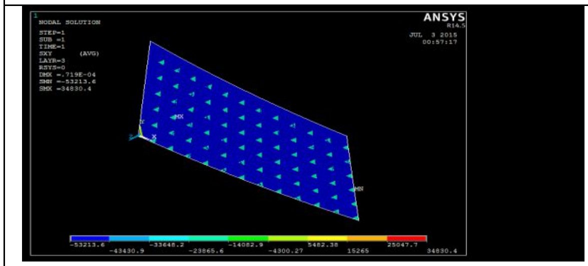


Figure 4.21: Shear Stress in XY Direction

(h)When 0^0 Layer is orienEted with 75^0

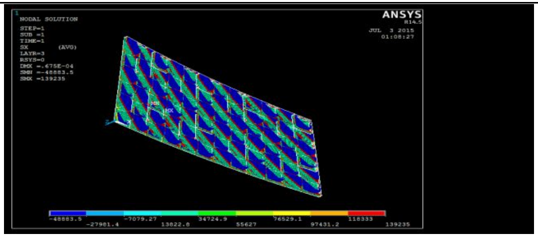


Figure 4.22: Stress in X Direction

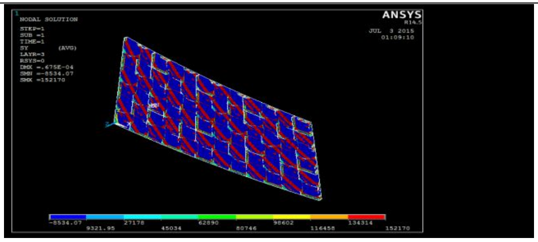


Figure 4.23: Stress in Y Direction

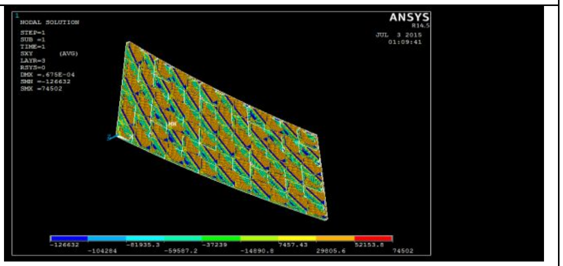
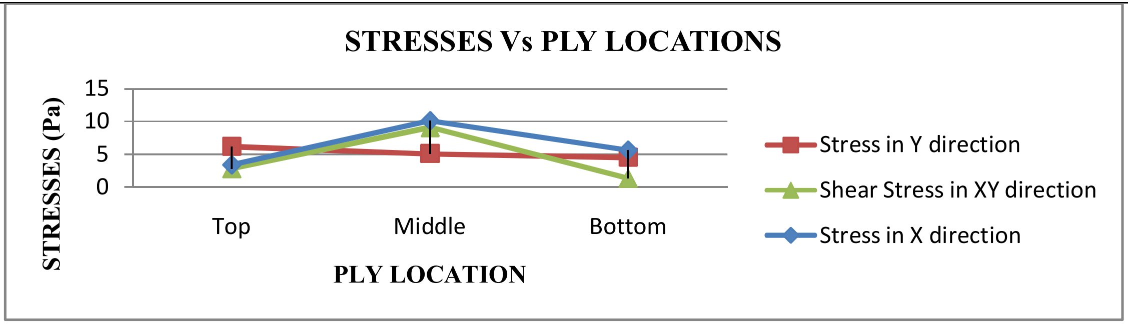
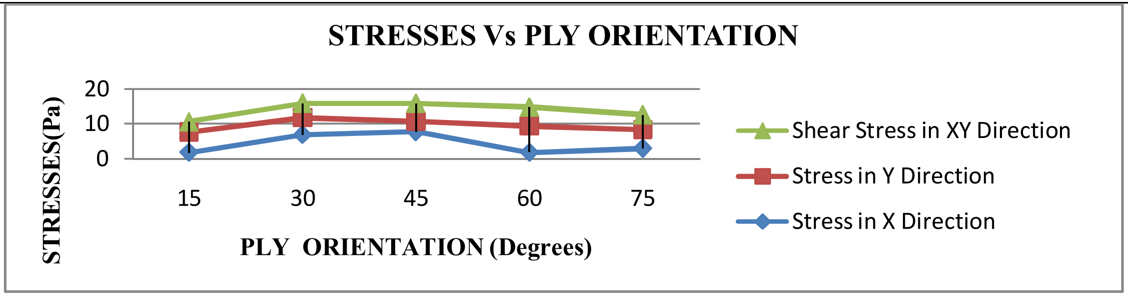


Figure 4.24: Shear Stress in XY Direction

Graph 4.1 Stresses Vs Ply Locations



Graph 4.2 Stresses Vs Ply Orientations



Graph 4.3 Strains Vs Ply Locations

Table 4.1: Tabulation of Results: Regarding the Location of 0^0 Ply

Design Parameter	**When 0^0 Layer is Located at Bottom**	**When 0^0 Layer is Located at Middle**	**When 0^0 Layer is Located at Top**
Stress in X Direction**(Pa)**	$\mathbf{5.5767\times10^4}$	$\mathbf{10.101\times10^4}$	$\mathbf{3.3513\times10^4}$
Stress in Y Direction**(Pa)**	$\mathbf{4.5312\times10^4}$	$\mathbf{5.0510\times10^4}$	$\mathbf{6.1875\times10^4}$
Shear Stress in XY Direction **(Pa)**	$\mathbf{-1.2800\times10^4}$	$\mathbf{-9.067\times10^4}$	$\mathbf{-2.7504\times10^4}$

Different ply location and respective stresses are detailed in Table 4.1, The bottom ply location is the optimized location for stresses in Y direction and for the shear stress.

4.2 Optimization of Orientation Ply Orientation

The 0^0 location at bottom ply location is oriented in 15^0,30^0,45^0,60^0,75^0 and the values of stresses are developed to estimate optimised ply orientation in tensile loading of a laminated composite plate and the results are tabulated in Table 4.2.

Table 4.2 Tabulation of Results Regarding Optimization of Ply Orientation

Design Parameter	**When 0^0 Layer is Oriented with 15^0**	**When 0^0 Layer is Oriented with 30^0**	**When 0^0 Layer is Oriented with 45^0**	**When 0^0 Layer is Oriented with 60^0**	**When 0^0 Layer is Oriented with 75^0**
Stress in X Direction **(Pa)**	$\mathbf{1.7823\times10^4}$	$\mathbf{6.9241\times10^3}$	$\mathbf{7.6931\times10^3}$	$\mathbf{1.8365\times10^4}$	$\mathbf{2.9591\times10^4}$
Stress in Y Direction **(Pa)**	$\mathbf{5.8004\times10^4}$	$\mathbf{4.8094\times10^4}$	$\mathbf{2.9193\times10^4}$	$\mathbf{7.537\times10^3}$	$\mathbf{-5.230\times10^3}$
Shear Stress in XY Direction**(Pa)**	$\mathbf{-3.0518\times10^4}$	$\mathbf{-4.0815\times10^4}$	$\mathbf{-5.1469\times10^4}$	$\mathbf{-5.3214\times10^4}$	$\mathbf{-4.4121\times10^4}$

5. CONCLUSIONS

In this paper, Finite element analyses have been carried out for various ply locations (0^0, 30^0,- 45^0) and orientations. The study the effect of stresses of laminated composite plates subjected to tensile load. From the results it is concluded that The stress in Y direction and shear stresses are minimum if ply location is at bottom. Also concluded for load application in X direction 30^0 is optimum orientation of the composite Lamina. The stresses Y direction is minimum at $45^0$and for shear stress is 15^0 for the same loading conditions indicates the load carrying property changes with the ply orientation of the composite.

5.1 Future Scope

The work may be extended by changing the aspect ratio, length to width ratio (a/b), width to thickness ratio(b/h) also..

6. REFERENCES

1. Alnefaie, K., 2009. Finite element modelling of composite plates with internal delamination. Compos Struct.: 90, 21– 27.
2. Hassan, N.K., Mohamedien, M.A., & Rizkalla, S.H. (1996). Finite element analysis of bolted connections for PFRP composites. Composites: Part B, 27B, 339-349.
3. L. Jun, H. Hongxing and S. Rongying, "Dynamic finite element method for generally laminated composite beams", Int. J. Mechanical Sciences, vol.50, pp.466-480, 2008
4. H.B.H.Gubran and K.Gupta, "The effect of stacking sequence and coupling mechanisms on the natural frequencies of composite shafts", J. Sound and Vibration, vol.282, pp.231-248, 2005.
5. Yegao Qu, Xinhua Long, Hongguang Li, Guang Meng, "A variational formulation for dynamic analysis of composite laminated beams on a general higher-order shear deformation theory", Composite Structures, Vol. 102, 175–192, 2013.
6. K. Mosalam, L Glascoe, J Bernier, ―Mechanical properties of unreinforced brick masonry‖, *Lawrence Livermore national laboratory*, TR-417646.
7. Shahid Nazir, Manicka Dhanasekar, ―Modelling the failure of thin layered mortar joints in masonry,‖ in *Engineering Structures 49 (2013)*, pp. 615–627.