Analysing Unidirectional Fibre Orientations Under Transverse Static Load Using Glass Fibre

P.V.Elumalai[1] R. Sendil Kumar[2] N. Prem Kumar[3] S.Sejin[4] Sasi Rekha[5]
[1,2,]Assistant Professor [3]Associate Professor[4,5]Student
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Dhanalakshmi College of Engineering ,Chennai, Tamil Nadu -631502, India.

Abstract— The composite plate material have found widespread applications in various fields of engineering such as aerospace, marine, automobile and mechanical applications. The effect of fiber orientation in a rectangular composite lamina under transverse static loading by using the finite element method. The results are obtained with the help of four different boundary conditions, three different materials and five different angle of orientation.

***Key words*:** Orientation, Composites, Glass Fiber

I. INTRODUCTION

A. *Composite material*

Composite material is one in which two or more materials that are different properties are combined to form single structure with identifiable interface. The properties of that new structure are dependent upon the properties of the constituent materials as well as the properties of the interface. Additionally, where metal alloys have isotropic characteristics, composites have very selective directional properties to meet specific application needs.

B. *Metals-Matrix Composites*

The basic attributes of metals reinforced with hard ceramic particles or fibers are improved strength and stiffness, improved creep and fatigue resistance, and increased hardness, wear and abrasion resistance, combined with the possibility of higher.

C. *Polymer-matrix composites*

The wide range of processes used to produce reinforced plastics is partly new, and partly derived from established methods of processing ordinary polymeric materials. The manner of combining fibers and matrix into a composite material depends very.

1) *Properties of Mmc:*

- Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness,
- Increase in creep resistance at higher temperatures compared to that of conventional Alloys,
- Increase in fatigue strength, especially at higher temperatures,

D. *Advantages of Composites*

- Stronger and stiffer than metals on a density basis
- Capable of high continuous operating temperatures
- Highly corrosion resistant
- Electrically insulating/conducting/selectively conducting properties
- Tailor able thermal expansion properties
- Exceptional formability
- Outstanding durability

E. *Application of Composites*

Commercial and industrial applications of composites are so varied that it is impossible to list them all. In this section, we highlight only the major structural applications areas, which include aircraft, space, automotive, sporting goods, marine, and infrastructure. Potential use of composite exists in many engineering fields. Putting them to actual use requires careful design practice and appropriate process development based on the understanding of their unique mechanical, physical, and thermal characteristics.

Composite are also used in electronics (e.g., printed circuit boards), building construction (e.g., floor beams), furniture (e.g., chair springs), power industry (e.g., transformer housing), oil industry (e.g., offshore oil platforms and oil sucker rods used.

II. FIBERS

Fibers are the principal constituents in a fiber reinforced composite material. They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on a composite structure. Proper selection fiber type, fiber volume fraction fiber length and fiber orientation is very important, since it influence the following characters of composite laminate:

- Density
- Tensile stress and modulus
- Compressive strength as well as the fatigue failure mechanisms
- Fatigue strengths as well as the fatigue failure mechanisms
- Electrical and thermal conductivities
- Cost

1) *Boron Fibers*

The most prominent feature of boron fibers is their extremely high tensile modules, which is in the range of 379-414 GPa (55-603106psi). Coupled with their relatively large diameter, boron fibers offer excellent resistance to buckling, which in turn contributes to high compressive strength for boron fiber-reinforced composites. The principal disadvantages of boron fibers are their high cost, which is even higher than of many forms of carbon fibers. For this reason, its use is at present restricted to a few aerospace applications.

2) *Glass Fibers*

Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites (PMC). The principal advantage of glass fibers are low cost, high tensile strength, high chemical resistance, and excellent insulating properties. The disadvantages are relatively low tensile modulus and high density sensitivity toabrasion during handling (which frequently decreases its tensile strength), relatively 6low fatigue resistance, and high hardness (which causes excessive wear on molding dies and cutting tools).

B. Matrix

The essentially homogeneous material in which the fiber system of a composite is embedded.

1) AluminiumMatix

Reinforcement of aluminum alloys with short staple, alumina matrix of importance in recent years because of the enhanced mechanical properties of the resulting composites, particularly at elevated temperatures. The elevation of such composites in the marketplace has ken rapid. The automobile components such as diesel pistons, connecting rods, piston pins etc, are now being routinely fabricated to meet more stringent empty requirements. In these applications, short domain fibers are fabricated into a. perform, usually palazzo orientation, and them infiltrated with molten metal under pressure.

2) Ceramic Matrix

Silicon carbide (SiC) and aluminum oxide (A1203)fibers are examples of ceramic fibers notable for their high-temperature applications in metal and ceramic matrix composites. Their melting points are 28308c and 20458c, respectively. Silicon carbide retains its strength well above 6508c and aluminum oxide has excellent strength retention up to about 13708c.

Both fibers are suitable for reinforcing metal matrices in which carbon and boron fibers exhibit adverse reactivity. Aluminum oxide fibers have lower thermal and electrical conductivities and have higher coefficient of thermal expansion than silicon carbide fibers.

3) Epoxy Matrix

Starting materials for epoxy matrix are low molecular weight organic liquid resins containing a number of epoxy group which are three member rings are one oxygen atom and two carbon atoms. The polymerization reaction to transform the liquid resin to the solid state is initiated by adding a small amount of reactive cutting agent just before incorporating fiber into liquid mixture. The properties of a cured epoxy resin depend on principles on the cross link densities. In general the tensile modulus the glass transition temperature and thermal stability aweless chemical resistance are improved with cross link density.

C. Fiber Architecture

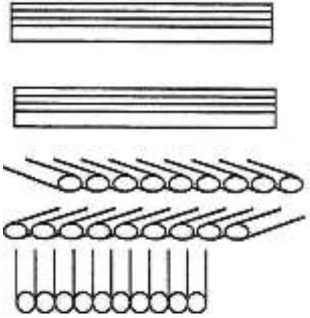
Fiber architecture is defined as the arrangement of fibers in a composite, which not only influence the properties of the composite, but also its processing. The characteristics of fiber architecture that influence the mechanical properties include fiber continuity, fiber orientation, fiber crimping, and fiber interlocking. During processing, matrix flow through the fiber architecture determines the void content, fiber wetting, fiber distribution, dry area and others in the final composite, which in turn, also affect its properties and performance.

A laminate is constructed by stacking a number of laminas in the thickness (Z) direction. Examples o f few special types of laminates and the standard lamination code are given as follows:

1) Unidirectional laminate

In a unidirectional laminate (Figure 3.4.1), fiber orientation angles are the same in all laminas. In unidirectional 0’ laminates, for Example, 0=0 in all laminas.

D. Different Types Of fibre Orientation



Composites are used in the form of unidirectional laminates, since one of their great merits is that the fibers can be arranged so as to give specific properties in any desired direction. Thus, in any given structural laminate, predetermined proportions of the unidirectional plies will be arranged at some specific angle, θ, to the stress direction. In order to calculate the properties of such a multi-ply laminate,

It is first necessary to know how the elastic response of a single unidirectional lamina, such as that which we have been considering so far, will vary as the angle to the stress direction is changed. This is done by transforming the axes through some arbitrary angle, θ, a procedure that will familiar to anyone who has studied the derivation of the Mohr’s circle construction.

III. FINITE ELEMENT ANALYSIS

ANSYS is a powerful general purpose finite element modeling package to

Numerically solve a wide variety of mechanical, structural and non-structural Problems. These problems include: static structural analysis (both linear and non linear). Heat transfer and fluid problems, a finite solution may be classified into following three stages. This is a general guideline that can be used for setting up any finite element analysis

(1) Pre-processing: Define the problem

The major steps in preprocessor are as follows

- Define key points/ lines/areas/volume
- Define element types/material and geometric properties
- Mesh lines/areas/volume as required

(2) Solution

Assigning loads constraints and solving

In the solution level the loading condition such us point load or pressure and constraints or boundary condition are specified and finally the resulting set of equations are solved

(3) Post processing: Further processing and viewing the result

(i) This stage provides different tools to view tools to view the results including

List of nodal displacement element forces and moments

(ii) Deflection plot

A. Introduction of Ansys

Finite element analysis, the core of computer aided engineering dictates the Modern mechanical industry and plays a decisive role in cost cutting technology. It is a technique to simulate loading conditions on a design and determine the Designs response to those conditions. The design is modeled using discrete Building blocks called elements; each element has extract equations that describe how it responds toCertain load.

ANSYS the leading **FEA** simulation software, with its robust capabilities guides the Engineers to arrive at perfect design solution. ANSYS finite element analysis software enables engineer to perform the following tasks.

(1) Build computer models or transfer CAD models of structure, products, components or systems.
(2) Apply operating loads or other design performance conditions.
(3) Study physical responses, such as stress levels, temperature distributions, or electromagnetic fields.
(4) Optimize a design early in the development process to reduce production costs.
(5) To do prototype testing in environment otherwise would be undesirable or impossible.

B. Definition of Structural Analysis

Structural analysis is probably the most common application of the finite element method. The term structural implies not only civil engineering structural such as bridges and buildings, but also naval, aeronautical, and mechanical structure such as ship hulls, aircraft bodies, and machine housings as well as mechanical components such as pistons, machine parts, and tools.

C. Definition of Static Analysis

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects such as those caused by time varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity) and time varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonlyDefined in many building codes) Static analysis is used to determine the displacement, stress, strains, and forces in structure or components caused by loads that do not induce significant inertia and Damping effect. Steady loading and response conditions are assume. That is the loads and the structure response is assumed conditions are assumed.

The kinds of loading that can be applied in a static analysis.

(1) Externally applied forces and pressure
(2) Steady state inertial forces
(3) Imposed displacement
(4) Temperature
(5) Fluencies

IV. BASIC SUPPORT OF THE ANALYSIS

Element Types	Element Number
Beam	BEAM188;BEAM189;
Solidshell	SOILD SHELL190
Solid	SOLID186;SOLID46;SOLID191;SOLID95
Shell	SHELL99;SHELL91;SHELL181

Table 1: Shows Types of Elements Shell99

When modeling composites one of the key challenges is balancing the sophistication of the materials models against reasonable computational solution. In the first design phase, when many different solutions must be analyzed in a short space of time. It is necessary to be able to complete the analysis of alone million element model with in one day. This is not currently possible using full composite materials characterizations.

The situation is even more severe when performing stochastic analyses or undertaking multi objective optimizations. Both typically required the running of 60-100 simulations to complete. If it is taking a day or more to run each analysis and then the whole process could easily take longer than three months.

When addressing the issue of modeling composites, it is often necessary to start with micro models of the foams, fabrics, fiber reinforced materials, etc in order to develop an understanding of the physics of the situation behavior of the materials involved and their mutual interactions. The next stage is to develop mesh models, with the ultimate goal being macro models that provide accurate characterizations based on relatively small amount of material property data. ANSYS allows you to model composite materials with specialized elements called layered elements. Once you build your model using these elements, you can do any structural analysis

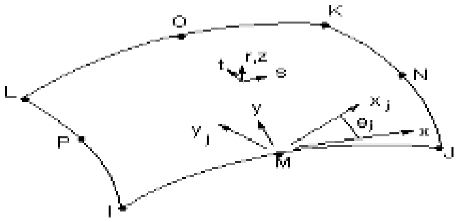
Composite are somewhat more difficult to model than an isotropic material such as iron or still. You need to take special care in defining the properties and orientations of the various layers since each layer may have the different orthotropic materials properties. In the section we will concentrate on the following aspects of building a composite model:

(1) Choosing the proper element type.
(2) Defining the layered configuration.
(3) Specifying failure criteria
(4) Following modelling and processing guidelines

A. Choosing the Proper Element Type

The following element types are available are available to model layered composite materials: SHELL99, SHELL91, SHELL181, SOLID46, and SOLID191. Which element you choose depends on the application the type of results that need to be calculated and so on. Check the individual element descriptions to determine if a specific element can be used in your ansys product. All layered element allow failure criterion calculations.

Used for layered applications of a structural shell model or for modeling thick sandwich structures. Up to 100 different layers are permitted for applications with the sandwich option turned off. Allows more layers. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes.



Shell 99 IS AN 8 N0DE 3D shell element with six degree of freedom at each node. It is designed to model thin to moderately thick plate and shell structure with a side to thickness ratio of roughly 10 or greater. For structure with smaller ratios, you consider using SOLID 46. The SHELL99 element allows a total of 250 uniform thickness layers.

B. Purpose Of Analysis

Shock, impact, or repeated cyclic stresses can cause the laminate to Separate at the interface between two layer a condition known as delamination.Individual fibers can separate from matrix e.g. fiber pull out. Composites can fail on the microscopic or macroscopic scale. Compression failure can occur at both the macro scale or at each individual reinforcing fiber in compression buckling. Tension failure can be net section failures of the part or degradation of the composite at a microscopic scale where one or more of the layer in the composite fails in the tension of the matrix or failure the bond between the matrix and fibers.

Some composites are brittle and have little reserve strength beyond the initial onset of failure while others may have large deformations and have reserve energy absorbing capacity past the onset of damage. The variations in fibers and matrices that are available and the mixtures that can be made with blends leave a very broad range of properties that can be designed in to composite structure. The best know failure of a brittle ceramic matrix composite occurred when the carbon –carbon composite tile on the leading edge of the wing of the space shuttle Columbia fractured when impacted during off. It led to catastrophic break-up of the vehicle To aid in predicting and preventing failures, composite are tested before construction.Pre-construction testing uses computer aided engineering tools such as NEi software Nastran FEA for ply-by-ply analysis of curved surfaces and predicating wrinkling, crimping and dimpling of composite.

C. Material Properties

Two different orthotropic materials are used to analysis the effect of fiber orientation. The material properties are given in the following table, where E, G, represent modulus of elastically, modulus of rigidity and poisons ratio respectively.

MATERIALS PROPERTIES	**BORON/ ALUMINIUM**	**SILICON CARBIDE/CERAMIC**	**WOVEN GLASS/ EPOXY**
E_X	235 GPa	121 Gpa	29.7 Gpa
E_Y	137Gpa	112 Gpa	29.7 Gpa
E_Z	137 Gpa	112 Gpa	29.7 Gpa
G_{XY}	47 Gpa	44 Gpa	5.3 Gpa
G_{YZ}	47 Gpa	44 Gpa	5.3 Gpa
G_{ZX}	47 Gpa	44 Gpa	5.3Gpa
μ_{XY}	0.3	0.2	0.17
μ_{YZ}	0.3	0.2	0.17
μ_{ZX}	0.3	0.2	0.17

Table 2:Table Shows Material Properties

D. Boundary Conditon

The following boundary conditions are fixed to analyze the stress and displacement.

B1 =left and right side uy=0, uz=0 and top to bottom uz=0, ux=0 arrested.

B2=left side all degree of freedom arrested.

B3=left and right side degree of freedom arrested and top to bottom uz=0, ux=0 arrested.

B4= All side degree of freedom arrested.

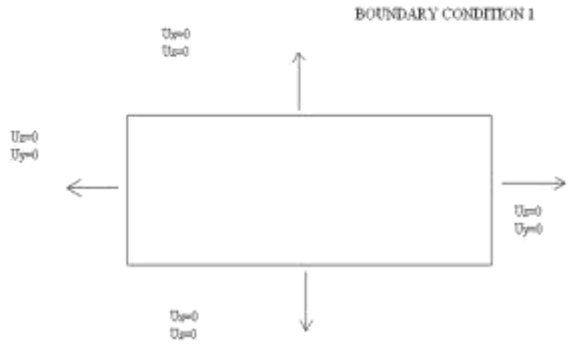


Fig 5.4.1 shows boundary condition 1

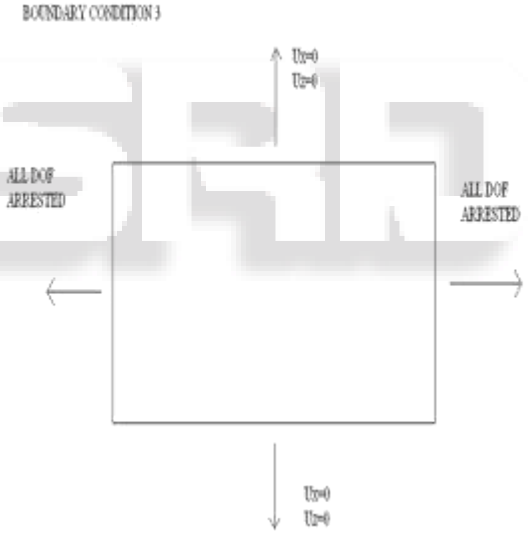


Fig 5.4.3 shows boundary condition 3

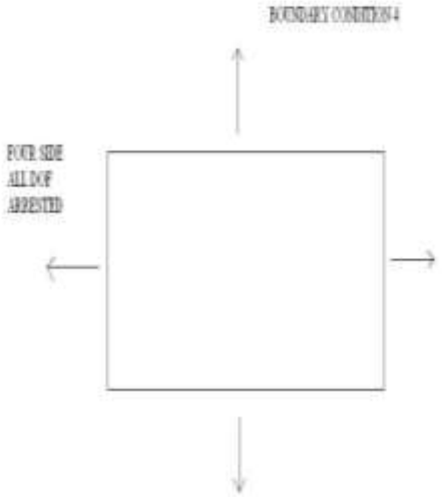


Fig 5.4.4 shows boundary condition 4

V. LAYER ANALYSES

A. *Modeling Of Structure*

To study influence of fiber orientation up on deflection and scf for different stresses. a laminated composite plate of dimension 200mm×100mm×1mm with a unidirectional cross section using the finite element analysis software. The following figure illustrates the basic model of the problem.

Using pre-processor element the modeling of rectangular lamina in shell element was created. After created circular area and subject in the rectangular lamina looks like the following figure. Using fine mesh the model is meshed and the load is applied to the surface of area. After applying load it can be solved by using solution command Prompt. Results can be displayed by using postprocessor and vonmises stress is plotted to show the maximum stress obtained.

Maximum stress is easily found out by using the ansys solve command But it is difficult to estimate the stress directly from the results. For that stress gradient graph is developed by means of path operations. By using the path operations the stress is easily calculated.

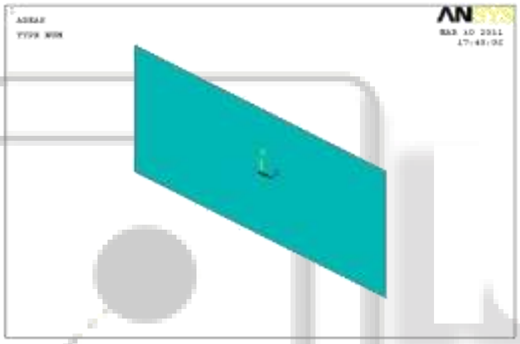


Fig 6.2.1 Isometric View of Laminate Plate

B. *Meshing Model*

In this method, a body or structure in which the analysis is carried out is subdivided in to smaller elements of finite dimensions called finite elements. Then the body is considered as an assemblage of these elements connected at a finite number of joints called nodes or nodal point. These properties of each type of finite element is obtained and assembled together and solved as whole to get solution.

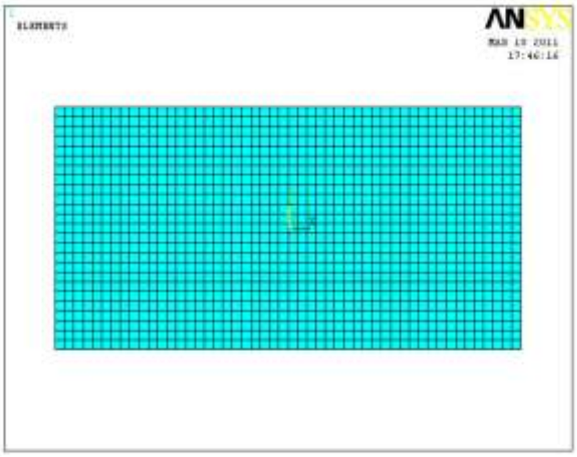


Fig 6.2.2 Meshed View Of Laminate Plate

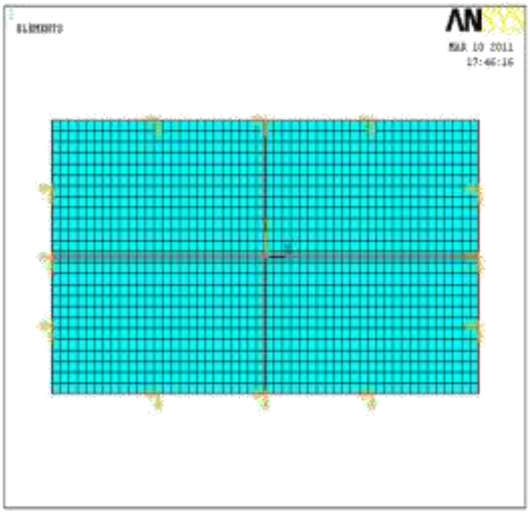


Fig 6.2.3 Solve The Laminate Plate

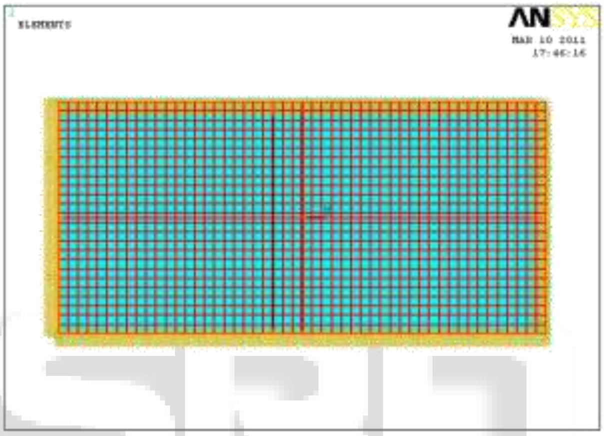


Fig 6.2.4 Solved Laminate Plate

C. *WOVEN GLASS /EPOXY STRESS RESULTS*

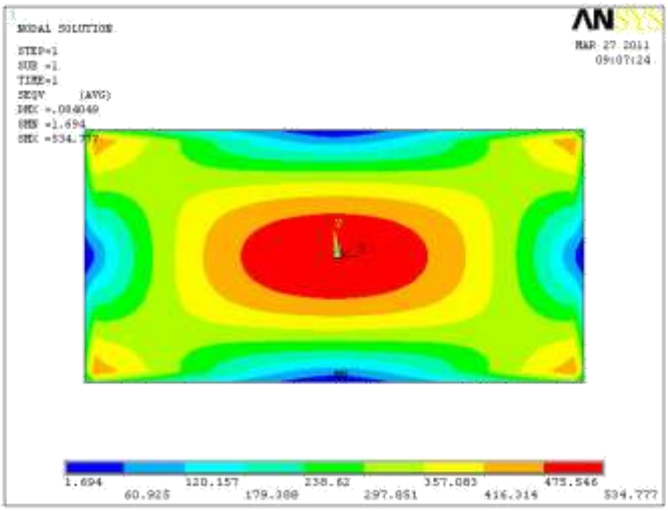
BOUNDARY CONDITIONS	**0 DEGREE**	**30 DEGREE**	**45 DEGREE**	**60 DEGREE**	**90 DEGREE**
B1	624.372	679.378	739.084	677.546	628.382
B2	11874	14384	12663	14284	11884
B3	692.412	623.521	583.291	625.521	698.842
B4	476.651	437.242	412.505	435.24	484.601

D. *WOVEN GLASS /EPOXY STRESS RESULTS*

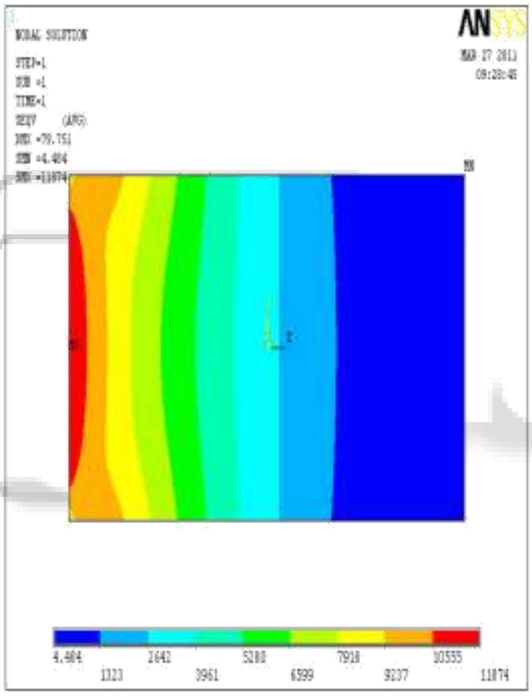
BOUNDARY CONDITIONS	**0 DEGREE**	**30 DEGREE**	**45 DEGREE**	**60 DEGREE**	**90 DEGREE**
B1	.469255	.448734	.438342	.468734	.475953
B2	79.751	115.409	120.875	125.409	81.851
B3	.391136	.37362	.366702	.35363	.381146
B4	.194586	.117971	.122807	.11880	.124586

E. SAFE MATERIAL FOR BORON AND ALUMINIUM

1) Boundary Condition 1 Zero Degree

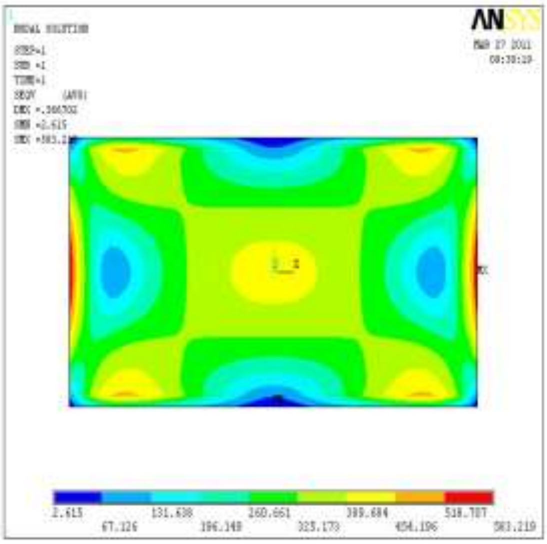


2) Boundary Condition 2 Zero Degree

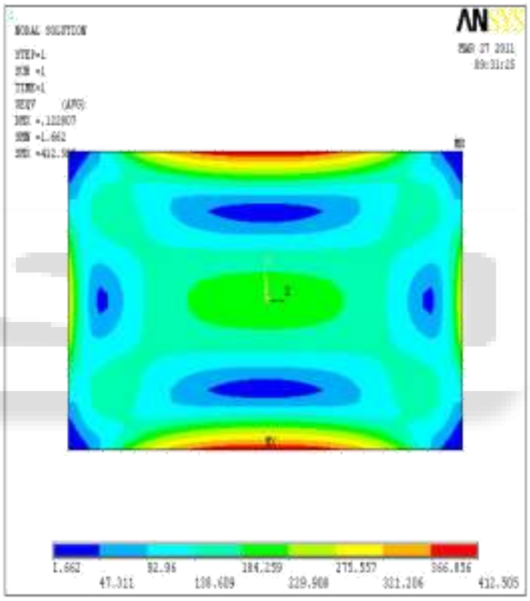


F. SAFE MATERIAL FOR WOVEN GLASS AND EPOXY

1) Boundary Condition 3 45 Degree

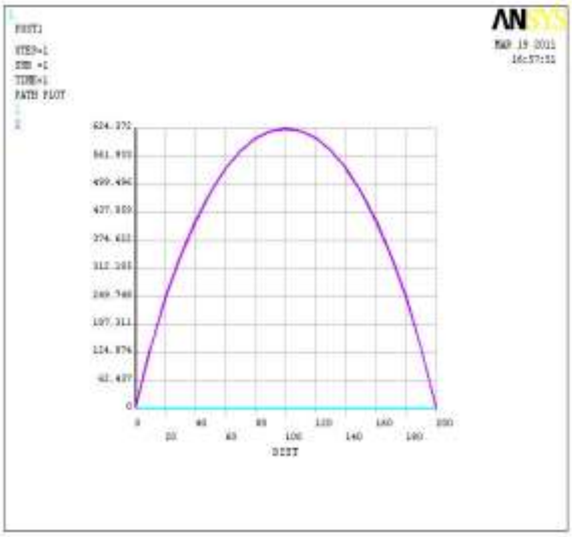


2) Boundary Condition 4 45 Degree

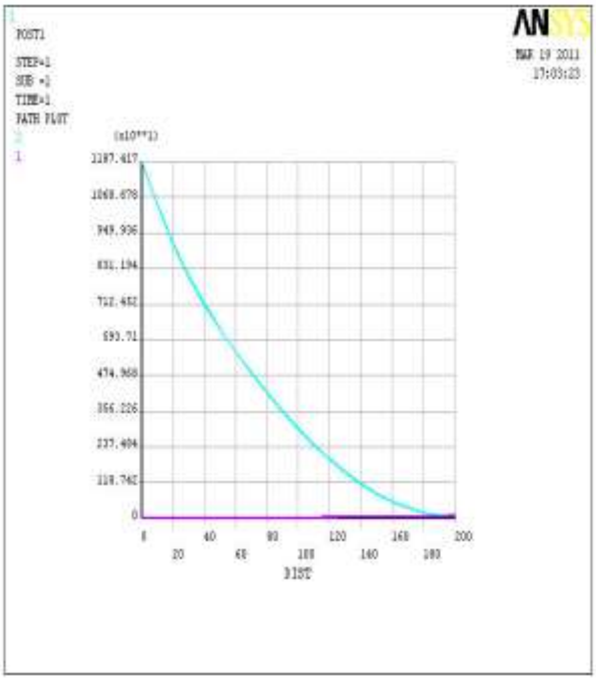


G. SAFE MATERIAL FOR WOVEN GLASS AND EPOXY

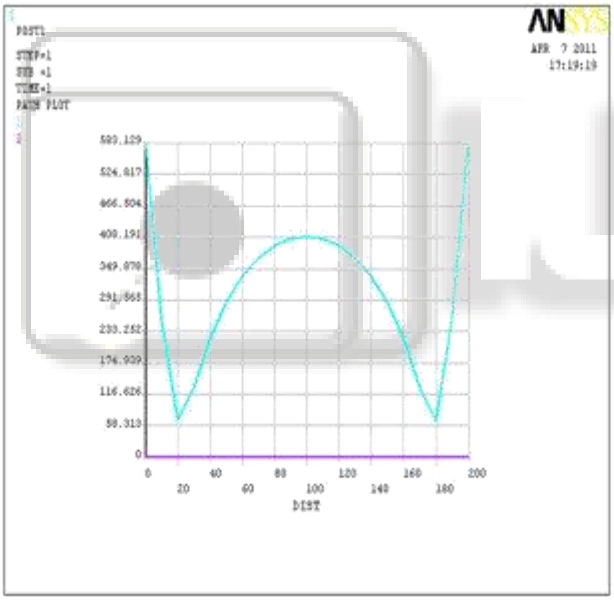
1) Boundary Condition 1 Zero Degree



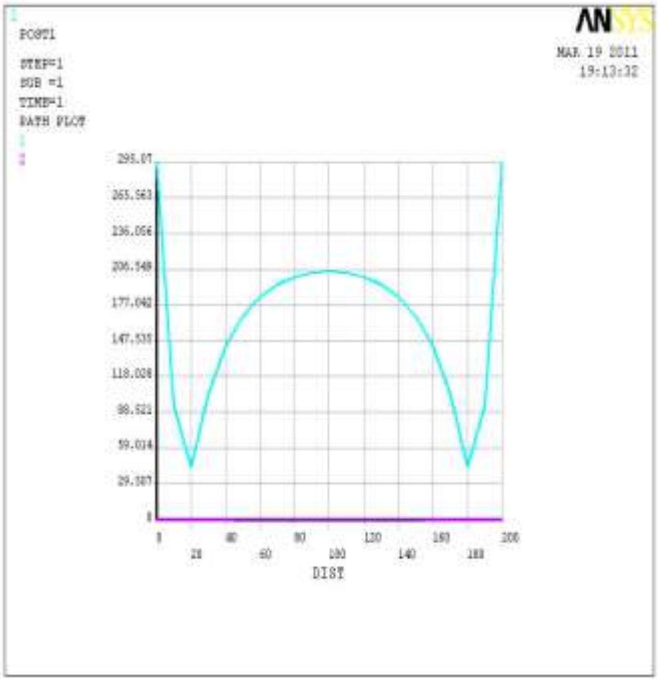
2) Boundary Condition 2 Zero Degree



3) Boundary Condition 3 45 Degree



4) Boundary Condition 4 45 Degree



VI. CONCLUSION

I here by conclude this orientation for corresponding materials are withstand (carry) more strength and displacement .From this conclusion we can use the safe orientation for better performance. The default orientation of material is replaced by safe orientation are show above results.

REFERENCE

[1] J. Mahesh patil and M.Salih Hybrid (BONDED/BOLTED) COMPOSITE SINGLE-LAP JOINTS AND ITS LOAD TRANSFER ANALYSIS International Edition of Advanced Engineering Technology 2003

[2] K. Kalaichelvan EFFECT OF ADHESIVE THICKNESS AREA OF SINGLE LAP JOINTS IN COMPOSITE LAMINATE USING ACOUSTIC EMISSION TECHNIQUE AND FEA, 2007

[3] B. Alexander Bogdanovich and P. Thomas Leschik JOINTS OF THICK 3-D WOVEN E-GLASS COMPOSITES FABRICATION AND MECHANICAL CHARACTERIZATION international conference on composite materials 1997

[4] Bala Krishna Murthy.V FRACTURE ANALYSIS OF ADHESIVELY BONDED SINGLE LAP JOINT WITH FOUR LAYERED international journal of applied engineering research, dindigul volume 1, no 4, 2011

[5] KRISHNAN K CHAWLA, Composite Materials Science and Engineering, International Edition,Springer, 2006.

[6] MALLICK, P.K. AND NEWMAN'S., Composite Materials Technology, Hanser Publishers, 2004.