Design Fabrication and Static Analysis of Single Composite Lap Joint

P.V.Elumalai[1] A.Sujatha[2] R. Senthil Kumar[3]
[1, 2, 3]Assistant Professor
[1, 2, 3]Department of Mechanical Engineering
[1, 3]Dhanalakshmi College of Engineering Tambaram, Chennai, Tamil Nadu, India-632002
[2]Thanthai Periyar Government Institute Of technology, Bagyam, Vellore, Tamil Nadu, India-632002

Abstract—Mechanically fastened joints are critical parts in composite aircraft structures. The composite structural members are highly used in the following applications such as aerospace, automobiles, marine, architecture etc., In the past decades, Adhesive bonding is a practical joint method for joining composite materials which provide low shear and Tensile strength .To improve the strength material joint is to be used in the work. A Glass fibre Epoxy composite is to be fabricated by hand lay-up method. And experimentally results are to be obtained. The Experimental results are to be compared with Analytical and Numerical results. For numerical analysis ANSYS software is to be used.

Key words: Composite, Hand layout method, Epoxy, Material joints

I. INTRODUCTION

Composites are made up of individual materials referred to as constituent materials. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties Due to strength and safety requirements, these applications require joining composites either to composites or to metals. Although leading to a weight penalty due to stress concentration created by drilling a hole in the laminate, mechanical fasteners are widely used in the aerospace industry. In fact mechanically fastened joints (such as pinned joints) are unavoidable in complex structures because of their low cost, simplicity for assemble and facilitation of disassembly for repair.

Mechanical fasteners remain the primary means of load transfer between structural components made of composite laminates. As, in pursuit of increasing efficiency of the structure, the operational load continues to grow, the load carried by each fastener increases accordingly. This increases probability of failure. Therefore, the assessment of the stresses around the fasteners holes becomes critical for damage-tolerant design. Because of the presence of unknown contact stresses and contact region between the Fastener and the laminate, the analysis becomes considerably more complex than that of a traction-free hole. The accurate prediction of the stress distribution of strength evaluation and failure prediction. The knowledge of the failure strength would help in selecting the appropriate joint size in a given application. An unskillful design of joints in the case of mechanical fasteners often causes a reduction of load capability of the composite structure even though the composite materials posses' high strength.

A. Polymer matrix composite:

Advanced composite materials (ACMs) are also known as advanced polymer matrix composites. These are generally characterized or determined by unusually high strength fibres with unusually high stiffness, or modulus of elasticity characteristics, compared to other materials, while bound together by weaker matrices. These are termed advanced composite materials (ACM) in comparison to the composite materials commonly in use such as reinforced concrete, or even concrete itself. The high strength fibers are also low density while occupying a large fraction of the volume.

B. Thermoset and Thermoplastic:

Thermoset resins require addition of a curing agent or hardener and impregnation onto a reinforcing material, followed by a curing step to produce a cured or finished part. Once cured, the part cannot be changed or reformed, except for finishing. Some of the more common thermosets include epoxies, polyurethanes, phenolic and amino resins, bismaleimides (BMI, polyimides), polyamides.

Of these, epoxies are the most commonly used in the industry. Epoxy resins have been in use in U.S. industry for over 40 years. Epoxy compounds are also referred to as glycidyl compounds. The epoxy molecule can also be expanded or cross-linked with other molecules to form a wide variety of resin products, each with distinct performance characteristics. These resins range from low-viscosity liquids to high-molecular weight solids. Typically they are high-viscosity liquids.

Thermoplastics currently represent a relatively small part of the ACM industry. They are typically supplied as nonreactive solids (no chemical reaction occurs during processing) and require only heat and pressure to form the finished part. Unlike the thermosets, the thermoplastics can usually be reheated and reformed into another shape, if desired.

C. Moulding Method:

In general, the reinforcing and matrix materials are combined, compacted and processed to undergo a melding event. After the melding event, the part shape is essentially set, although it can deform under certain process conditions. For a thermo set polymeric matrix material, the melding event is a curing reaction that is initiated by the application of additional heat or chemical reactivity such as organic peroxide. For a thermoplastic polymeric matrix material, the melding event is solidification from the melted state. For a metal matrix material such as titanium foil, the melding event is a fusing at high pressure and a temperature near the melt point.

For many moulding methods, it is convenient to refer to one mould piece as a "lower" mould and another mould piece as an "upper" mould. Lower and upper refer to the different faces of the moulded panel, not the mould's configuration in space. In this convention, there is always a lower mould, and sometimes an upper mould. Part construction begins by applying materials to the lower mould. Lower mould and upper mould are more generalized descriptors than more common and specific terms such as male side, female side, a-side, b-side, tool side, bowl, hat, mandrel, etc. Continuous manufacturing processes use a different nomenclature.

The moulded product is often referred to as a panel. For certain geometries and material combinations, it can be referred to as a casting. For certain continuous processes, it can be referred to as a profile. Applied with a pressure roller, a spray device or manually. This process is generally done at ambient temperature and atmospheric pressure. Two variations of open moulding are Hand Layup and Spray-up.

D. Hand lay-Up Method:

Hand lay-up is a simple method for composite production. A mould must be used for hand lay-up parts unless the composite is to be joined directly to another structure. The mould can be as simple as a flat sheet or have infinite curves and edges. For some shapes, moulds must be joined in sections so they can be taken apart for part removal after curing. Before lay-up, the mould is prepared with a release agent to insure that the part will not adhere to the mold. Reinforcement fibers can be cut and laid in the mould. It is up to the designer to organize the type, amount and direction of the fibers being used. Resin must then be catalyzed and added to the fibers. A brush, roller or squeegee can be used to impregnate the fibres with the resin. The lay-up technician is responsible for controlling the amount of resin and the quality of saturation.

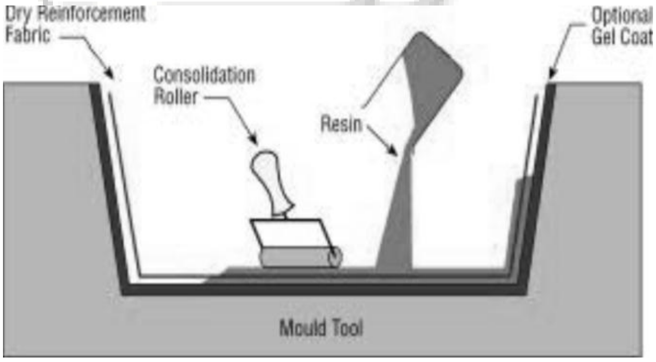


Fig. 1: Hand Lay-Up Method

II. MATERIAL AND FABRICATION

A. Epoxy Resin

Epoxy laminating resin boasts higher adhesive properties and resistance to water, ideal for use in applications such as boat building. Also used extensively in aircraft component manufacture. Epoxies are widely used as a primary construction material for high-performance boats or as a secondary application to sheath a hull or replace water-degraded polyester resins and gel coats

- Chemical name - Diglycidyl ether of bisphenol
- Chemical name – Araldite- LY556.

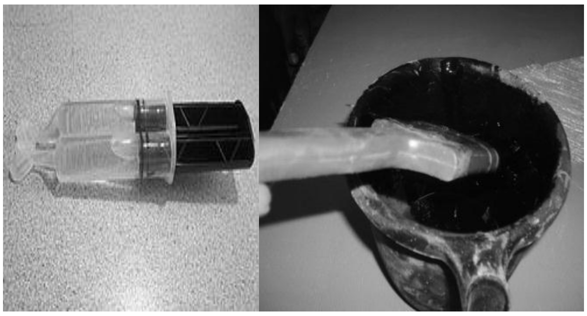


Fig. 2: Epoxy Resin

B. Properties of Epoxy:

- High-Strength Glass Fiber Reinforced
- Relative Density 1.6-2.0
- Melting temperature (°C)
- Thermoset Processing Range (°F)
- Shrinkage 0.001-0.008
- Tensile strength 5,000-20,000
- Compressive strength 18,000-40,000
- Flexural Strength 8000-30,000
- I Zod impact 0.3-10.0
- Linear expansion (10^{-6} in./in./°C) 11-50
- Hardness Rockwell M100-112
- Flammability V-0
- Water absorption 24h (%) 0.04-0.20

C. Catalyst

Hardener. An organic peroxide or similar compound which, together with the accelerator, initiates the polymerization process of polyester and other resins. It should NEVER be mixed directly with an accelerator-this can cause an explosion. Catalyst is available as a liquid or paste.

Catalyst is organic peroxide (a powerful corrosive) and should not come contact with eyes, mouth or skin. Should it do so, wash from the skin immediately under a running tap. If it is splashed in the eyes, flush them with running water for at least fifteen, minutes, and call a doctor

- Chemical name – Trietha Tetra mine.
- Company name – Aradur-HY951.

D. Accelerator

One of the two compounds (the other is catalyst) required to initiate the polymerisation process. See Reaccelerated. Mixed directly with catalyst, the accelerator reacts explosively it is therefore usually added to the resin in manufacture so only catalyst need be added later.

E. Chopped Strands

Short (6mm or 12mm) lengths of glass fibre. Can be used to make resin dough, stronger than that made by mixing resin with filler powder.

Fig. 3: Chopped Strand Mat

A popular and economical form of glass reinforcement for polyester resins. Short strands of glass are bonded with a powder or emulsion into a mat available in a variety of thickness.

F. Material Selection and Laminate Manufacture

The fiber-reinforced composite material used in this study was produced at IZOREEL firm. Other reason of the selection these lay-ups are to observe variety of failure modes. All laminates balanced about the mid-plane both to prevent thermal distortion during manufacture and to eliminate bending and twisting when under tension. All laminates were made from E glass fiber and epoxy resin using press-mould technique. For matrix material, epoxy LY556 and hardener HY951 were mixed in the mass ratio of 100:80. The resin and hardener mix was applied to the fibers. Fibers were coated with this mix. Subsequent plies were placed one upon another as required orientations. A hand roller was used to compact plies and remove entrapped air that could later lead to voids or layer separations. The mold and lay-up were covered with a release fabric. Once the matrix and fibers are combined, it is necessary to apply the proper temperature and pressure for specific periods of time to produce the fiber reinforced structure. For this purpose, resin-impregnated fibers were placed in the mold for curing. The press generates the temperature and pressure required for curing. In all cases, the mould was closed to stops giving nominal thickness. The glass fiber and epoxy were cured at 120 0C under a pressure of 9 MPa and this temperature was held constant for 4 hours for the first period. Afterwards, the temperature was decreased to 100 0C and held constant for 2 hours for the second period. After the second period, the laminates were cooled to room temperature, removed from press and trimmed to size.

G. Mechanical Properties

In this study, glass/epoxy material is used with the material properties measured at Department of Metallurgical and Materials Engineering; certain experiments were performed to measure the mechanical properties. By assuming in-plane assumption, the number of experiments required to characterize the material parameters are reduced.

Ex	Ey	Ez	Gxy	Gyz	Gzx	Mxy	µyz	µzx
39e5	8.6e5	8.6e5	3.8e5	3.8e5	3.8e5	0.28	0.28	0.28

Table. 1: Material Properties

H. Lap Joining Composite Material

The structures consist of essentially of an assembly of single elements connected to form a load transmission path. Joints in components or structures incur a weight penalty, are a source of failure and cause manufacturing problems; whenever possible, therefore, a designer will avoid using them. Unfortunately, it is rarely possible to produce a construction without joints due to limitations on material size, convenience in manufacture or transportation and the need for access. All connections or joints are potentially the weakest points in the structures so can determine its structural efficiency. To make useful structures, consideration must be given to the way structural components are joined together. The introduction of fiber-reinforced composites has been a major step in the evolution of airframe structures. Compared with conventional aluminum alloys, optimized use of composites can result in significant weight savings. Additionally, composites have many other important advantages, including improvement formability and immunity to corrosion and fatigue damage. From the joining view point a very important advantage of composite construction is the ability to form

LENGTH	200mm
WIDTH	60mm
THINKNESS	5mm

Table. 2: Single Lap Joint Dimension

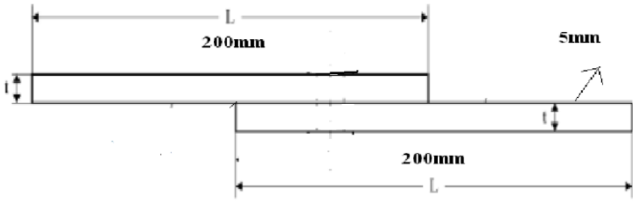


Fig. 4: dimension of Single Lap Joint

I. Preparation process:

MATERIAL	CHOPPED STRAND MAT
RESIN	EPOXY
METHOD	HAND LAY UP

Table. 3: Required elements

In the preparation process the fibre it can be used chopped strand mat and matrix it can be used epoxy resin and fabricated with the hand lay-up method. First wax it can be used for cleaning the plate after words the resin it can applied in to plate. Then the chopped strand mat one by one layer it can be placed in the resin area. We fabricate two single plate Shown in Figure 5 before joining the plate most of the joining method is adhesive bonding, bolted joining .In the fabrication process we joining two plate with the help of chopped strand mat bonded joint Shown in the Figure 6after joining the plate.

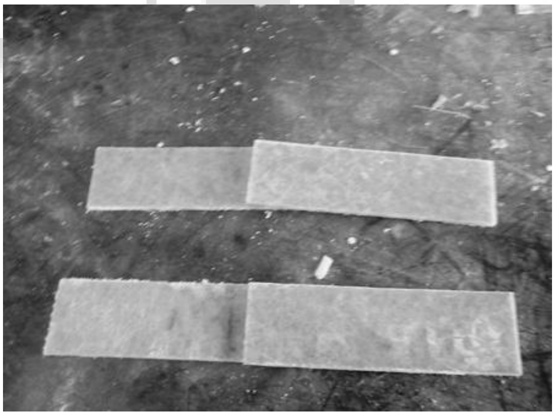
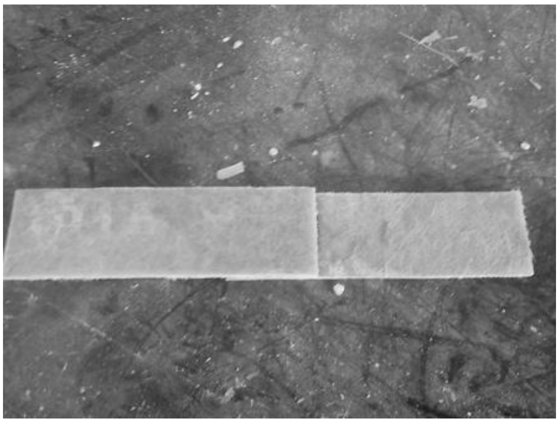


Fig. 5: Before Joining the Plate



Fig, 6: After Joining the Plate

III. EXPERIMENTAL, ANALYTICAL AND NUMERICAL

A. Experimental Evaluation

In this chapter, the glass/epoxy material is fully characterized experimentally and the results are presented. The results of static experiments for measuring the stiffness and strength of a chopped strand mat under tension, compression and in-plane shear loading conditions are summarized. It is necessary to determine of basic properties of the chopped strand mat for use as basic input data for the model. A chopped strand mat under static loading was fully characterized to prepare complete set of input data. The experimental determination of the mechanical properties of chopped strand mat under static loading conditions has always been a key issue in the research on composite materials. With the rise of huge variety of composites, the need for an efficient and reliable way of measuring these properties has become more important. The experiments, if conducted properly, generally reveal both strengths and stiffness characteristics of the material.

B. Determination of the Tensile Properties

Tensile properties such as Young's modulus (E1), (E2); Poisson's ratio (v12), (v21); and lamina longitudinal tensile strengths (Xt) and transverse tensile strength (Yt) are measured by static tension testing longitudinal [00]6 and transverse [900]6 chopped strand mat specimens according to the ASTM D3039-76 standard test method. The tensile specimen is straight sided and has constant cross-section. The tensile test geometry to find the longitudinal tensile properties consists of six plies which are 200 mm wide and 60 mm height.

The tensile specimen is placed in the testing machine, taking care to align the longitudinal axis of the specimen and pulled at a cross-head speed of 0.5 mm/min. The specimens are loaded step by step up to failure under uni-axial tensile loading. A continuous record of load and deflection is obtained by a digital data acquisition system.

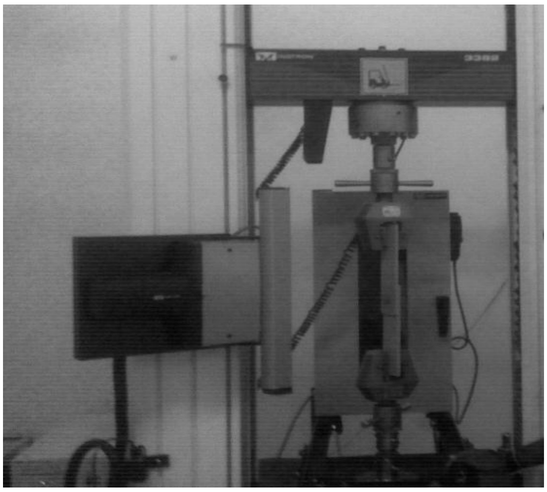


Fig. 7: Tensile Testing Machine

C. Modeling of the Problem

The geometry of the plate investigated in this study was shown in the mat is symmetric with respect to the z = 0 plane. Perfect bonding between each mat and frictionless contact are assumed. The composite plate is loaded with an in-plane load P for the bonded joint. It is desired to find the maximum failure load P_{max} that can be applied before the joint fails and the mode of failure for each geometry. By increasing the load to a certain value, failure will start at a position near the edge. This load is first ply failure load. If after failure initiation the load is increased, failure will propagate in different directions. Finally at higher load damage will propagate to an extent that the plate cannot tolerate any additional load. This value is ultimate strength.

The position of the initial failure and the direction of the failure propagation provide an estimate of the mode of failure. Depending on material properties, geometrical dimensions, and laminate configurations, failure takes place in a specific mode or combinations of these modes.

Fig. 8: Failure Mode Lap Joint

3.4 Analysis Procedure:

Step. 1 : Startup Main menu > Preference > structural > ok

Step. 2 : Pre-processing Preprocessor > Elementtype > Add/Edit/Delete > Add, Solid > solid 92 > Ok, Material properties > since material properties > orthotropic > give the vaule of material properties

Step. 3 : Modeling > Create > Area > rectangle > by center and by corner > ok

Step. 4 : Meshing > Next process is to mesh the model , this is done by using free mesh i.e., Tetrahedral mesh. First mesh the area with plane92.

Step. 5 : Define loads > apply > structural > displacement>on nodes > click the left and right side > apply > ok

Step. 6 : Structural > pressure > on area > select the full section area > apply constant value

Step. 7 : Solution > solve > current LS (load step)

Step. 8 : Post processing General post processor > plot results > contour plot > nodal solution > displacement .After solving the problem to find out the tensile strength

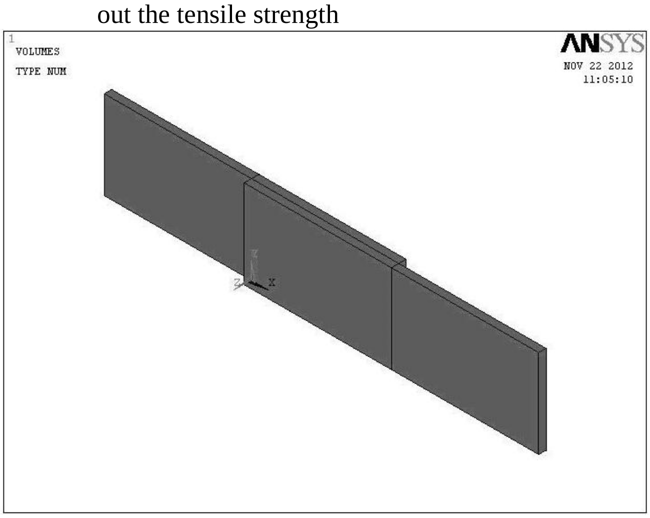


Fig. 9: Single Lap Joint

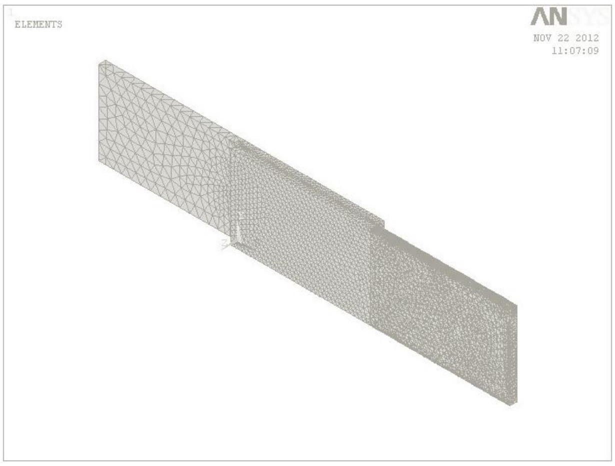


Fig. 10: Meshing Diagram Single Lap Joint

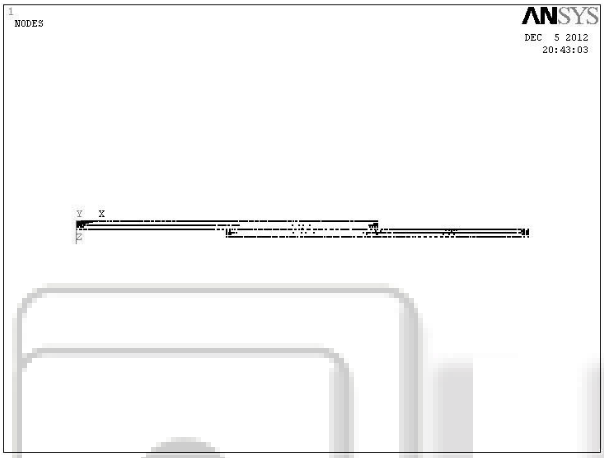


Fig. 11: Node Diagram Single Lap Joint

IV. RESULTS AND DISCUSSIONS

A. *Experimental Results:*

In the following subsections, the experimental results of loaded composite laminates are presented. The general behavior of the all composite mentioned above was obtained from the load/displacement chart record from the testing machine. Because the appropriate value of joint strength depends upon the failure load, failure loads in deterministic sense were measured and were presented below.

MATERIAL TYPE	EXPERIMENTALLY CALCULATED RESULTS
CHOPPED STRAND MAT	86.407
BREAKING LOAD	24.8kN

Table. 4: Joint Plate Result

MATERIAL TYPE	EXPERIMENTALLY CALCULATED RESULTS
BY DIRECTIONAL FLY	110.45
BREAKING LOAD	30kN

Table. 5: Joint Plate (By Directional fly)

MATERIAL TYPE	EXPERIMETALLY CALCULATED RESULTS
CHOPPED STRAND MAT	52.486
BREAKING LOAD	15.2kN

Table. 6: Single Plate Result

MATERIAL TYPE	EXPERIMETALLY CALCULATED RESULTS
BY DIRECTIONAL FLY	72.686
BREAKING LOAD	19.8kN

Table. 7: Single Plate Result (By Directional fly)

B. *Numerical Results*

The numerical results are calculated by using the given below.

$$Tensile\ Strength\ = F/S * L$$

Where,

τ – Stress or strength in N/mm^2,
F – Load in N
L-length in mm

$$Tensile\ strength\ = 28.4x10^{\wedge}3/300\ = 92.80$$

By using this formula the Tensile strength of composite is numerically calculated.

MATERIAL TYPE	NUMERICAL CALCULATED
CHOPPED STRAND MAT	92.80
BY DIRECTIONAL FLY	116.92

Table. 8: Numerical Result

LENGTH	WIDTH	TENSILE STRENGHT
300	60	86.407
400	60	72.638
500	60	63.587
600	60	57.067
700	60	49.786

Table. 9: Vary Length Width is Constant

LENGTH	WIDTH	TENSILE STRENGHT
300	60	52.678
400	60	48.395
500	60	43.49
600	60	31.761
700	60	26.248

Table. 10: Vary Length Width is Constant

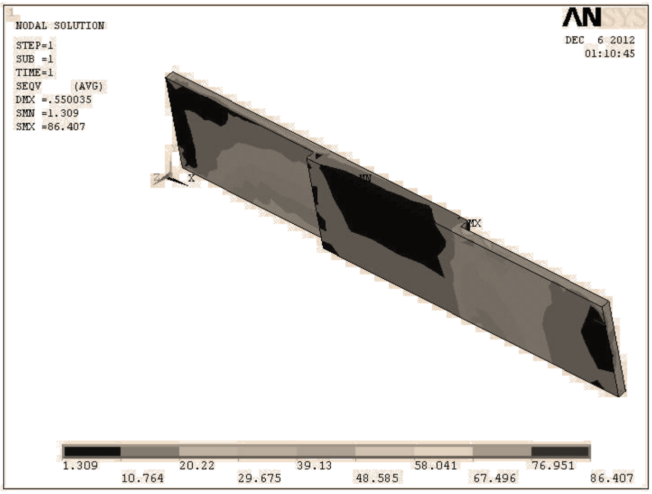


Fig. 12: Joint Plate Ansys Result

MATERIAL TYPE	EXPERIMENTALLY CALCULATED RESULTS Tensile strength(N/mm^2)	NUMERICALLY CALCULATED Tensile strength (N/mm^2)	ANALYSIS RESULTS Tensile strength (N/mm^2)
CHOPPED STRAND MAT	82.56	92.890	86.407
BY DIRECTIONAL FLY	110.45	116.92	114.82

Table. 11: Comparison Results

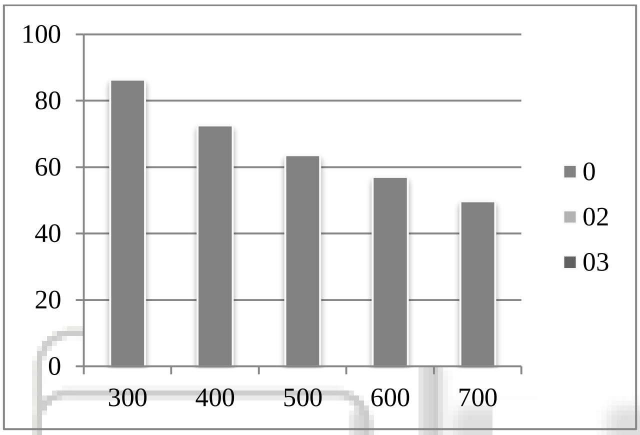


Fig. 13: Graph for Joint Plate

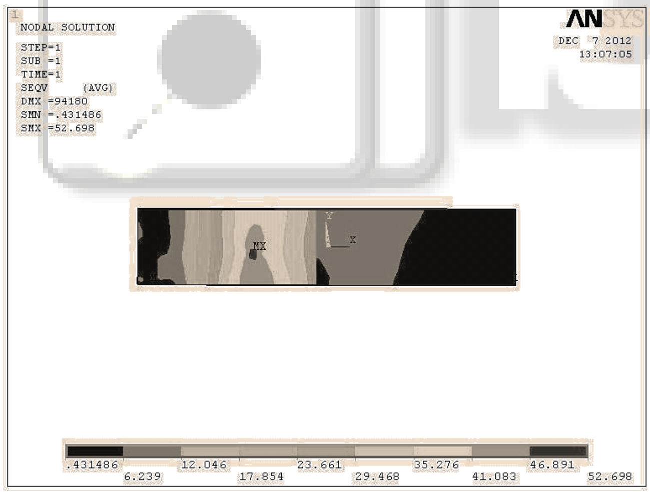


Fig. 14: Single Plate ANSYS Result

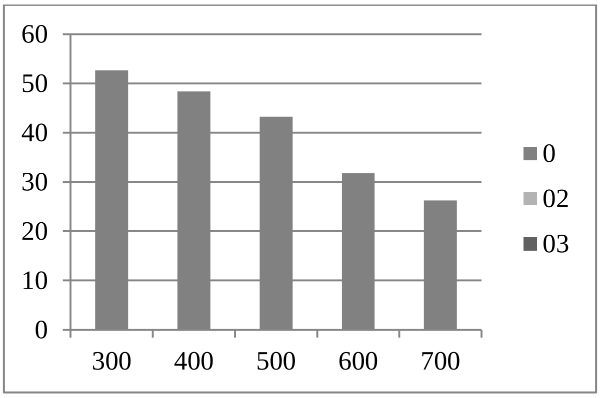


Fig. 15: Graph for Single Plate

V. CONCLUSION

In this project Glass fibre (Chopped strand mat) and Bt Directional ply was fabricated by hand lay-up method. The composite material was machined according to the dimension. In the material joining process component gave the more tensile strength When compared with same dimensions of single plate .The Experimental and Analytical and numerical results for glass fibre (Chopped strand mat) epoxy and By Directional ply composite are obtained. The ANSYS results are in good agreement with experimental and analytical results.

When Compared to chopped strand mat and by directional ply. The By directional ply can give more tensile strength then compared to chopped strand mat they can be proved by experimental , analytical and numerical calculation.

REFERENCES

[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.